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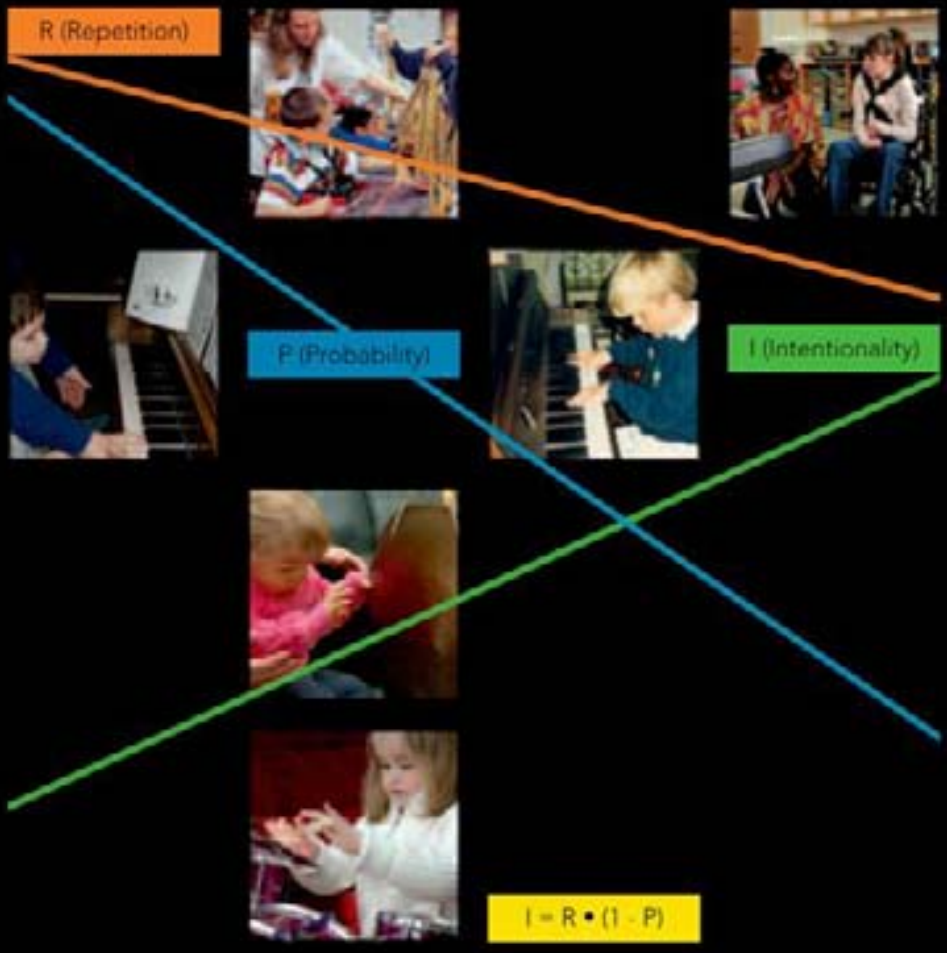

Using Zygonic Theory to Inform Music Education, Therapy, and Psychology Research

Adam Ockelford

Applied Musicology

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Using zygonic theory to inform music education, therapy, and psychology research

by

Adam Ockelford

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Dedication

Dedicated to the loving memory of
Abigail Lee
1991–2011
from whom we all learned so much

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Foreword

David J. Hargreaves

There is some doubt about who coined the expression "writing about music is like dancing about architecture": Thelonius Monk, Frank Zappa, and Elvis Costello are among the contenders, as is a less well-known humorist and artist Martin Mull, who is most likely to be the actual source. Whoever it was, Adam Ockelford takes a similar point of view as his starting point in this ambitious book. Whilst not opposing the idea of contemplating what people *think about* music, his opening contention is that most research on the musical experience relies on secondary evidence, and his book attempts to put this right. He uses his own zygonic theory (ZT) to do so, as the subtitle suggests: to put this (perhaps over-)simply, the basis of ZT is that the majority of musical structures demonstrate the property of *repetition with variation*: musical elements such as pitches, melodies, rhythms, and chords are repeated in a similar but not identical fashion in a great deal of music. To put this another way, ZT is based on the principle of *derivation through imitation*: the Greek word *zygon* means "yoke," and so "zygonic relationships" pertain to similar but (necessarily) non-identical musical events.

This leads me, and probably other readers, to ask two immediate questions: first, what is "applied musicology," and how does it relate to the varieties of empirical music theory that have been proposed by other musicologically based authors in recent years, including "empirical musicology" (Eric Clarke and Nicholas Cook, Henkjan Honing), "systematic musicology" (Richard Parncutt, David Huron), "cognitive musicology" (Christopher Longuet-Higgins, Fred Lerdahl and Ray Jackendoff); and how might it relate to "applied music psychology," which Adrian North and I attempted to map out in 2008? There is no space to compare these different proto-disciplines here, but Ockelford's approach is rooted in music psychology, and what soon becomes clear is that this perspective enables him to investigate, with considerable precision, phenomena as diverse as how the music therapist and her client influence one another when playing or singing together; how the course of musical development might proceed in children with learning disabilities; and how musical memory works in savants. These are new and significant insights in that they enable music theory to have some clear applications in the real world of music-making by expert performers and novices alike.

My second question concerns the extent to which the book is about applications of music theory in general, or whether it is specifically about those of ZT. Ockelford deals with the relationships between ZT and other music theories in Chapter 2, and it soon becomes apparent in the succeeding chapters that ZT affords the opportunity to examine the phenomena of the *intentionality* of musicians, as well as of the mutual *influence* of one musician upon another, from the evidence of transcriptions of their joint playing; as he points out, the musical interactions of some children on the autism spectrum, or of those with profound learning difficulties, can provide unique insights into their thinking which may be inaccessible by any other means. This is a powerful basis for further development, and it seems unlikely that other theoretical approaches would be able to do the same job with such facility. Even if the subject matter of applied musicology, as set out in this book, is based on Adam Ockelford's own research interests, he has undoubtedly provided the tools for others to pursue their own.

The book goes well beyond these practical concerns in applying ZT to other knotty theoretical issues. Chapter 6 deals with the question of absolute pitch, for example, which is possessed by musical savants to a much greater degree than by members of the population at large: this capacity, as well as the ability to break down chords into their constituent notes, seems to provide a key to the way in which savants process musical sound, and may also explain why many of them can play by ear so effectively. Chapter 8 deals with the explanation of musical expectancy and the arousal of emotion, a key area of interest in the field ever since Leonard Meyer's ground-breaking work in the 1950s and 1960s. Finally, Chapter 9 tackles another thorny topic upon which musicologists and music psychologists have tended to disagree—the perception of atonality. Why do listeners find much modern classical music so challenging, and what might composers do to ameliorate some of the difficulties their audiences face?

This book reveals not only the breadth and depth of Adam Ockelford's wide range of interdisciplinary interests, but also his ability to write fluently and engagingly in an accessible, popular style as well as in a highly technical way, and at other levels in between, as the subject matter dictates. It represents not only an important landmark in the development of his own work, but also a blueprint for the future of research in music theory and music psychology, especially in the application of this approach to issues of disability and special needs. I am sure that others will follow the directions that Ockelford has set out in this important book, and may indeed develop them further into other areas of applied musicology. In writing it he has performed a valuable service to several different research communities.

Preface

Recent advances in neuroscience notwithstanding, the musical mind remains, by and large, a black box. For sure, we are getting better at knowing *where* things happen in the brain, and how discrete areas of neural circuitry implicated in particular aspects of music-processing link up, but we can no more get a sense of the musical experience by viewing functional MRI scans or EEGs than we can by measuring fluctuating voltage levels inside an iPod. This will, no doubt, change in the future, as our capacity to observe neural activity becomes ever more refined. But for the time being, musical neuroscience must remain one weapon to complement others in the psychologist's armory.

In fact, it is likely that the majority of our knowledge and understanding of the musical mind will continue to derive, as it has always done, through metacognition—whether in the form of the free-flowing introspection of philosophers or the more constrained cogitations of the participants in psychological experiments, reporting that they hear musical stimuli as the same or different, or more or less expected, for example, or reflecting, through words, on their emotional responses to passages in contrasting styles or keys. But why have those researching music relied to such a great extent on language as their medium of data-gathering? Given the well-rehearsed difficulty of talking about music in words (in E. T. A. Hoffmann's immortal phrase, the former beginning where the latter takes off), surely this approach is fraught with methodological difficulties? Why hasn't the stuff of music itself—abstract patterns of sound—been used more often to analyze what is going on inside the heads of those who listen, perform, and compose? After all, as Leonard Bernstein once asserted, music, as a product of the mind, should offer us "a striking model of the human brain in action and as such, a model of how we think" (Bernstein 1976, p. 169).

There are, I believe, two main reasons for the rarity of *music* analysis being used to inform music-psychological, educational, and therapeutic research. First, language, unlike music, has tangible meaning: nouns and verbs and their modifiers point more or less consistently to concepts that are held to be common among observers (even universally understood) and are susceptible to analysis that is both testable and amenable to replication. In contrast, music is generally held to much less tractable; in the words of Ian Cross (2005, p. 30), it has a " 'floating intentionality'. . . gathering meaning from the contexts within which it happens and in turn contributing meaning to those contexts." This very ambiguity, which contributes so much to music's richness as a communicative medium, makes it hard to manage as an interrogative tool in research.

Second, while music analysis exists as a field of theoretical endeavor in its own right, it has tended to be the province of the few, concerning itself more with the experience of "elite" listeners rather than addressing the question of how most people experience music most of the time. Yet such an approach is anathema to the majority of social scientists—including psychologists—who have tended to be more interested in what is "typical" or "normal" in the human condition (Margulis, 2005b, p. 335). The fact that the concept of "the musical mind" even exists implies an assumed commonality across the population.

However, there are some approaches to music analysis that do have the capacity to reflect how pieces of music are *usually* heard, including those based on my own "zygonic" theory (which is the subject of this book). Zygonic theory holds that a universal feature of music—and what distinguishes it from other forms of humanly organized sound—is the sense that it engenders

of *derivation through imitation*. That is, when one note or group of notes is heard, consciously or non-consciously, as echoing another or others, then musical structure is cognized. The art of zygonic analysis is to determine, from the welter of sameness and similarity that characterizes all music, the many different esthetic consequences of repetition, and the impact of its relationship to the *non*-repetition—variation—that is invariably present too. Zygonic analyses can explore the musical space within or between pieces, as a tool of "critical" or "style" analysis (Meyer, 1973, pp. 6–9).

It is this capacity to operate *inter*-opusly that enables the zygonic conjecture to be used to interrogate the black box that is the musical mind. The methodological principle is this: by first providing subjects with a musical stimulus and asking them to give a musical response, and then analyzing how the latter derives from the former, we can start to get a sense of the invisible music processing that is at work. If the input is A and the output is B♭, then we have the first variable in a potential equation. If the second input is C and its corresponding output C♯, we have an emergent pattern. But what is its significance? How do we know that it occurred other than by chance? How can we gauge intentionality just by analyzing sequences of sounds? As we shall see, by varying the stimuli and the contexts in which they occur, it is possible gradually to build up a more and more complete and reliable picture of the cognitive functioning, constraints, and preferences operating in the musical domain.

Of course, this approach, like any other, has its limitations. Listeners are generally incapable of reproducing much of what they can evidently hear in their heads (they may be able to recognize a melody without being able to sing it, for example, or be capable of distinguishing between several different interpretations of a piano sonata without being able to play a note of it themselves). Nonetheless, people tend to underestimate their capacity for making music, and can often produce fragments (through humming or tapping a rhythm, for instance) much more effectively than they believe—and, as we shall see, musical snippets are frequently all that is needed to provide a surprisingly rich and detailed view of the musical processing that is in train.

And there are particular groups of people—some children on the autism spectrum, for example, and those with severe or profound learning difficulties—whose capacity to interact musically may offer a unique window onto their thinking, given a paucity or even a complete absence of language. Indeed, in certain circumstances, gauging intentionality and influence in musical interaction may offer proxy measures of communicative intent. Hence, the familiar scenario of words being used to describe musical engagement may be reversed, and music may itself be employed to explicate and share thoughts and feelings that would usually be captured and conveyed by language.

Clearly, this approach, using zygonic theory, can only ever offer certain, limited insights into the working of the musical mind, and it lays no claim to being anything other than one piece in a conceptual jigsaw whose dimensions still lie beyond the horizon of current music-psychological understanding. Nonetheless, its contribution to the rapidly expanding terrain of music science is, I believe, both valid and of potential value.

Acknowledgements

I would like to thank all those who have played a part, directly or indirectly, in the production of this book. First, and most importantly, I am very grateful to the families who permitted me to report my work with their children, work which lies at the heart of theoretical models that are advanced: Abby (to whom the book is dedicated), Avni, B, Freddie, J, K, Romy, and Shivan, and a host of others whose names have been changed. I am particularly indebted to Derek Paravicini, to another musical savant A, and to fellow musician S, whose good-natured enthusiasm for participating in what were sometimes demanding longitudinal research projects made the whole experience such a pleasure. The book would not have been possible without the insights and support of colleagues and students, to whom I extend my gratitude: Aleksander Aksentijevic, Evangeline Cheng, Lamorna Jewell-Gore, David Hargreaves, Evangelos Himonides, Nigel Marshall, Annamaria Mazzeschi, Anna Powell, Linda Pring, Desmond Sergeant, Kagari Shibazaki, Michael Thorpe, Hayley Trower, Graham Welch, Katherine Woolf, and Sally Zimmermann. My thanks too to the team at OUP, Martin Baum, Charlotte Green, Elizabeth Chadwick, and Bridget johnson, who made the whole process from commissioning, through proof-reading to publication pain-free (pleasureable even), and who have been a delight to work with. And last but not least, I am indebted to my family—my wife Sue, and children Felicity, Eloise, and Thomas—for their patience with a husband and father whose mind has largely been elsewhere for the last 9 months!

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Part I

Rationale and theoretical context

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Chapter 1

Introduction

Music: the (trumpeting) elephant in the room

Leaf through virtually any journal or book devoted to music education, music therapy, or music psychology and you are likely to encounter a good deal of text, interspersed, in many cases, with illustrations in the form of figures, tables, or graphs. There may be pictures of those engaged in music-making, or their instruments. Explore more systematically and you *may* find music represented in one form or another, though it's by no means guaranteed: over the years, a number of classic papers, monographs, and edited collections in the three fields have scarcely troubled the music typesetter—if at all—on their way to press.

Delve a little deeper, and you may well find that much of the discourse, in one guise or another, is what may be termed a "second-level metanarrative": it is *about* what people think *about* music, rather than being directed at our perception of the sounds themselves. Of course, this is perfectly appropriate: in epistemological hybrids of the arts and social sciences such as those described, one would expect people's accounts of what of they perceive, of their feelings and preferences, and of how they learn, acquire, and share expertise, to be presented as headline acts on the main stage of intellectual action. But the human activity in which we are interested is ultimately engagement with *music*—and all too often there appears to be a reluctance to get to grips with the world of organized sound that lies at the heart of things.

The challenge of developing a shared musical understanding

Why should this be so? Partly, no doubt, on account of the fact that music, comprising our own unique internal representations of ephemeral, abstract patterns of sound, is notoriously difficult to grasp conceptually; as the phenomenologist Edmund Husserl observed, no sooner does a note enter our consciousness than it is gone, replaced by another, then others, in rapid succession (Husserl, 1905–1910/1964). Even pointing other people to the musical elements that we want them to think about—developing a shared awareness—can be problematic. I am reminded of an incident when, in the 1970s, I was listening to a band in the company of a school friend, when he suddenly asked (in a less than complimentary tone) whether I could *believe* what the bass player was doing. I had to admit that the bass line hadn't been on my auditory radar, since my attention had largely been taken up with the antics of the female lead vocalist. But then my classmate was Mark King, shortly to emerge as the great slap-bass guitarist in the pop group Level 42. Little wonder that he was particularly interested in what fellow bassists were up to. Evidently, although we were both being exposed to the same physical array of sounds, what we were *hearing* was very different.

In everyday life, this issue may be of little consequence: as the guitarist continued playing, I was able to change the subject of my auditory focus, and could appreciate what Mark was saying. But in a range of other contexts, from therapists seeking to grasp the significance of a client's cursory musical riposte, to teachers trying to ascertain *who* is influencing *whom* in a group improvisation,

or psychologists wanting to analyze subjects' sung responses to a battery of musical stimuli, a shared perception of the sounds involved is clearly critical. And in its absence, it is difficult to see, for those wishing to communicate their thinking more widely, how music-related professional or academic discourse could ever get off the ground.

Identifying what it is we want to talk about

This problem of developing a shared musical understanding is not unique to those working in the context of the social sciences: musicologists of various persuasions have long faced a comparable challenge. For Western music theorists and analysts in particular, who often want to convey detailed explanations of how complex pieces of music work, the problem is acute. Many have sought to address the issue of fleeting and fickle musical "realities" by usurping the notation used by classical musicians to freeze passages in time, fixing them on the page as visual representations upon which readers can reflect at their leisure. These may well be interpreted by enhancing the visual appearance of certain notes deemed to be particularly important, as in the work of Rudolph Reti (1951), or annotated with additional symbols that highlight notes or chords of special interest or illustrate potential connections between them (e.g. Meyer, 1973; Narmour, 1990), or even suggest structures that are said to be implied, but not present, in the original: notably in the analyses of Heinrich Schenker (e.g. Schenker, 1932).

Readers can use these augmented score fragments in a number of ways: those with the necessary decoding skills can enauralize what is presented, imagining the sounds and their interpretations internally; others may seek recourse to an instrument to reify the dots on the page; others still may use them to guide their ear when listening to a performance—an approach that seems set to become more widespread with the growth of multimedia publishing, through which digital audio files can be embedded in texts stored electronically. Indeed, we can foresee a time when the format of books and lectures about music will converge, enabling analyses of pieces in styles and genres that are not traditionally notated—and, potentially, fragments of music education and therapy sessions—to be disseminated far more readily than at present.

Issues of ecological validity

These future possibilities aside, the epistemological challenges of discussing music do not stop with the identification and reproduction of the relevant sonic materials, since there are important issues of ecological validity too (Clarke, 2005). By removing a passage from its original context, the sense of what is occurring may be completely altered, whether it be the recapitulation of the first subject of a Mozart piano sonata (usually identical in sound to the exposition, though functionally very different from it), a Coltrane saxophone improvisation in, say, *Giant Steps* (did it precede or follow the piano solo?), or a spark of communicative musicality enriching the interaction between a mother and her baby. Here, who was imitating whom? Without hearing the beginning of the sequence, it may be impossible to say who was initiating each element in a repetitive series of vocalizations, and who was responding.

Different listening perspectives

Moreover, once a musical segment is captured as a visual representation or a digital recording, analyst-listeners can play and replay it, physically or in their imagination, as often as they like, pondering the significance of the sounds, and the relationships perceived to exist between, them at their leisure. But to what extent did such connections figure in the mind of the composer,

the improviser, the therapist, or the client? Music is a highly structured form of communication, supersaturated with repetition and regularity of one form or another, only a small proportion of which, we may surmise, is detected cognitively (Ockelford, 2005a). The danger is that someone approaching a passage with an analytical mindset may discover patterns that were incidentally present in the musical fabric, and ascribe to them a significance that was neither part of the thinking that lay behind their design (whether intuitive or conscious) nor part of the "typical" listening experience (Ockelford, 2009b, p. 88).

For those working in the field of music theory (it is argued) such revelations may be of esthetic value, serving to open the ears of listeners to new ways of hearing a work (Dubiel, 1999, p. 274). Indeed, in extreme cases, music analysis that uses a score-based approach has enabled patterns to be recognized visually that would be extremely difficult if not impossible to detect aurally (Forte, 1981, p. 139; Lewin, 1987, pp. 220–5) and that may have intrinsic interest and value beyond music as it is usually experienced. Moreover, some Western classical composers, among them Bach and Schumann, for example, used symbolic references or ciphers, in which particular features of structure, rhythm, or pitch (by virtue of the letter-names of notes) were imbued with extra-musical meanings, which will almost certainly be overlooked by listeners unless they are led through extra-musical means to hear them (cf. Lerdahl, 1988).

For social scientists, who are more likely to be concerned with how music is perceived in everyday situations rather than how it *could* it be apprehended in exceptional circumstances, borrowing indiscriminately from a music-theoretical approach is fraught with potential pitfalls. While some of the techniques that analysts use to show how music works may conceivably be of value in educational, therapeutic, or psychological contexts, the lens through which the findings of such research are viewed should be shaped by an awareness of the circumstances in which material was created or cognized.

Imagine, for example, trying to gauge the musical significance of a series of swirling patterns of sound created by a non-verbal, severely autistic child using a Soundbeam®. This is a device that produces an adjustable ultrasonic ray serving as a line of intangible MIDI switches in the air, which enable a wide range of movements to be converted into any digitally created or stored sounds. Now, to the music-analytical ear, it may appear that the melodic lines were generated through the conscious inversion or retrogression of material, but without additional contextual information it may be impossible to be sure. For example, the sounds may have been produced through the habitual arm movements of the child, which were entirely unaffected by the introduction and subsequent removal of the beam and the resulting streams of notes. Here, it would appear, regular musical structures were merely a by-product of the child's brachial stereotypy. Conversely, it may be that he or she was a synesthete, known to be preoccupied with mirror symmetry. Here, it may be that using the Soundbeam® offered a kinesthetic connection between equivalent visual and auditory patterns, and it would be entirely appropriate to analyze the musical materials in terms of motivic inversion or retrogression. In either scenario, extra-musical information is used to inform music analysis.

Using music analysis to address extra-musical concerns

The opposite approach—through which the analysis of musical products is used to illuminate extra-musical attributes, activities, or relationships—is also possible in music-educational, therapeutic, or psychological study, although, with one or two notable exceptions in the field of music therapy (e.g. Wosch and Wigram, 2007) it has not been systematically applied. A key aim of the current volume is to demonstrate new and hopefully generalizable ways in which such

cross-disciplinary inference may be achieved. For example, we will address two key questions for those seeking to understand how spontaneous musical activity with others works, and its potential wider impact: *intentionality* and *influence*. For instance, when young children improvise together, how are ideas shared among members of the group, and how is a coherent narrative maintained? Are there natural leaders and followers? What can the unfolding music tell us about the children's individual identities and social roles? Or, in a different context, many therapists expect to enter into a relationship of reciprocal musical influence with their clients, which may shift at different times according to changing needs. But how can therapists assess where the locus of control lies at any given point, and the potential impact this has on those with whom they are working?

Zygonic theory

Gauging musical intentionality and influence is the province of "zygonic" theory, which was first developed in an effort by the author to explain how music intuitively makes sense. It is suggested that this will occur if the elements of a piece are heard to be logically connected, and the zygonic hypothesis is that such connections stem from imitation—not only of motifs and themes (a feature of musical structure that is widely recognized), but also of notes and chords, dynamics, timbres, textures, and tonalities. Take, for example, the famous opening of Beethoven's 5th symphony, comprising two groups of four notes, played fortissimo by the strings and clarinets (Fig. 1.1).

Listen to the music (or hum the tune), and hear how the second group seems to derive from the first: it has essentially the same rhythm (though the final note is held on a little longer) and an identical melodic contour (three repeated notes followed by one that is lower), which is moved down by a single scale-step. These similarities are reinforced by consistency in the domains of timbre and dynamic—the qualities of sound that Pierre Boulez (1963/1971, p. 37) called the "carriers" of the musical message. Zygonic theory holds that it is this sense of derivation that makes the opening of the symphony sound coherent. Observe, however, that the second motif is not merely a clone of the first: metaphorically, change is a passenger on the ship of repetition, and the relationship between the groups of notes is transformational, serving to define the early direction of travel of the music. It is this diversity within unity that makes musical communication at once interesting and intelligible.
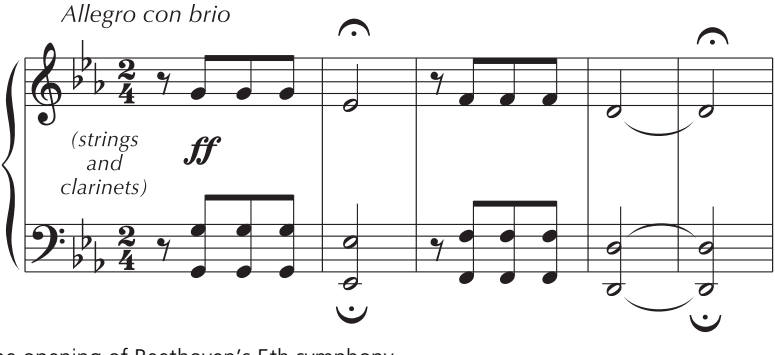
Fig. 1.1 The opening of Beethoven's 5th symphony.

How this book is organized

The principles of zygonic theory are explained in more detail in Chapter 2, drawing on a comparison between the construction of meaning in (verbal) language and in music.

Chapter 3 addresses the problem of gauging *intentionality* in musical interaction in educational, therapeutic, and psychological contexts, given the impact of both environmental and person-based constraints. How is a therapist to know that a non-verbal child's vocalization was intended as imitation, for example? Chapter 4 takes a further step, and moves from intentionality to *influence*. Here, we explore how the capacity of zygonic theory to gauge the way in which one performer has an impact on another in creative musical engagement may be exploited to analyze the nature and potential significance of musical interaction in a range of educational and therapeutic contexts.

Chapter 5 is based on the premise that, if the recognition of repetition does indeed lie at the heart of our apprehension of musical structure, then each of us must go through a process of developing the requisite cognitive skills. This chapter examines the musical development of children with severe or profound and multiple learning difficulties, an area that, until the recent emergence of the *Sounds of Intent* project (Ockelford *et al*., 2005), was a research-free zone. Observational evidence and accounts of "neurotypical" music development are fused through zygonic theory to provide a putative music-developmental framework comprising six levels of engagement that are conceptualized within three domains: "reactive," "proactive," and "interactive."

In Chapter 6, the theory is used as an analytical tool in the investigation of exceptional musical abilities—in particular "absolute pitch" and the capacity to disaggregate chords (that is, mentally to break down clusters of simultaneous musical sounds into their constituent notes). These capacities appear to be central to the way that musical savants function and enable them to play by ear so effectively. In my view, savants can fulfill a special role in music-psychological research since, like the great majority of listeners, their musical understanding is implicit rather than explicit, perceptual rather than conceptual, and intuitive rather than intellectual (Ockelford, 2011, p. 282). Unlike most of us, though, they can reproduce what they can hear in their heads, offering a unique window through which researchers can view music-cognitive processing in action. Chapter 7 takes advantage of this fact to explore musical learning, memory, and creativity using savant data, which is analyzed zygonically.

Chapter 8 examines music-structural cognition, using an expectation paradigm based on zygonic theory. Here the methodological assumption is that, given incomplete fragments of music, what listeners expect will follow reflects their understanding of the preceding musical structure. There are some surprises among the results! In Chapter 9, we take an extreme case, and examine the cognition of music that purports to be devoid of a structural feature that is thought to be central to most styles: tonality. Using zygonic analysis, we ask what strategies people adopt when they listen to "atonal" music (without a sense of key), and how these compare with the conceptual thinking of the composers concerned, such as Arnold Schoenberg.

Finally, in Chapter 10, we consider how the theoretical possibilities set out in this book may be taken forward in the future, and in particular how the ideas may be adopted by teachers and therapists to inform their practice, and by psychologists to assist in diagnosis and further their research.

Chapter 2

Music theory and the zygonic approach

Introduction

In this chapter we consider the place of zygonic theory in the broader field of music theory and analysis, and note that it is "psychomusicological" in nature. The zygonic conjecture is introduced by considering how language functions as a medium of human communication, and then noting the differences and similarities between this and music. The perceived capacity of musical sounds for self-imitation lies at the heart of the theory, and this is placed within a broader framework, which takes into account the wider environment in which music-structural cognition resides. This enables a definition of "music" to be generated, which underpins the thinking in the chapters that follow, in which the theory is applied in educational, therapeutic, and psychological contexts.

Music theory and analysis

Music theory seeks to answer questions such as "How does music work?," "What effects does it have?," and "How does it have those effects?"—issues that have engaged thinkers for at least 2500 years, since the time of Pythagoras. Music-theoretical thinking can apply to individual compositions, or to pieces collectively (pertaining to particular styles or genres), or even to music universally. This application is known as "music analysis," and in recent times, in the West, a number of different music-theoretical approaches have emerged, resulting in a wide range of analyses of many different works. There has been a strong bias towards Western "art" music, however, partly, no doubt, on account of the fact that such pieces tend to be notated, making their sonic constituents easier to identify and scrutinize.

Among the more "traditional" contributions are Donald Tovey's *Essays in Musical Analysis* (1935–1939), which comprise collections of program notes of pieces in the Western classical repertoire: accounts that fuse technical and metaphorical description as they seek to guide listeners in tracking the structure and emotional impact of works as they unfold in time. For example, in relation to a passage from the last movement of Brahms's 4th Symphony, Tovey writes (1935, p. 117): "The sequel rises through heroism . . . to radiant happiness in a procession of themes . . .. Then comes a cloud of mystery—from which the triplet theme emerges triumphant." Verbal commentaries on music are given a more contemporary sociological slant in the work of writers such as Christopher Ballantine (1984) and Susan McClary (1991), whose contention is that it is impossible to understand music divorced from the culture in which it was created: as Ballantine says, "social formations crystallize in musical structures" (Ballantine, 1984, p. xvi).

In contrast, the musicologist Heinrich Schenker (1906) and the composer Arnold Schoenberg (1911) each looked to the nature of sound itself and how it is perceived—today a field known as psychoacoustics—to explain the foundations of music in their celebrated early 20th-century textbooks on harmony. Both were ultimately interested in what gave pieces their esthetic unity, but, in seeking answers to this question, their thinking diverged radically. Schenker's search for unifying structures took him deeper and deeper beneath the "surface" of music, and he eventually

came to the view that all great works were elaborations of a single melodic/harmonic progression that he called the "Ursatz" (Schenker, 1935/1979). Schoenberg was more interested in the intricacies of the surface design, specifically "motives" ("motifs"), which he regarded as the "smallest common multiples" of pieces, appearing at the beginning and subsequently, through repetition and variation, producing "unity, relationship, coherence, logic, comprehensibility and fluency" (Schoenberg, 1967, p. 8).

Rudolph Reti was also concerned with motivic connections, and believed that the unity of Western classical compositions (within and between movements) could either be ascribed to overt relationships between material, through: "*imitation*, [the] literal repetition of shapes, either directly or by inversion, reversion, and so forth, [or] *varying*, [the] changing of shapes in a slight, well traceable manner," or, more importantly, in his view, attributed to hidden associations, generated through "*transformation*, that is, creating essentially new shapes, though preserving the original substance, [or] *indirect affinity*, that is producing an affinity between independent shapes through contributory features" (Reti, 1951, p. 240). Reti illustrated such links using note-heads of different sizes.

Allen Forte was one of the first to adopt a mathematical approach to music theory, partly in an attempt to imbue the discipline with a new rigor. In particular, Forte's application of set theory to music was intended to offer a mechanism through which the structure of the atonal music of Schoenberg, Webern, Berg, and other composers written in the first half of the 20th century could be understood (Forte, 1973). In Forte's method, groups of notes in a musical texture are isolated, stripped of all information except the letter names of their pitches, termed "pitch-classes" (A, F♯, B♭, etc., which are recorded as numbers), and manipulated to facilitate identification and comparison.

David Lewin (1987) developed this thinking further by moving away from the idea of notes as objects in sets, related by association, focusing instead on the transformations that can link them. That is, how does the ear get, for example, from A to F♯ and then to B♭? Lewin illustrated the intervals that are mentally traversed in this way using an arrow between two points. He generalized the notion of intervals (usually understood in terms of pitch) to any perceptual domain in which the elements of music are structured—including, for example, the durations of notes and the distances between their onsets. Moreover, Lewin showed that such transformations can exist in chains, enabling his theory to model series of musical events.

Others, such as Leonard Bernstein (1976), turned to the structure of language—syntax—as a metaphor for how music works. Fred Lerdahl and Ray Jackendoff (1983) went further, producing a fully fledged generative grammar of music based on Chomskian linguistics. Nicolas Ruwet also developed a system of analysis based on the concept of a musical syntax using the principles of semiology (Ruwet, 1966/1987). His method was to break down pieces into small parts and identify how they related to each other, through repetition or variation. His ideas were subsequently taken up by Jean-Jacques Nattiez (1990, 1998) among others.

Finally, we should mention Leonard Meyer's psychologically inspired accounts of music (Meyer, 1956, 1967, 1973), which combined Gestalt theory and the work of John Dewey. Meyer showed how some aspects of musical meaning could be explained by patterns in sound setting up expectations whose realizations could be deferred. According to Meyer (1967), it is the resulting psychological inhibition and subsequent sense of release that is a primary source of our emotional response to music.

In summary, the field of music theory is very diverse. Some writers, such as Tovey and Reti, are content to explain how pieces work in more or less abstract terms, using their intuitions as expert listeners to assign varying levels of significance to the internal relationships between

sounds that they can identify (typically with reference to a score). Others believe that external factors are critical to understanding how compositions are created and musical meaning is constructed. For example, musicologists such as McClary and Ballantine emphasize social and cultural contexts; Schoenberg and Schenker start from the disposition of sounds in nature; and Meyer seeks answers in psychology. Others yet bring extra-musical paradigms to bear in framing their analyses: for example, mathematics in the case of theorists such as Forte and Lewin; linguistics in the instance of Bernstein, and Lerdahl and Jackendoff; and semiology in the case of Ruwet and Nattiez.

Where does zygonic theory stand in relation to this field? Its aim is to explain how musical structure is modeled in cognition, and its starting point is the substance of music itself—sound—acknowledging that what is apprehended is likely to vary from one listener to another, according to their experience and expertise, and even between the same listener on different occasions, depending on his or her prevailing mood and knowledge of the material in question (Ockelford, 2005a, p. 32). However, the theory also holds that, in most circumstances, there will be sufficient commonality in the way that listeners intuitively process music in styles with which they are familiar for meaningful analytical discourse to occur; and that where analysis is undertaken from a particular perspective—for example that of the composer or an expert listener with the assistance of a score—this should be acknowledged (Ockelford, 2009b, p. 88).

While the starting point of zygonic theory is *music*, it also recognizes that extra-musical forces have a crucial role to play. For example, the theory takes into account the fact that music is fundamentally influenced by the physical properties of sounding objects and the way that acoustical energy is propagated in different environments (Ockelford, 1999, pp. 266–77). It attributes a key role in the way that music is designed and processed to cognitive preferences and constraints (Ockelford, 2002), and it acknowledges the wider impact of the prevailing culture on music's creation and apprehension. The theory is also responsive to the potential influence of and interaction with other modalities of artistic expression that may function simultaneously with streams of musical sound, including, for example, words (in the lyrics of songs) and movement (in the form of dance).

Zygonic theory holds that music, as we understand it, exists only in the minds of listeners (although the sounds we hear in our heads often have correlates in the physical world). Hence it is a musicological theory underpinned by psychological principles: an epistemological hybrid, in which the idiographic intuitions characteristic of music theory and analysis are informed by the nomothetic findings proper to cognitive psychology (Cross, 1998; Gjerdingen, 1999; Ockelford, 2009b). Thus it can most appropriately be described as "psychomusicological" in nature. Certain ideas from mathematics are employed to explicate and illustrate the conceptual framework on which the theory rests, and to manipulate the quantitative data it can generate as an analytical tool. Some of the principles of linguistics—in particular semiology—have proved useful to introduce the thinking behind the theory, and it is to these that we now turn.

Zygonic theory—an introduction

According to T. S. Eliot (1920/1997, 1933), language communicates on an esthetic level in three ways: through an *objective correlative*—a "set of objects, a situation, a chain of events which shall be the formula of that *particular* emotion"; through the *manner* of representation (including, for example, the use of metaphor); and through the sound qualities and structure of the language itself. Hence, meaning in a literary work arises from its semantic, syntactic, and sonic elements working together in an evocative fusion of content, structure, and sound (Ockelford, 2005b, p. 84).

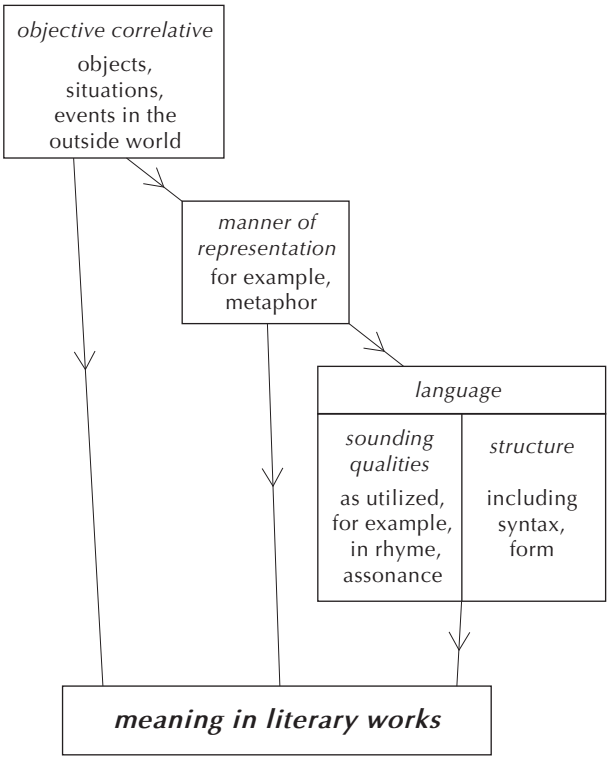

Fig. 2.1 Meaning in literature derives from the semantic, syntactic, and sonic elements of language.

This thinking may be represented as shown in Fig. 2.1. But "pure" music has no external referents, no "objective correlatives," to use Eliot's term; so whence does its meaning derive (Fig. 2.2)? Logic suggests that it must stem from the fabric of music itself: from the sounds and the relationships that we perceive between them. Zygonic theory contends that each of these sonic elements potentially bears an "emotional charge" (albeit, in some cases, a very small one), that can cause or enable an affective response (cf. Johnson-Laird and Oatley, 1992, p. 20; Sparshott, 1994, p. 28). There appear to be two main sources of such responses: "expressive non-verbal vocalizations" and "music-specific" qualities of sound.

"Expressive non-verbal vocalizations" consist of the cues used to express emotions vocally in non-verbal communication and speech (Juslin *et al.*, 2001/2002). They are present across cultures (Scherer *et al.*, 2001), suggesting a common phylogenetic derivation (that is, across the human species) from "non-verbal affect vocalizations" (Scherer, 1991) and apparently embedded ontogenetically (on an individual basis) in early mother–infant vocal interaction (Malloch 1999/2000; Trehub and Nakata, 2001/2002). It seems that these cues can be transferred in a general way to music, and music-psychological research over the last 70 years or so has shown that features such as register, tempo, and dynamic level relate to identifiable emotional states with some consistency (Gabrielsson and Lindström, 2001). For example, passages in a high register can feel exciting (Watson, 1942) or be perceived to exhibit potency (Scherer and Oshinsky, 1977), whereas series of low notes are more likely to promote solemnity or to be considered serious (Watson, 1942). A fast tempo will tend to induce feelings of excitement (Thompson and Robitaille, 1992), in

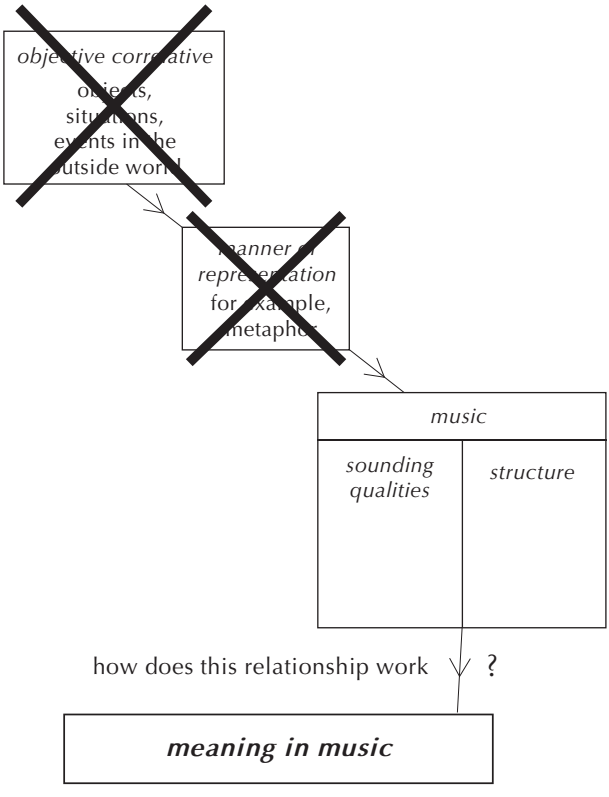

Fig. 2.2 Meaning in 'pure' music derives from the qualities of its constituent sounds and their perceived structure.

contrast to slow tempi that may connote tranquility (Gundlach, 1935) or even peace (Balkwill and Thompson, 1999). Loud dynamic levels are held to be exciting (Watson, 1942), triumphant (Gundlach, 1935), or to represent gaiety (Nielzén and Cesarec, 1982), while quiet sounds have been found to express fear, tenderness, or grief (Juslin, 1997). Conversely, "one cannot imagine sadness being portrayed by a fast forte tune played in a high register, or a playful child being depicted by a solemnity of trombones" (Meyer, 2001).

However, while these properties of sound appear to be necessary for determining musical expression (London, 2000), they are not sufficient to evoke a response that is inherently *musical*. Indeed, any succession of sounds may induce a primitive emotional reaction according to the disposition of what Meyer (2001, p. 342) terms their "statistical parameters" (which he takes to include register, dynamic level, speed, and continuity). What are the ingredients needed to arouse a specifically musical response?

One factor is the very nature of the sounds that are used in most styles and genres: they have intrinsically musical characteristics that, like those identified above pertaining to vocalization, have the capacity to induce consistent emotional responses, within and sometimes between cultures. For example, in the West and elsewhere, music typically utilizes a framework of intervals with close connections to the harmonic series—a characteristic that, as we noted above, was important in the early theoretical thinking of Schenker (1906) and Schoenberg (1911). These intervals are used idiosyncratically, with context-dependent frequencies of occurrence and

transition patterns, together yielding the sensation of "tonality" (Krumhansl, 1997; Peretz *et al.*, 1998). These frameworks of relative pitch can accommodate different "modalities," each potentially bearing distinct emotional connotations. In Indian music, for example, the concept of the "raga" is based on the idea that particular patterns of notes are able to evoke heightened states of emotion (Jairazbhoy, 1971/1995), while in the Western tradition of the last four centuries or so, the "major mode" is typically associated with happiness and the "minor mode" with sadness (Hevner, 1936; Crowder, 1985).

While the reactions that individual or small groups of sounds can engender are important in setting the "auditory scene" of music, they do not, as they stand, add up to a coherent musical response, but merely amount to a series of separate sensations pertaining to a sequence of discrete events. How, then, are these distinct, abstract responses bound together into a unified esthetic experience—to create meaning that unfolds over time—during the course of listening to a piece of music?

Consider verbal language again. Eliot's "objective correlative" is likely to be a series of events, actions, feelings, or thoughts that are in some way reckoned to be logically connected, each contingent upon one of the others or more through relationships of causation or other forms of dependency. Such relationships will be conveyed and given additional layers of meaning through language-specific relationships such as metaphor, rhyme, and syntax (see Fig. 2.3).

How does a comparable sense of coherence and unity come about in music when it cannot borrow a sense of contingency from the external world? In the absence of an objective correlative, musical events can refer only to *themselves* (Sélincourt, 1920/1956, p. 156). Self-evidently,

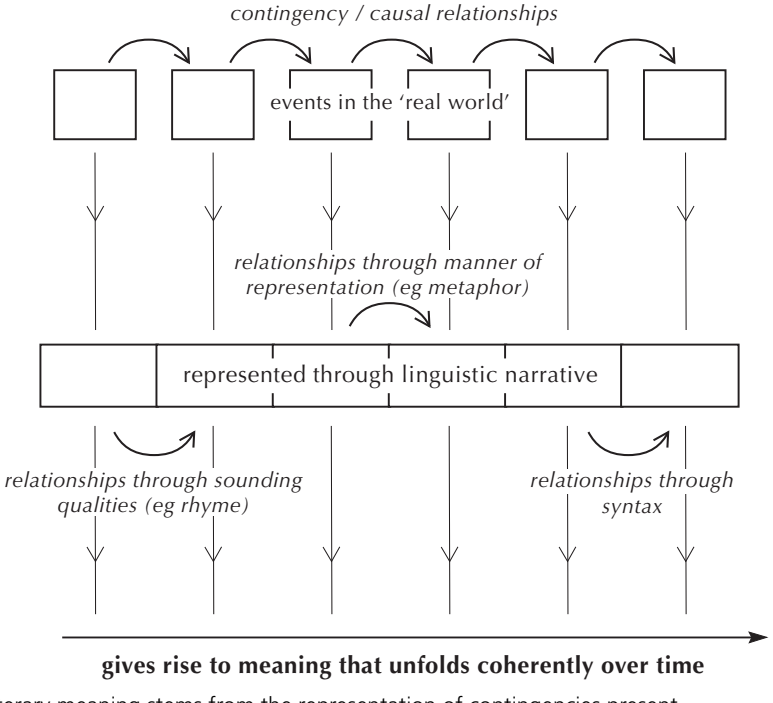

Fig. 2.3 Literary meaning stems from the representation of contingencies present in the external world.

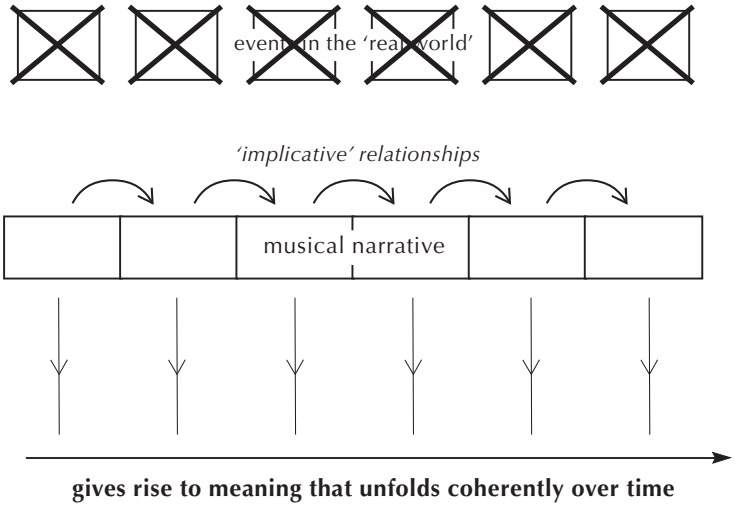

Fig. 2.4 Musical meaning stems from contingencies that are perceived to exist between sonic events.

one sound does not *cause* another one to happen (it is performers who do that), but one can *imply* another (Meyer, 1989, pp. 84). That is, one musical event can be felt to stem from another, and it is my contention that this occurs through *imitation*. If one fragment or feature of music echoes another, then it owes the nature of its existence to its model. In the mind, one musical element appears to *generate* a second, or, to put it another way, the second seems to *derive* from the first. And just as certain perceptual qualities of sound are felt to derive from one another, so, too, zygonic theory hypothesizes, are the emotional responses to each. Hence over time a metaphorical (musical) narrative can be built up through abstract patterns of sound (see Fig. 2.4).

The importance of repetition in music

Zygonic theory predicts that if music makes sense through a feeling of derivation (which stems from imitation), then repetition in music should be pervasive. And, indeed, it is: a phenomenon that is recognized in a wide range of literatures. For example, the ethnomusicologist Bruno Nettl (2006) finds features common to all musical dialects, including the fact that material is habitually repeated or varied. The essayist Basil de Sélincourt (Sélincourt, 1920/1956, p. 155) notes that the "foundation of musical expression is repetition. [It] begins in the bar, and continues in the melody and in every phrase or item into which we can resolve it." Similarly, the critic and musicologist Victor Zuckerkandl (1956, p. 213) writes: "music can never have enough of saying over again what has already been said, not once or twice, but dozens of times; hardly does a section, which consists largely of repetitions, come to an end, before the whole story is happily told all over again."

Composers themselves have expressed the same view. Igor Stravinsky, for instance, observes that "we instinctively prefer coherence and its quiet strength to the restless powers of dispersion – that is, we prefer the realm of order to the realm of dissimilarity" (Stravinsky, 1942, pp. 69, 70); according to Carlos Chávez, "repetition has been the decisive factor in giving shape to music . . . the various devices used to integrate form are, again and again, nothing but methods of repetition"

(Chávez, 1961, pp. 38, 41); while the composer and theorist Arnold Schoenberg is characteristically unequivocal: "Intelligibility in music seems to be impossible without repetition" (Schoenberg, 1967, p. 20).

Repetition features widely in other theoretical and analytical work too, its presence and functions acknowledged, if not explicitly, then by implication. Consider, for example, the traditional western notion of form, as espoused by writers ranging from Stewart Macpherson (1915) to Wallace Berry (1986). Here, the concept of stereotyped structures such as A A′ A′ A‴ . . . (characteristic of variation sets), A B A ("ternary" form), and A B A C A . . . (the "rondo") implicates repetition both within pieces and between them. Then, as we have seen, repetition is central to Schoenberg's and Reti's motivic thinking, and Alan Walker, working in the same tradition, states: "The whole point of an inspired composition is that it diversifies a unity. On the other hand, the whole point about musical analysis is that it seeks to show the unity behind the diversity"(Walker, 1962, p. 79).

Schenker too acknowledges the part played by repetition, both at the level of motifs and in the construction of large-scale forms, in his early *Harmonielehre* of 1906. This recognition carries over into the sophisticated models of musical structure that followed: in *Free Composition* (Schenker, 1935/1979) the question of repetition at deeper structural levels is aired in some detail, and repetition underpins the symmetries within the *Ursatz*.

Meyer's evolving reflections on musical patterning variously involve repetition, most overtly in his notion of "conformant relationships," "in which one (more or less) identifiable, discrete musical event is related to another such event by similarity" (Meyer, 1973, p. 44). Although it is not stated openly, the concept is no less important, however, in the first chapter of *Music, the Arts, and Ideas* (Meyer, 1967), where the author's previously developed model of musical meaning is reviewed in the light of information theory. Moreover, Meyer identifies a number of different basic melodic structures (subsequently termed "processes"—see Rosner and Meyer, 1986), including conjunct, disjunct, and symmetrical patterns, whose internal regularity and use as stylistic archetypes imply repetition within and between works (Gjerdingen, 1988).

Repetition is also central to Forte's set-theoretical analysis, which, as we have seen, entails abstracting groups of pitch-classes and tracing similarities between them, and to semiological analysis, to which motivic similarities are fundamental at the paradigmatic stage. As Ruwet (1966/1987, p. 16) says: "I shall start from the empirical appreciation of the enormous role played in music, at all levels, by repetition, and I shall try to develop an idea proposed by Gilbert Rouget: '. . . certain fragments are repeated, others are not; it is on repetition—or absence of repetition—that our segmentation is based.'"

Finally, consider that repetition ("parallelism") accounts for four of the five preference rules underlying Lerdahl and Jackendoff's "generative theory of tonal music." As the authors state: "The importance of parallelism in musical structure cannot be overestimated. The more parallelism one can detect, the more internally coherent an analysis becomes, and the less independent information must be processed and retained in hearing and remembering a piece" (Lerdahl and Jackendoff, 1983, p. 52).

In relation to music analysis—the application of theory to a particular piece or group of pieces—Ian Bent and William Drabkin (1987, p. 5) provide a useful summary:

> Analysis is the means of answering directly the question "How does it work?". Its central activity is comparison. By comparison it determines the structural elements and discovers the functions of those elements . . . comparison of unit with unit, whether within a single work, or between two works, or between the work and an abstract "model" . . .. The central analytical act is thus the test for identity.

Hearing zygonic theory in action

So much for the recognition of repetition in music. To reiterate: zygonic theory takes a further step and suggests that it is a sense of *derivation* stemming from one musical element imitating another that is important in creating the sense of narrative in music. The easiest place to hear the theory in action is in "canons," which are explicitly structured through repetition: one musical line consciously being made to copy another. Figure 2.5 shows the opening of *Et in unum Dominum* from Bach's B minor Mass, where the composer uses the derivation of the alto part from the soprano within a unified musical framework as a symbol of the Father *begetting* (not creating) the Son, which, according to Christian dogma (and Bach, by all accounts, was a devout believer), subsequently co-existed as parts of the same spiritual entity.

Irrespective of the symbolism, it is easy to appreciate how each note in the alto voice, ensuing shortly after an identical event sung by the soprano, sounds irresistibly to the musical ear as though it derives from it. In the mind, each pair of notes appears to be connected via a mental "bridge" that spans the two perceived sounds. Each of these may be termed a "zygonic relationship" or "zygon" (after the Greek word for "yoke," meaning the union of two similar things—see Ockelford, 1991, pp. 140ff.). In order to make analysis and understanding easier, it is sometimes helpful to represent these putative cognitive connections visually, and, at its simplest, this can be achieved through an arrow with a superimposed "Z," as shown in Fig. 2.6.

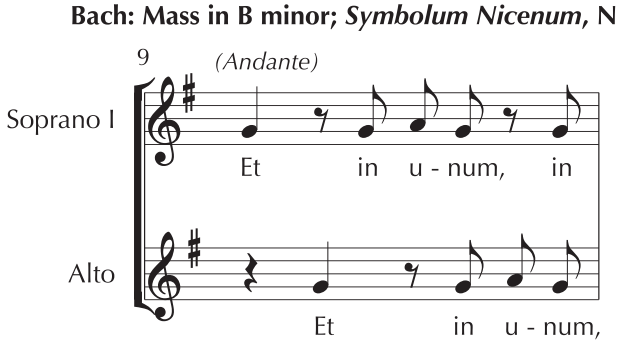

Fig. 2.5 A sense of derivation occurring through canonic imitation.

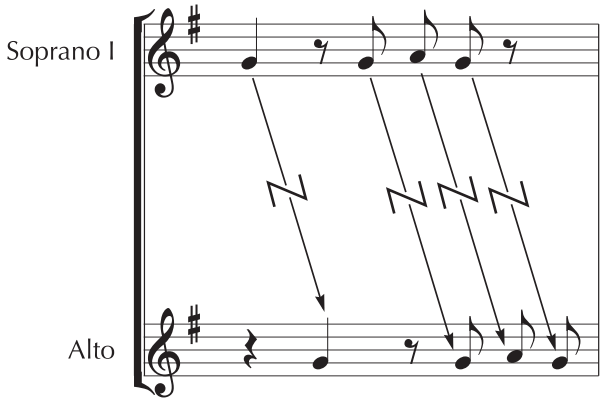

Fig. 2.6 Visual representation of zygonic relationships.

Of course, most derivation is less straightforward than this, which involves entire notes being imitated with respect to pitch, duration, and (arguably) other qualities such as timbre and loudness. Because these characteristics can operate independently in music, zygonic theory treats each of them as a potentially discrete variable in the domain of perceived sound, and acknowledges that each has unique psychoacoustic properties. For example, some features, like timbre and loudness, gauge perceived *qualities* of the sonic medium, while others detail its perceived *location* in time or space; some, such as pitch, pertain to *individual* notes, while others, including tonality, are characteristic of a *group*. Crucially, however, these elements, which together comprise the "auditory scene" of music (Bregman, 1990), share a fundamental similarity in that each has a number of potential modes of existence. These are termed "values" (Ockelford, 1991, 1993), whose range in each case represents the freedom of choice open to those striving to create new pieces of music.

Zygonic theory holds that the imaginary connections between notes illustrated in Fig. 2.6 are one form of "interperspective relationship"—a psychological construct through which, it is hypothesized, incoming perceptual data are compared (cf. Krumhansl, 1990, p. 3).[1] Interperspective relationships may be understood as forms of "link schemata" (Lakoff, 1987, p. 283), which occupy the mental space pertaining to music processing (cf. Fauconnier, 1985/1994; Lakoff, 1987, pp. 281, 282). Such relationships can function in any perceptual domain pertaining to music. In most circumstances they appear to be formulated unthinkingly, passing listeners by as a series of qualitative experiences. However, by employing the metacognitive processes typical of music theory and analysis, we can capture interperspective relationships conceptually, and, as we have seen in Fig. 2.6, represent them using symbols.

Non-zygonic interperspective relationships may be assigned values, some of which can be expressed as a difference or ratio, while others necessarily reflect the complex nature of the aspects of perceived sound to which they pertain. They may be illustrated using an arrow on which the letter "I" (for "interperspective") is superimposed. Because every musical event has a number of different perceived sonic qualities, it is often necessary to "tag" relationships to indicate to which feature they refer. In diagrams, superscripts are used to fulfill this function, whereby the perceived aspect (or "perspect") of sound concerned is represented by its initial letter or letters. In the example set out in Fig. 2.7, the two perspects that are analyzed are "scale degree" (equivalent to the do, re, mi, fa, sol, la, ti of solfège), abbreviated to "Sd," and "onset," the point in time at which a note begins, shortened to "O."

As the analysis in Fig. 2.7 shows, interperspective relationships can exist at different levels, whereby "primary" relationships link the values of perspects themselves (known as "perspective values"), "secondary" relationships connect primaries, and "tertiary" relationships offer a medium through which "secondaries" can be compared (Ockelford, 2002). The level of a relationship is indicated by the appropriate subscript (here, "1" in the case of the primary relationships of onset, and "1" and "2" pertaining to the primary and secondary relationships of scale degree). The values of the relationships (shown near the arrowhead as +1, +2, +♪, etc.) have two components: "polarity" (direction) and "magnitude."

[1] "Interperspective": a term I coined in Ockelford (1991) to mean "between *perspects*" (that is, "*per*ceived a*spects*") of music; used in contradistinction to the term "parameter," which is reserved solely to refer to the physical attributes of sound. Hence the perspect "pitch," for example, most closely corresponds to the parameter "frequency," though the connection between the two is far from straightforward (cf. Meyer, 1967, p. 246).

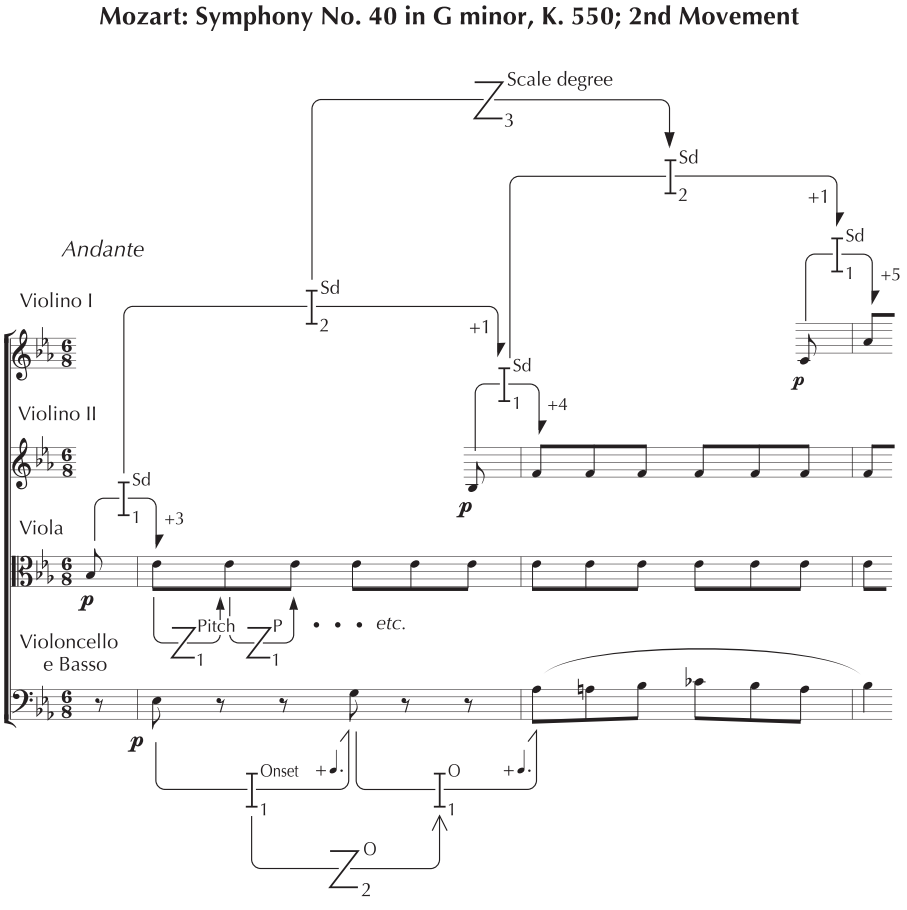

Fig. 2.7 Examples of the representation of interperspective and zygonic relationships.

As we have seen, interperspective relationships through which derivation is acknowledged cognitively are deemed to be of a particular type that is termed "zygonic." In Fig. 2.7 it is suggested that primary zygons of pitch link the repeated notes in the viola,[2] the phenomenological implication being that each note is felt (albeit non-consciously in the "typical" listening experience) to derive from the one that precedes.[3] A secondary zygonic relationship of onset is illustrated in the cello and bass part, reflecting the fact that the first three notes are equally spaced in time, and that the second inter-onset interval between them may be considered to exist in imitation of the first.

[2] Although they are not shown, it is assumed that primary zygonic connections would operate similarly in the second violin part.

[3] It is also possible that a note will be heard as deriving from others further back in the sequence. Hence, the third E♭ in the series may be thought to be generated in part from the first E♭ (as well as the second), for example. So it is conceivable that *networks* of relationships may link values that exist as part of a set of three or more. The webs of implicative relationships that potentially pertain to groups of identical (or similar) values are termed "constant systems" (see Ockelford, 2005a, p. 25).

This is only one of many examples of the zygonic forces that can be considered to be at work in the realm of perceived time within a texture that, like that of almost all music, is replete with repetition and regularity in the domains of onset, duration, and meter. Finally, it is proposed that a tertiary zygon of scale degree connects the two secondary interperspective relationships that express the common difference between the successive melodic intervals with which the entries of the violas, second violins, and then the first violins begin.

The zygonic relationships shown in Figs 2.6 and 2.7 use *full* arrowheads, which signify relationships between values that are the same, as opposed to the *half* arrowheads of the interperspective relationships, which are indicative of difference. Zygonic relationships too can make use of half arrowheads, when the values they link are similar rather than identical. *Open* arrowheads (such as those pertaining to onset in Fig. 2.7), indicate relationships between single values, whereas *filled* arrowheads link perspective values that persist in time (in Fig. 2.7, those pertaining to pitch and scale degree). More detailed accounts of zygonic theory are to be found in Ockelford (1993, 1999, 2005a, 2009a).

It is clear that zygonic relationships can at best offer only a highly simplified version of certain cognitive events that we can reasonably surmise take place during participation in musical activity. However, while simplification is always necessary to make headway in theoretical terms, some idea of the complexity involved can be gleaned by appreciating that the single concept of a zygon bequeaths a vast perceptual legacy, with many potential manifestations: between, for example, pitches, timbres, loudnesses, durations, inter-onset intervals (the lengths of time between notes' inceptions), tonal regions, textures, processes and forms that are the same; over different periods of perceived time; and within the same and between different pieces, performances, and hearings. There is, of course, no suggestion that the one concept is perceptually or even neurologically equivalent in all these manifestations, but *logically* so in terms of musical structure. Whatever the context, zygons may function in a number of ways: reactively, for example, in assessing the relationship between two extant values, or proactively, in ideating a value as an orderly continuation from one presented. They may operate between anticipated or remembered values, or even those that are wholly imagined, only ever existing in the mind. Hence, empirical evidence in support of the theory is likely to be drawn from a diversity of sources.

Currently, for example, one can point to experiments in auditory processing (such as the "continuity illusion," summarized in Bregman, 1990, pp. 344ff., and work on the perceptual restoration of omitted or obscured notes; see, for instance, DeWitt and Samuel, 1990) to support the presence of proactive zygonic-type processes. More recently, zygonic theory has been used to build a model of expectation in music (Ockelford, 2006a), which has been tested experimentally with some success (Thorpe *et al*., 2012; Ockelford and Sergeant, in press), research that is reported in Chapters 8 and 9 of this book. And there is increasing evidence to support the theory in studies of children with learning difficulties, whose musicality tends to evolve in small steps, making the identification of the early stages in the development of music-structural cognition more straightforward than would otherwise be the case (Ockelford, 2008b; Cheng *et al*., 2009; Welch *et al*., 2009; Ockelford *et al*., 2011). This work, together comprising the *Sounds of Intent* project, is the subject of Chapter 5.

Although, for the sake of theoretical simplicity, we have considered the creation and reconstruction of musical meaning in "absolute" terms, in reality, these processes do not exist in isolation, but reside within and contribute to the "cognitive environment" of listeners (Sperber and Wilson, 1995, pp. 38ff.). This is influenced to a greater or lesser extent by extra-musical forces, pertaining both to the inner world of the person concerned (which is in turn determined by internal and external factors, past and present) and to his or her reaction to the immediate

circumstances in which the performance is being heard. One extra-musical factor that has been of concern to philosophers and psychologists alike is the power of *association*, which can completely overwhelm a listener's reaction to intra-musical attributes which, ceteris paribus, would occur, while nevertheless leaving intact her or his ability to recognize the sentiments which the piece would typically evoke in other listeners, and without compromising the internal "sense" of the music. Hence, the wedding march played following the death of one's partner may still be recognized as essentially joyful (even though it may elicit intense grief) and be perceived as musically coherent (even though its effect in esthetic terms is the opposite of that which the composer intended).

Other factors pertaining to listeners include: the emotional and esthetic range of experiences they bring to bear; their knowledge of music, gained through previous hearings of this and other performances of the current piece and others; "extra-musical associations" (connotations of non-musical entities or events established through previous experience that may be stimulated by

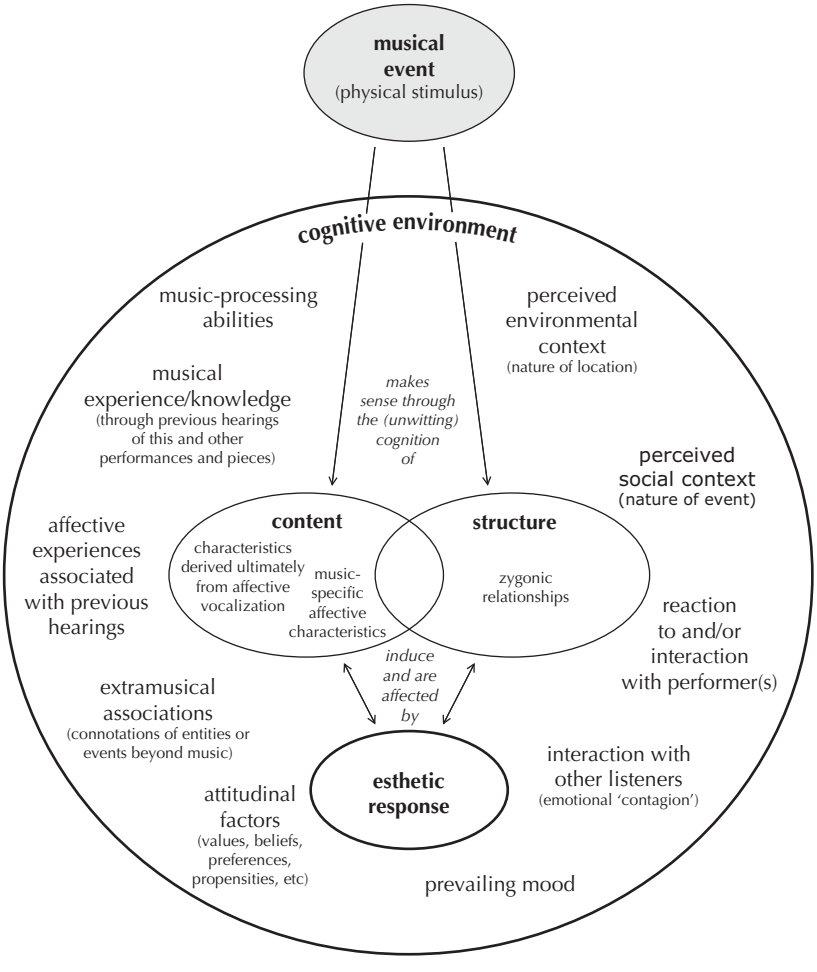

Fig. 2.8 The wider environment in which music-structural cognition resides.

further hearings of a piece or feature of it); their music-processing abilities; attitudinal issues, such as values, beliefs, preferences, and propensities; and their prevailing mood, which will provide the affective backdrop against which any emotions aroused by the music will be superimposed as phasic perturbations (Davidson, 1994). The external environment can influence esthetic response in a number of ways too. A listener may well be affected by the behavior of the performer and by the reactions of other people who are present, through empathy and "emotional contagion" (Scherer and Zentner, 2001, p. 370). Other considerations include the social context in which the music is being heard and the nature of its location (Scherer and Zentner, 2001, pp. 364–5). All these factors contribute to the cognitive environment of the listener, which may be represented schematically as in Fig. 2.8. This shows the central place that the cognition of structure plays in the listening process as a whole.

An example of zygonic analysis: the opening of the first movement of Mozart's piano sonata K. 333

The remaining chapters in this book are devoted to showing how the zygonic approach to music-structural understanding can be used in music-psychological, educational, and therapeutic contexts. Before embarking on this path, and in order to give a sense of the theory in action, there follows part of the analysis of the first movement of Mozart's piano sonata in B♭, K. 333, which first appeared in Ockelford (1999, pp. 704–61) and subsequently in Ockelford (2005a, pp. 35–66). In the current context, the important thing is less the specific findings of the analysis than the demonstration of the *type* of data that zygonic theory brings to light—both quantitative and qualitative—and the explanation of how these work together to create musical meaning. Although (clearly) K. 333 is "art" music, it is my contention that the nuts and bolts of how the piece "works" in cognitive terms are essentially the same as in the musical efforts of children and young people—including those with learning difficulties—described in the chapters that follow. For sure (as we will see) Mozart's masterpiece may have subtleties of construction and additional layers of meaning that are not shared by the more modest creative enterprises of musically "typical" children, but ultimately they are all products of the human mind that, I believe, are held together with the same cognitive "glue" of derivation through imitation. This begs the question of just what makes music "music," and where the boundaries of music and other types of human sound production lie: an interesting, relevant, and philosophically challenging topic taken up in the final section of this chapter.

But for now, let us return to K. 333. To the ear familiar with Western classical music, nothing could sound more natural, more unpretentious, and less like a multidimensional matrix of meticulously crafted logical connections in sound, than the first movement of this piano sonata. Yet zygonic analysis indicates that there as many as *40* types of structural imitation in this movement potentially operating at any given time (Ockelford, 1999, pp. 704ff.), connecting individual pitches, the intervals between them, and their relative probabilities of occurrence; harmonies, harmonic transitions, forms of dissonance, and the manner in which these are resolved; keys, modulations, and longer-term tonal structures; the durations of notes, their inter-onset intervals, meter, rhythms, phrase lengths, and lengths of sections; textures, melodies, the connections between them, and overall form. Wide-ranging analyses (Ockelford, 1999) suggest that, far from being the exception, integrated, multimodal organization on this scale is the rule in the great majority of music. Moreover, were the structure in any one of the dimensions to be compromised, the musical fabric as a whole would no longer hang together coherently. Of course, I am not suggesting that Mozart gave any of this a moment's conscious thought as he composed

the sonata. For him, by all accounts, creating music was as natural and effortless as speaking. But just as producing and understanding cogent and expressive verbal language makes huge demands on cognitive processing (of which speakers and listeners are typically wholly unaware), so too does generating and attending to music. And, it appears, it is only by imbuing the musical message with a very high degree of redundancy—far beyond that of verbal language—that musical communication, generated through pure, abstract patterns of sound, and devoid of the semantic tags that, as we have seen, hold a linguistic narrative together, is cognitively achievable.

The first structural element we will consider is the "background" organization of the movement: general characteristics that are more or less common to other pieces in a similar style. Hence they do not determine what makes a piece unique (it is largely the nature of relationships between successive events that give a work its exclusive identity). The great majority of background structure, and by far the most musically sophisticated and significant, occurs in the domains of pitch and perceived time (Ockelford, 2005a, p. 37). For example, 78% of inter-onset intervals between successive notes are in the ratio 1:1, implying vast networks of potential zygonic relationships (see Fig. 2.9), whose cognition, it is believed, facilitates memory, frames understanding, and fuels expectation (cf. Huron, 2006).

Other inter-onset ratios are encountered far less frequently, as the chart pertaining to the first movement of K. 333 given in Fig. 2.10 shows. Similarly skewed distributions are found in other piano sonatas by Mozart, implying the existence of perceived temporal imitation between pieces operating on a statistical level. In the piano sonatas K. 284, K. 310, K. 311, and K. 333, for example, the degree of similarity in the distribution of inter-onset ratios is 92% (where dissimilarity is calculated as the average divergence from the mean of each category of ratio):

$$\text{Similarity (\%)} = 100 - \sum \left(\frac{\Sigma \left| x_i - \left(\frac{\Sigma x_i}{n} \right) \right|}{n} \right) \tag{2.1}$$

The predominance of very few inter-onset ratios is characteristic of a good deal of other music too (Fraisse, 1978, p. 243; Ockelford, 1999, pp. 355–71), and features strongly in the children's improvisations described in the chapters that follow.

With regard to K. 333, in the domain of pitch, an analysis of melodic intervals between adjacent notes reveals substantial background organization across the first movement as a whole. A little over 90% of intervals are a perfect 4th (five semitones) or smaller. Of these, major 2nds (two semitones) alone account for almost 40% of all melodic transitions (see Fig. 2.11). Moreover, the essential characteristics of this distribution are a feature of other pieces too, implying stylistic imitation of the type shown.

The tendency of small intervals to occur much more frequently than large ones is by no means confined to the music of Mozart, as a number of studies pertaining to various Western genres have shown. These range from folksongs to many styles of classical music and popular music of the 20th century (e.g. Fucks, 1962; Jeffries, 1974, p. 904; Dowling, 1978, pp. 351, 352; Huron, 2006, pp. 74, 158–61). Again, it is also typical of the children's music analyzed in Part II of this book.

So what is it that makes K. 333 stand apart from the run-of-the-mill efforts of schoolchildren, or, indeed, many other musicians seeking to create new music? Zygonic analysis suggests that it is the fusion of the music's logic with its expressive character—the "carrier" and the "message" are one—that makes the first movement of K. 333 wholly persuasive and, by critical consent, of particular beauty to stylistically attuned ears. How does this fusion occur? Take, for example, Mozart's

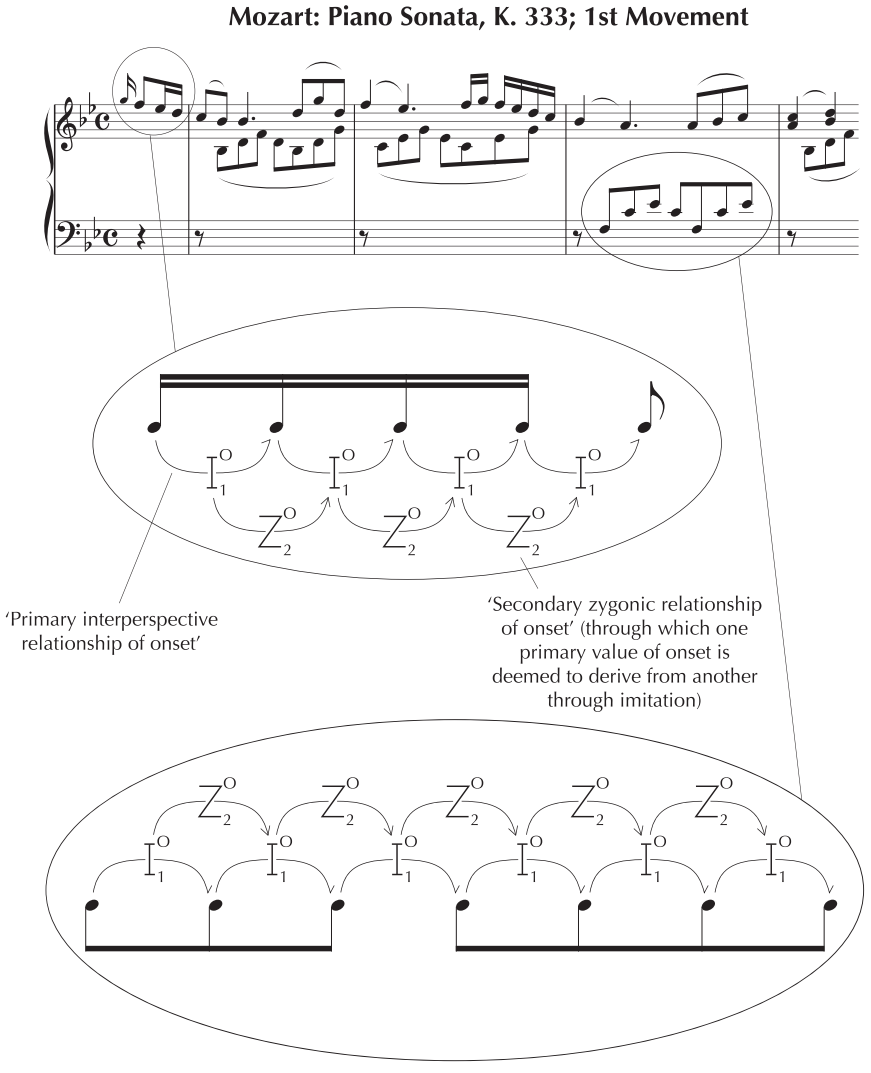

Fig. 2.9 Examples of the potential zygonic relationships linking successive inter-onset intervals of the same magnitude in the first movement of K. 333.

use of appoggiaturas[4] in the opening phrase. Zygonic theory contends that the fourth appoggiatura, heard structurally as a product of the first three, does more than *replace* their affective qualities in current consciousness: it *transforms* them. That is, the relative stability of the opening descent (comprising three pairs of notes that unfold the major tonic triad) is remodeled to generate the conclusion to the second phrase, consisting of a further appoggiatura that resolves onto the supertonic minor harmony—a metamorphosis that engenders a sense of yearning that

[4] Appoggiaturas are ornamental notes that do not belong to the sounding harmony. They occur on the beat and precede a main, harmonic note, by which they are separated by one scale degree.

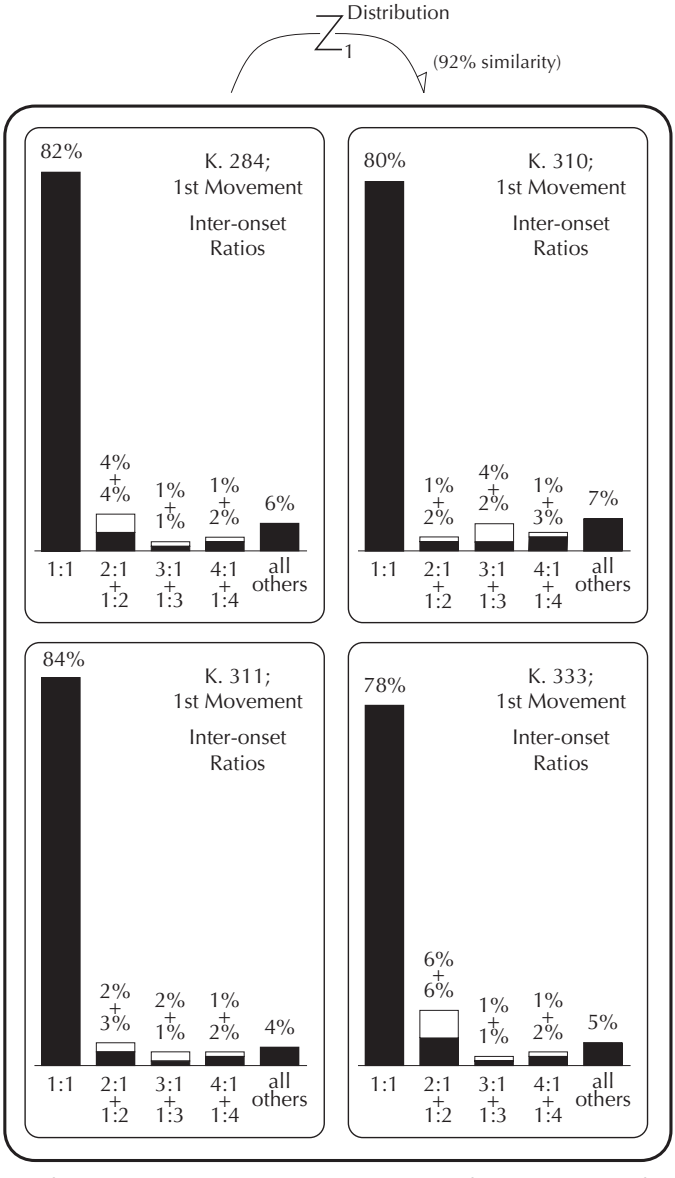

Fig. 2.10 Imitation of inter-onset ratios within and between the first movements of piano sonatas by Mozart.

the minor chord in isolation would not have produced (see Fig. 2.12). Intuitively, to resolve the miniature esthetic narrative built up to this point, the appoggiatura needs to be transformed again, and made to re-appear in the context of a tonic harmony. Mozart achieves this through compelling though unobtrusive structural logic (Fig. 2.13). The opening phrases are linked in other ways too, simultaneously implying retrogression on one level and transposition on another (Fig. 2.14).

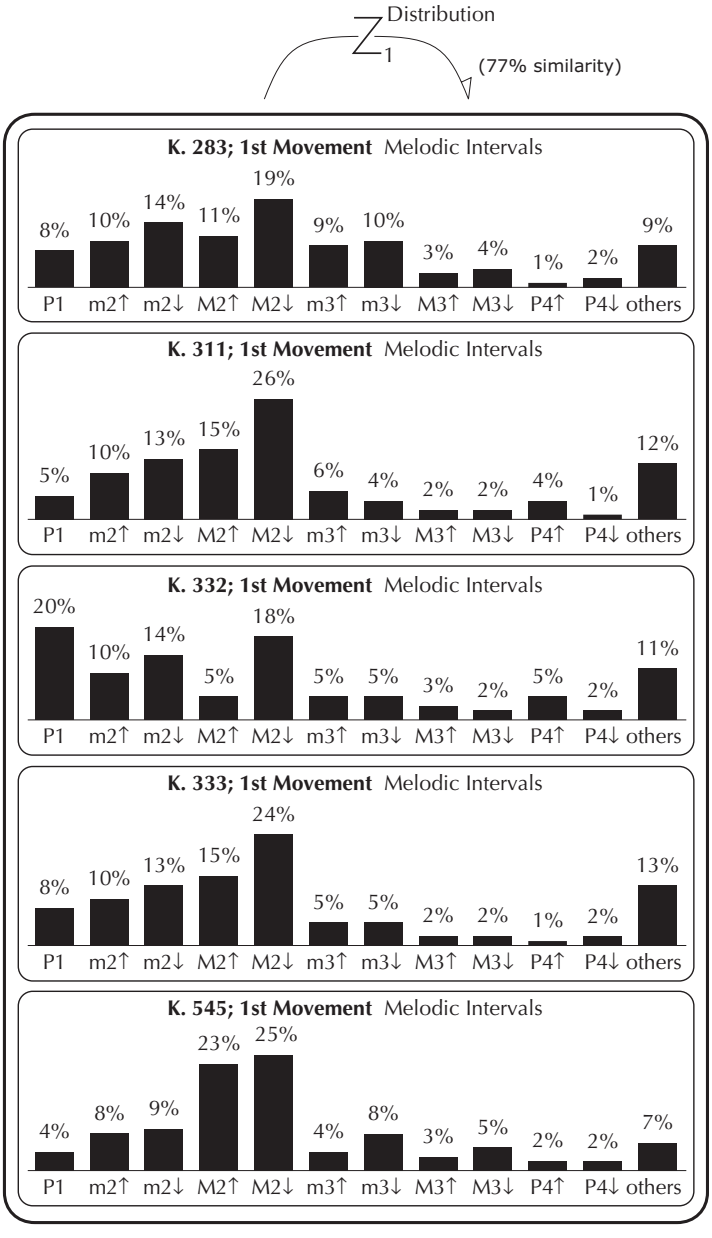

Fig. 2.11 Imitation of melodic intervals within and between the first movements of piano sonatas by Mozart.

Hence in less than 10 seconds of music (just 51 notes), Mozart sets a unique musical scene, albeit one within well-worn stylistic territory, and introduces the listener to a sophisticated musical narrative, with different layers of meaning that unfold simultaneously. It seems that it is quite possible, though, to "get the message"—or, at least, the main thrust of it—without appreciating all the nuances and depths of the musical language that Mozart chooses to use (and it is, of course, quite

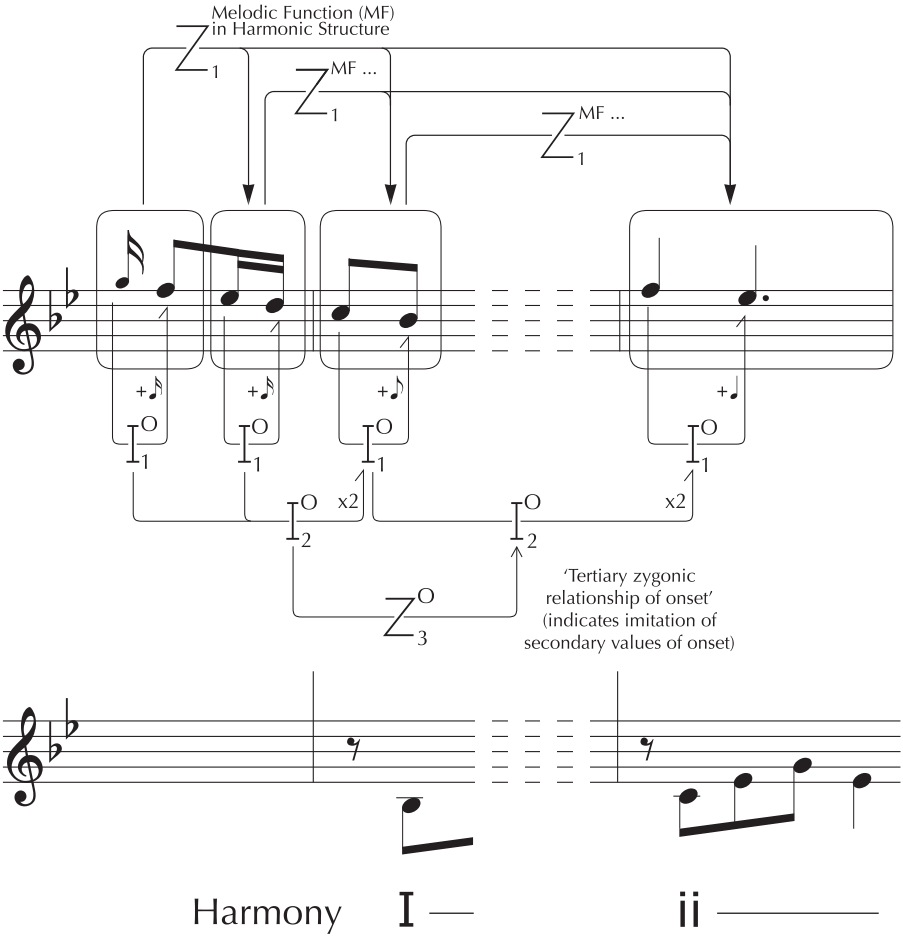

Fig. 2.12 The structural and affective use of appoggiaturas in the first two bars of K. 333.

possible to perceive the deeper shades of meaning without understanding how they are formulated). But the important point in the context of applied musicology is that, according to zygonic theory, *all* intra-musical meaning ultimately works in the same way (through a sense of derivation arising from imitation): therefore, the difference between K. 333 and (for example) a child's composition in terms of analysis is a matter of degree rather than substance.

Using zygonic theory to define "music"

Solving one theoretical problem merely raises another, however: given that applied musicology, by definition, pertains to *music*, and given that humans produce and attend to a wide range of organized sounds, what distinguishes music from other forms of sound production and cognition (see Ockelford, 2012d)? The question of just what constitutes music has been regarded a legitimate area of philosophical concern since the time of the ancient Greeks, and there are those that contend that, since music has varied (and continues to vary) so much with time, place, and culture, it would be impossible to arrive at a single, fully inclusive definition of music

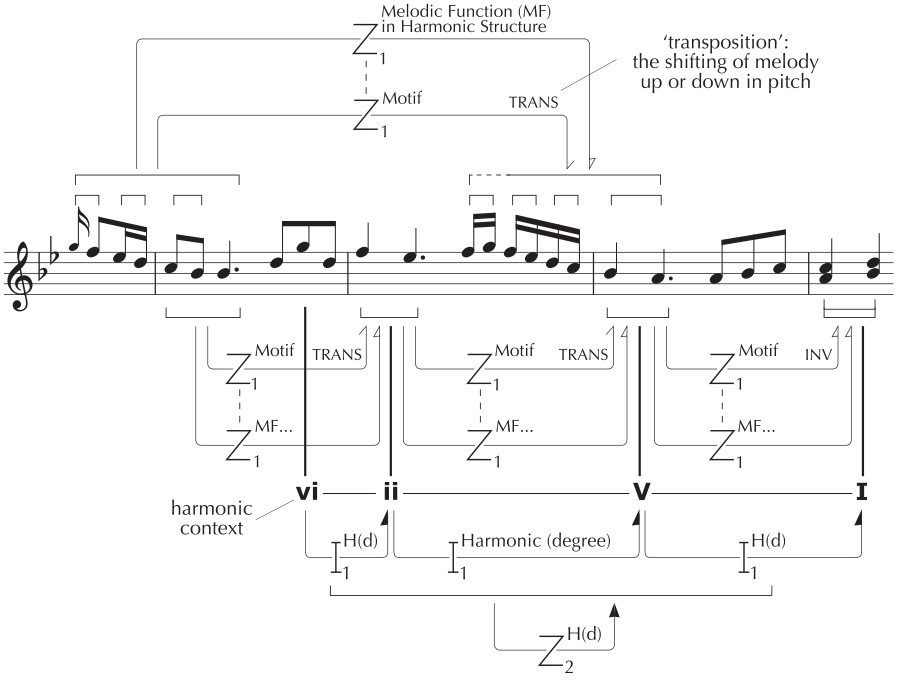

Fig. 2.13 Systematic relationships between appoggiaturas and harmonic and melodic structure in the opening bars of K. 333.

(cf. Molino, 1975, p. 37). As Nattiez says: "By all accounts there is no single and intercultural universal concept defining what music might be" (Nattiez, 1990, p. 55). However, that is not the same as arguing for a more limited form of universality, whereby there may be *aspects* of music that are necessary to its existence, even if they are not sufficient to offer a comprehensive definition in all contexts. If so, what might some of music's universal features be?

One contender must surely be Edgar Varèse's all-embracing notion of "organized sound," which the composer coined in the 1920s in an attempt to broaden the generally accepted concept of "music" that was prevalent in the West at the time, to include his own, experimental work. The controversy this caused had less to do with the idea of musical elements needing to be "organized" than Varèse's inclusive definition of "sound" in a musical context, which encompassed what many people took to be "noise": that is, sounds they did not like and which therefore could not, in their view, constitute "music"—the art of the beautiful (see Varèse and Wen-Chung, 1966, p. 18).

Almost 100 years later, the universe of sounds that people regard as potentially "musical" has widened considerably, and it is easier to focus on the real problem with Varèse's definition: that organized sound does not have to be "musical." In his ecological approach to auditory event perception, Gaver (1993) points out that there are essentially two ways in which we hear sounds: through "musical listening," which focuses on perceptual qualities such as pitch and loudness, and via "everyday listening," which is more concerned with function. To these two categories, we should add the organization of sound as verbal language (Scruton, 2009, p. 4). Hence Varése's definition of "organized sound" can be seen to suffer from "overextension," in that it does not apply exclusively to music.

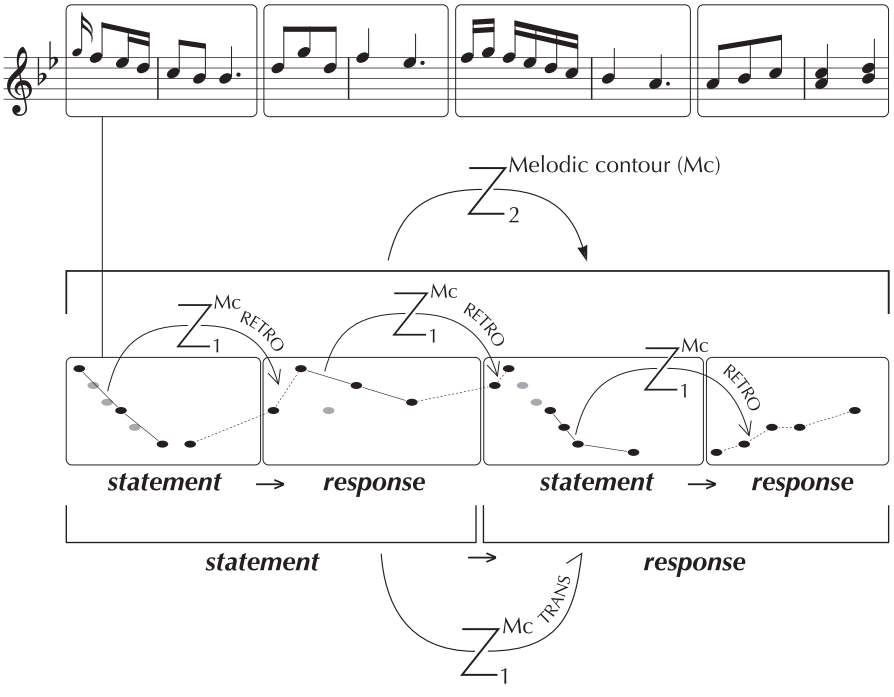

Fig. 2.14 Effect of statement and response at different levels in the structural hierarchy accomplished through complementary forms of zygonic organization.

Scruton's account (Scruton, 2009, p. 5) takes a further step, by making it clear that music "relies neither on linguistic order nor on physical context, but on organization that can be perceived in sound itself, without reference to context or to semantic conventions." But by resolving one issue, Scruton raises another: that of "perception." Whose perception? As Lerdahl (1988) points out, and as we have seen in relation to K. 333, the organization that composers utilize in their work need not be detectable by listeners. Moreover, because of the high degree of redundancy that typically characterizes the musical message (Moles, 1958/1966; Cohen, 1962), there may well be structures that can be identified in pieces that were incidental to the process of composition (Ockelford, 2009b, p. 86). Indeed, that special breed of listener—the music analyst—is capable of identifying structures that lie beyond practical levels of engagement with music (Ockelford, 2009b, p. 88) (see Fig. 9.14).

Thus what is music to one person's ears need not be music to another's. Indeed, it is conceivable that material that was never intended to be construed as music (ranging from the sounds of nature to the noise of machines) could be heard as such. Hence we appear to have argued our way back to the relativist position that what constitutes music is purely in the ear of the beholder, and that so-called "universals" are necessarily illusory constructs pertaining to the prevailing culture of discourse. But this feels counterintuitive. The very fact that the great majority of people apparently engage with what they think of as "music" every day of their lives implies that there is a single concept, or, at least, a bundle of concepts, to which most of us, in part or as a whole, can subscribe. So let us see if we can escape the circularity of the arguments that have been advanced by analyzing what makes music "music" using zygonic theory. Such thinking runs as follows.

Zygonic theory holds that:

1 The essence of music is that one sound or group of sounds, or feature or features thereof, should be heard as deriving from another or others through imitation. Hence music is a purely cognitive phenomenon (existing only in the mind), and while there may (but need not) be physical correlates of our internal audition, these do not constitute "music."

2 A sense of derivation through imitation enables us to hear discrete sonic events as a coherent stream of abstract sounds, as "music": and just as each event has the capacity to induce an emotional reaction, so the contingencies we hear in a series of musical sounds can evoke an emotional narrative that unfolds in time. (This is distinct from musical meanings that derive through association.)

3 Almost without exception, mature humans have the capacity to hear sounds and the relationships between them as being derived from one another through imitation; this requires no formal education, and typically occurs non-consciously: we are virtually all intrinsically "musical."

4 A sense of derivation through imitation is a necessary feature of all structures that we perceive as musical; a consequence of this is that all music is infused with repetition in all domains and at all levels.

5 Hence music is typically supersaturated with far more repetition than is required for it to be coherent, and this has two consequences: (a) listeners do not need to hear all the available structure for a given musical message to make sense, and (b) different listeners (or even the same listener on different occasions) can apprehend different structural elements, yet each can still have a coherent musical experience. Moreover, it is possible that a sense of derivation through imitation that was conceived by a composer may not be detected by listeners, and vice versa. Nonetheless, there is normally enough common perceptual ground for pieces of music to exist as shared and meaningful cognitive enterprises.

6 Music can and may well be associated with other social and communicative activities (such as dance and verbal language), which may interact with the cognition of purely musical structures and contribute additional layers of meaning. In some cultures, the notion of "music" embraces more than just abstract patterns of sound. Nonetheless, streams of sound, structured through a sense of derivation through imitation, are a feature of all the musical experience.

We will now test this definition in a number of different scenarios.

Take, for example, the notion of music in nature (for example, Rothenberg, 2001; Sallis, 2006, p. 56) and consider (for instance) Tennyson's "babbling brook." This may be regarded by some as "music to the poet's ears," but zygonic theory would contend that it can be so only in a metaphorical sense, since there is no imitation present; no coherent narrative in which sounds are deemed to derive from one another through imitation. Hence rushing water (or similar features of a naturally occurring soundscape, such as pattering rain and wind sighing through the trees) fail the "musical" test.

With another natural sound—birdsong—the position is more complex, however. Birds typically use short, distinct motifs that are well defined in terms of pitch, time, and timbre, and which as youngsters they have usually learnt from a conspecific adult (Phan *et al*., 2006; Gobes and Bolhuis, 2007). They often repeat their calls to form chains of avian melody. But do such concatenations constitute music? Consider, for example, the series of four "cuckoo" calls recorded in a natural setting shown in Fig. 2.15. It is, of course, impossible to say for sure whether the bird acted with any sense of self-imitation as he sang to defend his territory, or whether the repetition that

occurred was merely a by-product of his communicative instincts. There is evidence that cuckoos have some awareness of their vocal products, since they can distinguish their own songs from those of other species. However, since the development of their singing need not have been influenced by conspecific adults, and as their calls are very similar across a wide geographic range, it appears that they are innate rather than learned (Payne and Sorensen, 2005, p. 97), and therefore *not* deliberately imitative. However, it is perfectly conceivable that humans may hear the successive "cuckoos" illustrated in Fig. 2.15 as being derived through imitation, implying that the series of calls constitutes, in their minds, music (see Fig. 2.16), in effect constituting a reverse example of Lerdahl's mismatched "compositional" and "listening" grammars (Lerdahl, 1988, p. 403).

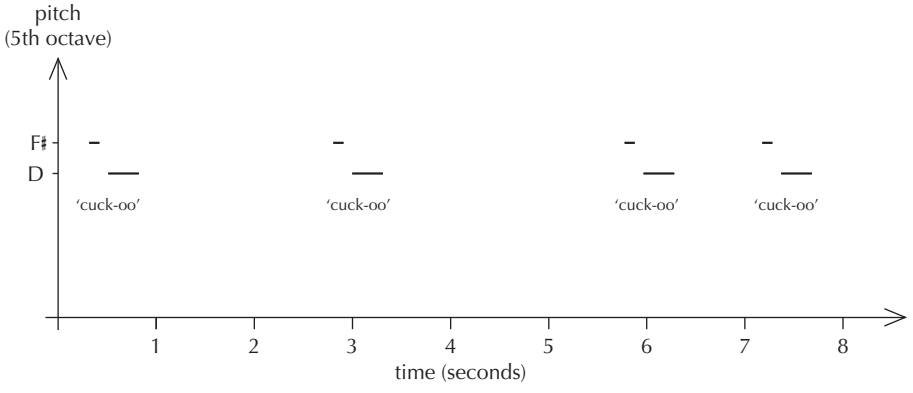

Fig. 2.15 Representation of four 'cuckoo' calls recorded in a natural setting: do they constitute music?

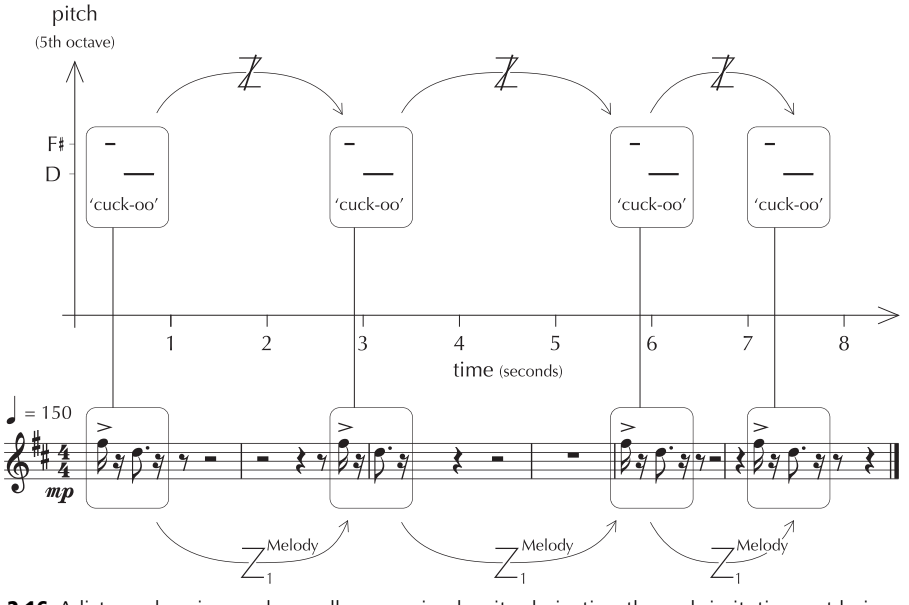

Fig. 2.16 A listener hearing cuckoo calls as music, despite derivation through imitation not being part of the bird's thinking.

So is the sequence music or not? Referring to points 1 and 5 above, the repetitive structure of the succession of calls means that they *have the capacity to be heard as music*, even though they were produced (we assume) with other-than-musical intent. Hence, the classification of the sequence as music will depend on the knowledge and beliefs of the listener. If this appears to be unnecessarily open-ended, a further scenario will show that a certain conceptual fuzziness is inevitable. Consider another set of four "cuckoos," similar to those shown in Fig. 2.15, but lower, more equal in duration, and with shorter time periods between each pair of sounds. These differences should not in themselves produce phenomenological change of any substance, so the ontological arguments set out in relation to the sounds' existence or non-existence as music still apply. But now consider that the tone-color is that of a B♭ clarinet. For those familiar with the timbre, it is unequivocally indicative of a musical instrument and therefore, very likely, a sense of human agency. The chances of the motifs being heard as deriving through imitation—of the passage being heard as music—increase markedly.

Finally, imagine a context in which the cuckoo calls are heard in combination with a nightingale's song (played on the flute) and a quail's (on the oboe), and appear in the context of the slow movement of a Western classical symphony (Fig. 2.17). To the culturally attuned ear, the implication of imitation is now irresistible, and representations of the sounds of nature are definitively "music"—although the original derivation of the bird calls is still obvious to listeners. Hence the full meaning of the music at this point arises from a "conceptual blend" (Fauconnier, 1985/1994; Fauconnier and Turner, 2002; Zbikowski, 1998, 2002; Cook, 2001).

We now move on to consider music and language. As Fig. 2.1 shows, language generally fails the "musical" test, since it is driven by semantics rather than the imitation of the sounding qualities of words. However, exceptions do exist: rhyme, assonance, and alliteration, for instance, provide examples where musical logic has arguably encroached upon the realm of verbal language (Fig. 2.3). The regularity of meter in poetry can also be interpreted as imitation in sound and therefore construed musically. Whether or not listeners *do* hear phonetic and metric repetition in a musical way remains to be determined. Some indirect evidence does exist, however. For example, it seems that elements of linguistic and musical syntactic processing may share neural resources

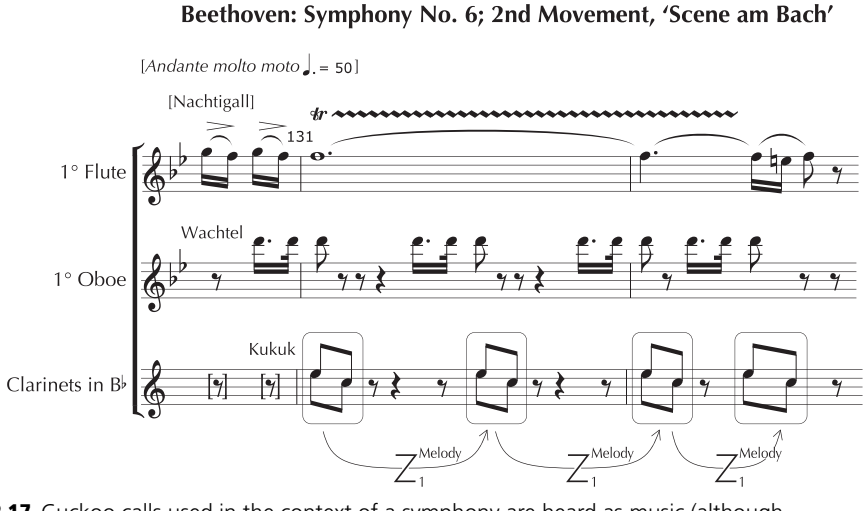

Fig. 2.17 Cuckoo calls used in the context of a symphony are heard as music (although the association with the bird remains).

(Patel, 2008, p. 285), and empirical work has suggested that in songs, music and language may be encoded together (Serafine *et al*., 1984; Morrongiello and Roes, 1990), although expert singers may have the capacity to decouple the two forms of auditory communication in neurological terms (Wilson *et al*., 2011). Then, the presence of a melody can increase phonetic recognition (Lebedeva and Kuhl, 2010), and a tune can facilitate the learning and recall of attendant words, *provided that the music repeats* (Wallace, 1994, p. 1471).

Given this, if aspects of language alone were being processed musically, we could reasonably hypothesize that verbal strings that were structured quasi-musically (for example, through the imitation of words' sounding qualities, as in poetry) would be learnt and recalled more easily than in the inherently "non-musical" prose. And there is indeed evidence that poetic forms support memory (Rubin, 1995). Furthermore, it appears that the cognitive advantages of "word-music" may not be confined to learning and recall: alliteration has been shown to aid verbal comprehension (Lea *et al*., 2008), for example, and the sounding features of words appear to influence lexical selection (Rapp and Samuel, 2002).

Other, more direct, evidence of language being processed musically can be found in the world of children whose development occurs in the context of what I term "exceptional early cognitive environments," incurred through severe visual impairment or autism (Ockelford, 2012c). Given the social and communicative challenges that both blindness and autism pose, it is perhaps unsurprising that in the case of a significant proportion of children with either of these disabilities, language acquisition can be delayed or aberrant (Fay, 1973). A characteristic of speech frequently found in both groups is so-called "immediate echolalia"—the prompt repetition of words or phrases that often has no obvious semantic or pragmatic function (McEvoy *et al*., 1988; Mills, 1993, p. 163). Elsewhere (Miller and Ockelford, 2005) I have suggested that echolalia may arise in part as a consequence of words being treated as musical objects, whereby they are structured primarily through imitation, rather than being treated syntactically as language.

This has correlates with other behaviors seen in some children on the autism spectrum with little or no language, which include treating environmental objects as potential music makers and everyday sounds as music (Ockelford, 2010a). For example, around the age of 10, Freddie (see pp. 158–60) enjoyed emptying out flowerpots from the patio, arranging them rather like an earthenware gamelan in the kitchen, and then playing them with rapid finger-flicks. Meanwhile, Romy, from the age of 8 (see pp. 89–93), would incorporate the sounds of airplanes and cell phone ring-tones into the pieces she plays by ear on the piano—rather like latter-day Beethovenian cuckoos (Ockelford, 2010b).

Parents report that some young blind children too can become very interested—even obsessed—with certain sounds in the domestic environment, such as the humming of the microwave or the whirr of the tumble-drier (Ockelford *et al*., 2006). Moreover, the accounts of parents of children with no sight suggest significantly higher levels of early interest in music than in those who are partially or fully sighted (Ockelford and Matawa, 2009; Ockelford *et al*., in press). Finally, the prevalence of absolute pitch (AP) in blind children (Pring and Ockelford 2005; Ockelford, 2008b; Dimatati, 2009; Dimatati *et al*., 2010) and autistic children (Heaton *et al*., 1998; Heaton, 2009) arguably indicates a cognitive preference for the *musical* processing of sounds. In this regard, it is of interest to note that AP frequently manifests itself around the age of 24–30 months (Ockelford, 1988)—the point at which general development, including the evolving use of language in children who are autistic or blind, so often seems to become derailed (Lösche, 1990; Dale and Salt, 2007, p. 685), reinforcing the notion that "early atypical processing biases may play an important role in the development of splinter skills" (Heaton *et al*., 2008, p. 216).

Conclusion

In this chapter, we have described the field of music theory, and seen how the zygonic conjecture fits with this as a psychomusicological approach. We have shown how zygonic analysis can work in practice and indicated that, in principle, the system is applicable to music of all types, styles, and genres. Hence it has potential application in analyzing music created in educational and therapeutic contexts, and in experimental and clinical psychology. Finally, zygonic theory was used to distinguish music from other forms of organized sound, and so delineate the perceived sonic materials to which the interdisciplinary field of "applied musicology" can reasonably be considered to pertain. The importance of this distinction will become evident in Chapter 5.

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Part II

Applying zygonic theory to investigate music education, therapy, and psychological assessment

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Chapter 3

Gauging intentionality in musical interaction in educational, therapeutic, and diagnostic contexts

Introduction

Most music therapists and some music teachers working with children with cognitive impairments use improvisation in their practice (Markou, 2010): in the case of therapists, largely to foster general development and well-being (Bunt and Hoskyns, 2002; Wigram, 2004), and in the case of teachers, mainly to promote musical and wider development (Ockelford, 2008b). The assumption is that improvised musical interaction offers a medium through which an adult can relate to a child and thereby promote *change* of one kind or another (Sobey and Woodcock, 1999). Underlying this supposition appears to be the conjecture that an adult's input to improvisation shared with a child can potentially affect the nature or level of his or her musical engagement, which may in turn have a broader musical or extra-musical impact (see Fig. 3.1).

While this principle may seem uncontentious, as we shall see, its underlying theoretical assumptions, and the practicalities of gathering and analyzing data that would provide supporting evidence, are by no means straightforward. Among the first questions that need to be addressed is how one can ascertain whether the adult's musical contribution does indeed have an impact on the child's, and, if so, just what that effect is. It will become apparent that there are two key forces at work here: *intentionality* and *influence*. But how can such human motivations and behaviors be determined merely by analyzing abstract patterns of sound?

In education, issues of this kind have typically been side-stepped, and connections made between a teacher's aims and the change in a child that take little or no account of the musical catalyst that (it is supposed) links the two. Hence a teacher may report, for example, that "In his one-to-one music sessions this term, Sam and I have been playing the drums together, which has helped to develop his awareness of self and other."

Therapists, at least in theory, have tools at their disposal to explore inside the musical "black box" (Fig. 3.1), dating back to Kenneth Bruscia's "improvisation assessment profiles" (Bruscia, 1987, pp. 403ff.), and more recent developments of these (set out, for example, in Abrams, 2007, Wigram, 2007, and Wosch, 2007), as well as other current approaches including Mercédès Pavlicevic's "Music interaction rating scale . . . of co-improvisation" (Pavlicevic, 2007) and Julie Sutton's "Analysis of . . . free musical improvisation as conversation" (Sutton, 2007). However, none offers a readily usable way of gauging the therapist's influence on a client's contribution to an improvised musical narrative, and in music therapy reports one frequently encounters comments such as "sessions have assisted Tanya to become more vocally communicative"—an observation that suffers from the same shortcomings as the pedagogical assessment of Sam's progress cited above.

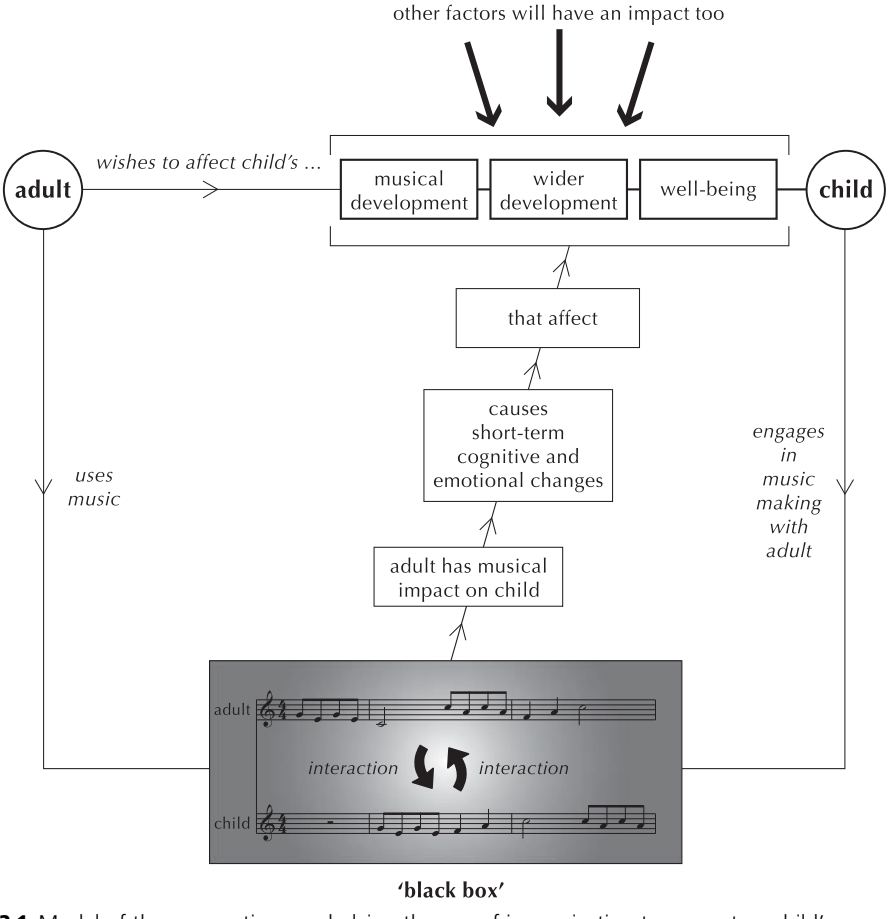

Fig. 3.1 Model of the assumptions underlying the use of improvisation to promote a child's development and well-being.

The problem is that, without getting to grips with what happens *musically*, we are unlikely to be able to ascertain whether the educational or therapeutic interventions were elements in a child's development or not. This could have had many causes, including other (non-musical) elements in the lessons or sessions; other (musical) experiences between-times; and even maturation, not directly attributable to any external factor. The musical interaction itself may have had no impact at all on the change in the child, have had some effect, or be its sole cause. It may even have exerted a negative influence. In order to tell, we need to tackle our original question: how can we analyze the forces of musical intentionality and influence that may have been at work?

Zygonic theory potentially offers a way forward since, as we have seen, it asks: to what extent, in a given musical context, can one element be deemed to derive through imitation from another? And clearly if one sound is reckoned to echo another then the first will be heard exerting a *perceived influence* on the second through *human intent*. However, the zygonic model of music cognition was conceived in the context of music theory and analysis, pertaining in the vast majority of cases to pieces consciously constructed as coherent narratives in sound, performed with the aim of realizing the composer's intentions to an audience expecting to encounter cogent musical communication. Is it reasonable to think that zygo-analytical principles can transferred

to spontaneous improvisation involving two parties or more, where at least one of the participants may have no concept of music as a logical sequence of events in sound?

To answer this question, let us consider some of the assumptions and evidence that inform zygonic analysis in the context of music as a cultural artifact. First, we can normally assume that the creator of the music (whether a composer or improviser) intended it to be understood: to communicate with another or others. Second, we intuitively know if the music we hear makes sense to us, and, through suitably informed metacognition, we can strive to identify the mechanisms underlying this comprehensibility. Third, it seems reasonable to assume a fair degree of overlap between the structures that were used (deliberately or unwittingly) by the composer and those that we can consciously identify as listeners—in Lerdahl's (1988) terms, the intersection of "compositional" and "listening" grammars (see p. 30)—while acknowledging that some organization planned by the composer may be missed, and some may be discovered that was not part of the thinking that informed the original compositional process. Fourth, we can seek to verify that our analysis is reflective of the composer's intent *directly*, by referring to drafts of the piece that may exist and verbal commentaries that he or she may have produced, and *indirectly*, by seeking the views of other analysts, and through stylistic and even statistical analysis of similar compositions, to ascertain which structures were unique to the design of a given work and which were part of the general background organization common to many (Huron, 2001b). This technique for gathering and analyzing data resides in the discipline that has become known as "empirical musicology" (Clarke and Cook, 2004; Honing, 2006).

How do these factors compare with those pertaining to a music improvisation session involving a teacher or therapist and, say, a child with learning difficulties? First, it is highly likely that the music that is created was not planned in advance, nor intended to form a coherent narrative to be conveyed to others as "art," but rather occurred spontaneously, resulting in a series of musical fragments, with no wider communicative intent. Second, it is quite conceivable that the adult and child may have been working to different musical agendas: the adult, perhaps, operating more consciously and reflectively, instinctively seeking to generate musical coherence where none was necessarily intended, weaving whatever the child produces into a compelling communicative thread. Third, as an extension of this, there is a danger that teachers, therapists, or other observers, subsequently analyzing what occurred and bringing their musically sophisticated ears to bear, will construct a narrative that the child never envisaged or was unaware of, or both; in effect the listener imagining "compositional" grammars that were never there. Fourth, *direct* evidence in the form of verbalizing metacognitive thinking may well be unavailable from the child; hence *indirect* evidence arising from non-verbal communication or activity in other domains (smiling, shouting, flapping the hands), or what is in effect "stylistic" or even "statistical" analytical data—placing the child's musical contribution in the context of his or her other music-making—may be required in order to gauge the significance of an event. This is equivalent to the "empirical musicological" approach adopted by some working in the fields of music theory and analysis mentioned above, and is a key element in what I term "applied musicology": in epistemological terms, taking a technique from the humanities and putting it to work in the social sciences.

An example of how context can affect musicological assumptions and analysis

Let us consider the implications of this line of thinking by reflecting on a number of scenarios. We begin by comparing two short examples, which on the face of it appear to be very similar: each comprising four steady beats on a drum with the second excerpt, perhaps, slightly slower than the first. The listener who is unaware of their provenance may hear their structures as being

identical. However, the very different contexts in which they were produced means that such a reading would not accurately reflect the intentions of their creators.

Scenario 3.1

An observer, broadly familiar with Western classical music, is about to encounter the opening of Beethoven's violin concerto for the first time through a video recording. She presses "play" on her computer, and a symphony orchestra with conductor and violin soloist comes into view. There is a moment's silence, then the conductor looks to the rear of the assembled musicians, raises his baton, brings it down, and the timpanist plays four equally spaced beats at a moderate pace on one of the two kettledrums, which is tuned to D (see Fig. 3.2).

What sense is the observer likely to make of this sequence? In phenomenological terms, zygonic theory suggests that cognitive processing along the lines described below may occur. Methodologically, the analysis owes much to Edmund Husserl (1905–1910/1964) and, like his approach, it amounts to supposition, generated through one person's metacognition. It could be argued that what is suggested does not reflect the imagined listener's non-conscious processing, for a number of reasons. First, it may be that involuntary thought is not in reality accessible metacognitively, and that the phenomenological analyses set out below are merely artifacts of self-reflection. Second, it could be that thinking about the listening process changes it. Third, we know from personal accounts that different people (indeed, even the same person) may perceive things differently on different occasions. However, the fact that communities of listeners *do* appear to share certain commonalities of experience in relation to given pieces suggests that there are key similarities at work between different individuals' music-cognitive processing, and it is these that ultimately make applied musicological discourse possible.

So, with a cautious methodological optimism, let us return to our imaginary observer. Before hearing a sound, though having seen the orchestra, soloist, and conductor, we can assume that she will have expectations pertaining to the type of music that is likely to follow, and that she will be aware this was designed by a composer to be re-created by performers to make sense to listeners on a first hearing.[1]

The timpanist raises a stick and brings it down on the drumhead.

The sound of this first note enters the observer's consciousness and a bundle of percepts relating to timbre, loudness, and pitch will be held in working memory. Whilst beginning a classical piece with solo timpani is unusual (though Beethoven was in the habit of introducing important motifs
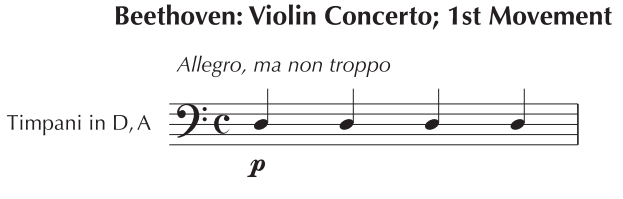
Fig. 3.2 The four strokes on the kettledrum in D that open Beethoven's violin concerto.

[1] The issue of expectation in music is investigated at some length in Chapter 8.

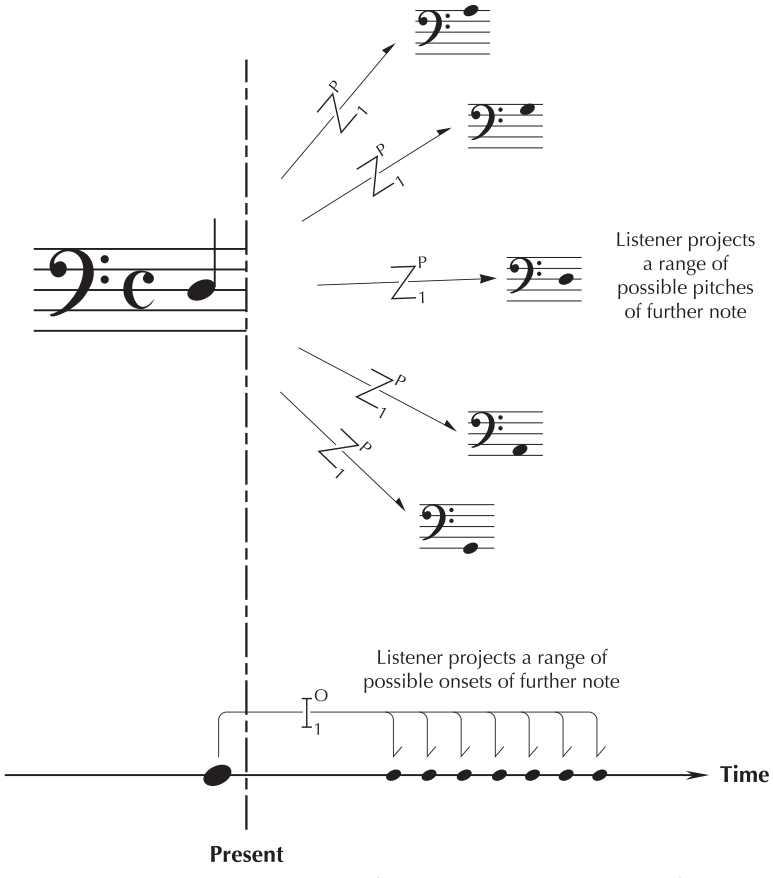

Fig. 3.3 First-time listener's hypothesized range of expectations in the domains of pitch and perceived time having heard the opening note of Beethoven's violin concerto.

on them—see Stowell, 1998, p. 61), expectations based on her previous experience of stylistically congeneric compositions are nonetheless likely to be set in train: that another note will follow, that it will occur shortly after the first, and that it will be the same or similar to it—typically separated by a perfect 4th or 5th (Huron, 2001a; Thorpe *et al.*, 2012; Fig. 8.2, this volume) (see Fig. 3.3).

A second note on the kettledrum follows, to all intents and purposes identical to the first.

We can surmise that, in the mind of the observer, this new stimulus is rapidly and unthinkingly compared with the first. The similarities in terms of timbre, loudness, pitch, and duration are recognized, which, according to zygonic theory, will lead her to hear the second note as being contingent on the first, appearing to derive from it through imitation (Fig. 3.4). Hearing the second note sets further expectations in train, and now, as well as an anticipation of *what* may occur next, in terms of the qualities of the sound that may follow, there is also a more specific sense of *when* it may occur, since the interval between the onsets of notes 1 and 2 is also open to imitation.

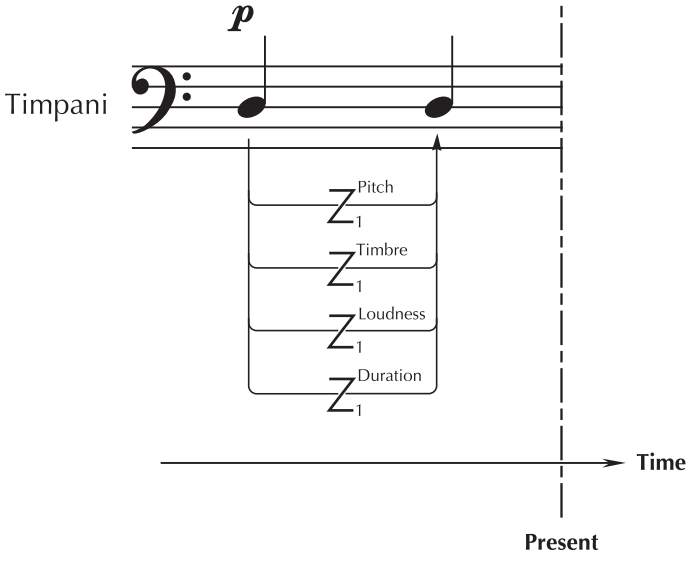

Fig. 3.4 The pitch, timbre, loudness, and duration of the second note is presumed to be heard as deriving from the first.

The timpanist plays a further "D", with the same timbre, dynamic, and duration as the first two.

As the third note is perceived, we can speculate that similarities between this and those that precede will be detected, and (according to zygonic theory) that it will be heard as being generated through imitation of the first and second notes and the inter-onset interval between them (Fig. 3.5).

Which primary zygonic relationships (those stemming from note 1 or those originating from note 2) are likely to bear greater perceived structural weight? Zygonic theory proposes that the more salient the stimulus, the more likely it is to be heard as functioning as a source or result of imitation (Ockelford, 2004). At the point when note 3 enters the observer's consciousness, we can predict that the memory of note 2 will be stronger than the retained impression of note 1, since it is closer in time and has only suffered interference from the current stimulus (note 3) rather than from both notes 2 *and* 3. However, we can suppose that the observer's perception of note 1, still less than 2 seconds in the past, continues to resonate in working memory. Hence it seems likely that, at the point of hearing note 3, the impact of note 2 will be greater than that of note 1 on structural perception (Thorpe *et al.*, 2012).

A final "D" on the kettledrum follows.

Zygonic theory suggests that the fourth note will be anticipated and subsequently perceived in similar fashion (Fig. 3.6).

So much for a first-time listener's possible take on the opening of Beethoven's violin concerto. How do these compare with the composer's intentions? According to Joachim and Moser (1905, p. 181), the beats on the timpani were "said to have occurred to Beethoven during the stillness

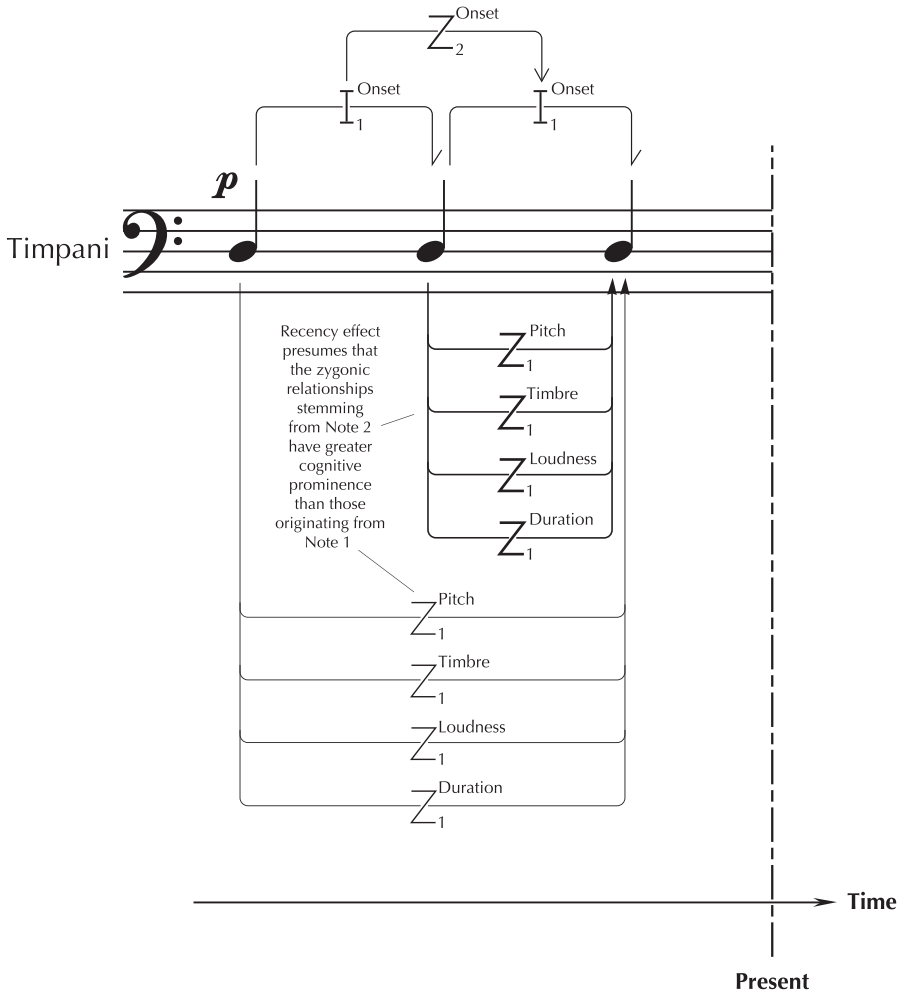

Fig. 3.5 Presumed perceived derivation of the third note from the first two.

of a sleepless night, on hearing someone knocking at the door of a neighbouring house." That is to say, Beethoven took material—the repeated blows on a door—that, despite being produced (we may assume) with other-than-musical intent, nonetheless had the capacity to be heard as music, and, by placing it in a musical context, the composer imbued the relationships between the sounds with imitative (that is, music-structural) status (cf. Fig. 2.17). This way of hearing the sounds (as a rhythmic Gestalt) is reinforced throughout the movement, as the pattern of regular beats reappears, sometimes in the foreground and on other occasions as an accompanying figure in the background.

Hence there seems to be no doubt that Beethoven used the sounds in a structural way, and that he intended them to be heard as such. Now, in contrast, let us consider a further scenario, whose auditory component is, on the face of it, very similar, but which is contextually quite different.

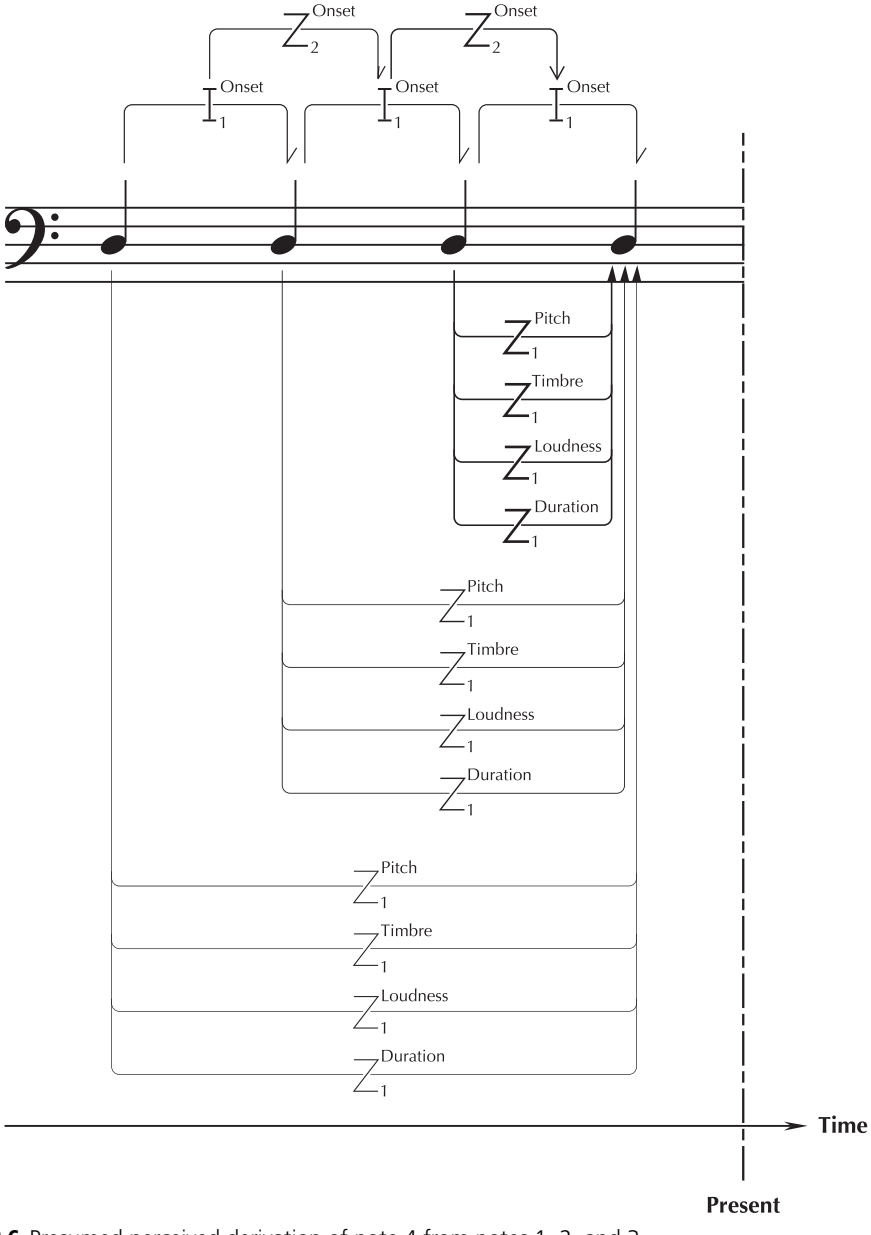

Fig. 3.6 Presumed perceived derivation of note 4 from notes 1, 2, and 3.

Scenario 3.2

The observer watches a further video recording, which shows a clip of a therapist working with a pupil who (a caption indicates) has severe learning difficulties and is non-verbal. The pupil's hearing is within the normal range and he is in a wheelchair. The adult is sitting opposite the child, and a large bodhrán (a Celtic drum) is shared between them on their laps. Again, we can assume that, although the particulars of the situation and the people in it are unfamiliar, the observer has a broad experience of engaging in musical activities with children with special needs.

Her expectations of the events that are about to unfold, and the participants' roles within them, are likely to be different from those triggered by the sight of a Western classical orchestra. For example, there can be no assumption of predetermined organization (by a composer): on the contrary, whatever will occur will be "in the moment." And on a practical level, expectations will inevitably be more constrained than was the case with the orchestra, with its many available sounds.

The action begins. Lifting up both his hands, the therapist brings them down with a distinct *bang* on his side of the bodhrán.

Let us call the therapist's contribution Event 1 (or E_1). As before, the listener will perceive this as a bundle of percepts—pitch, timbre, and loudness—in the domain of sound.

Although, as we have discussed, the situation differs from hearing a piece whose structure was thought through in advance of its performance, if what happens next is to form the beginning of a coherent narrative in sound, then, according to zygonic theory, it must be heard as imitating (exactly or approximately) that which preceded. Hence to the extent that the observer anticipates a cogent "musical" continuation (see pp. 324–8), she will expect another, similar strike on the bodhrán in the near future (Event 2 or E_2). In fact what happens is this:

With some apparent effort and concentration the child lifts his hands and produces a *bang*, similar in intensity to the therapist's earlier effort.

Reflecting on this scenario suggests that it would be difficult for the observer, with her musical intuitions fully engaged, *not* to hear E_2 as deriving from E_1 through imitation (the limitations on the musical resources available to the child notwithstanding) implying a similar structural cognition that was presumed to function in relation to the opening of the Beethoven—although, as we shall see, this may well be an erroneous reading of events. Such thinking may be reinforced by the tendency when seeking to engage with very young (or in this case developmentally delayed) children to imitate and expect imitation of our own facial gestures, movements, and sounds (Meltzoff and Moore, 1977; Zeedyk and Heimann, 2006) (see Fig. 3.7).

The adult reacts to the child's contribution by smiling and seeking to make eye contact. Then he lifts up his hands again, and, as before, strikes the bodhrán with a distinct *bang* (Event$_3$ or E_3).

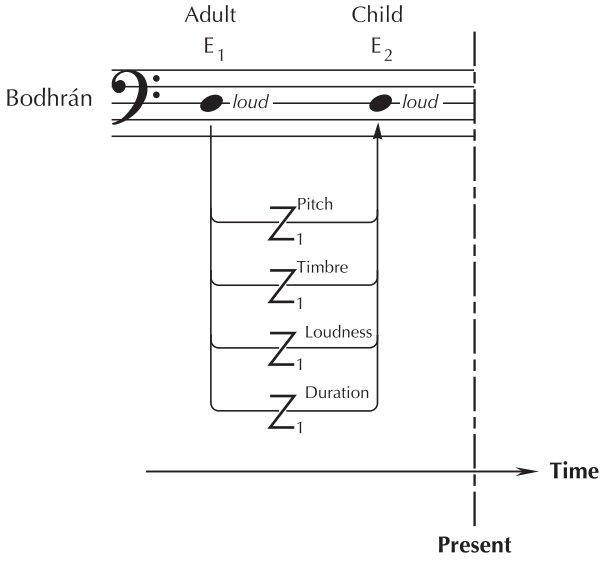

Fig. 3.7 An observer will tend to hear the child's contribution as imitative.

What is the observer to make of this? Given the strong tendency, which we have just noted, for adults to copy children in the early stages of their development, it seems incontrovertible that imitation is present . . . but is the therapist principally echoing the child's initial sound (E_2), or his own (E_1), or perhaps both, more or less equally? In the absence of verbalized intent on the part of the adult (for example, "I can copy you too"), evidence can be sought in the qualities and relative temporal disposition of the sounds themselves. For example, it may be that

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E_2 was somewhat quieter than E_1 and that the teacher's second stroke on the bodhrán (E_3) reflected this reduced dynamic.

This could reasonably be taken as an indication that E_3 was produced mainly in imitation of E_2, since a key feature in its bundle of perceived sonic qualities (that differed in E_1) was repeated (Fig. 3.8). Conversely, it may be that

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the dynamic pattern was reversed, whereby E_3 was played with the same loudness as E_1, and was noticeably louder than E_2.

This may lead the observer to assume that the therapist was largely engaged in self-imitation (Fig. 3.9).

The temporal spacing of the strokes on the bodhrán is of importance too. For example, let us assume that

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the time interval between E_2 and E_3 was shorter than that between E_1 and E_2.

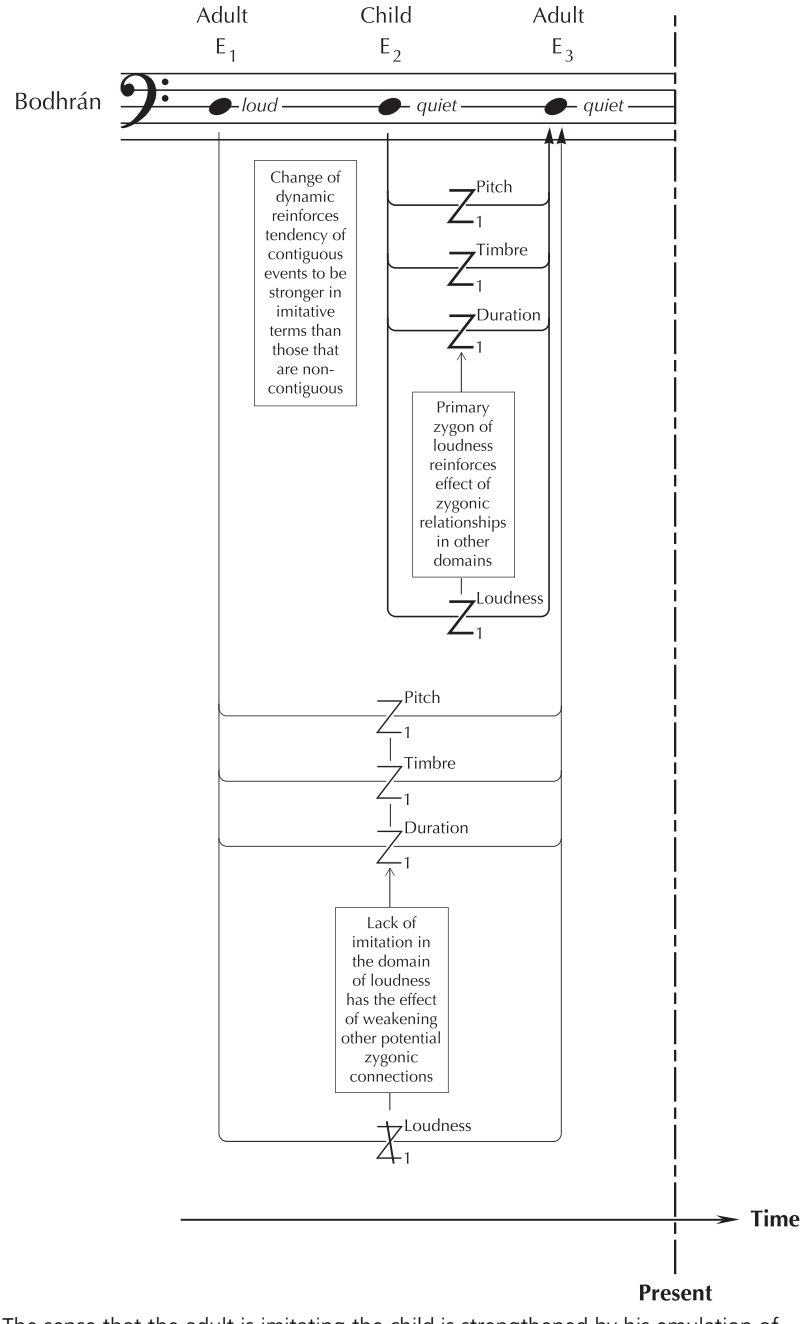


Fig. 3.8 The sense that the adult is imitating the child is strengthened by his emulation of the child's dynamic (rather than echoing his own).

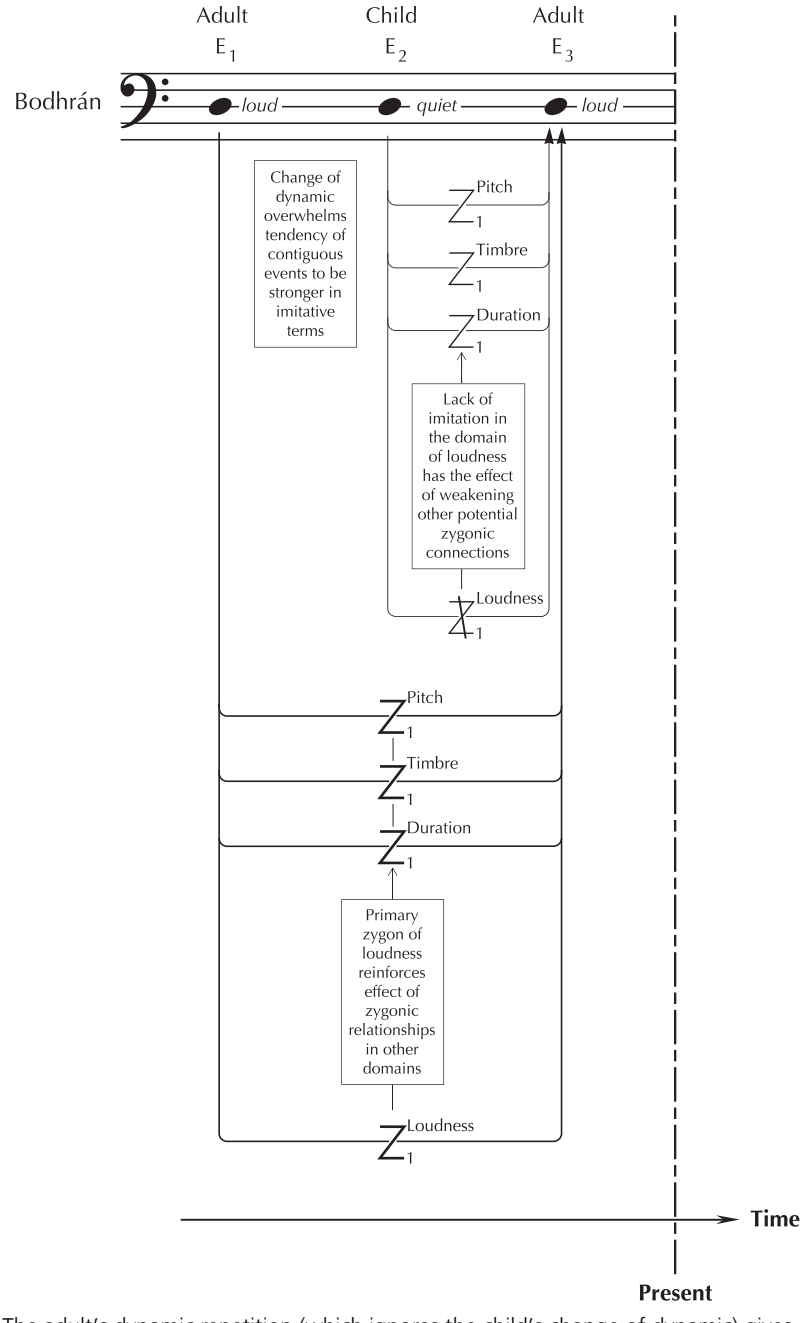


Fig. 3.9 The adult's dynamic repetition (which ignores the child's change of dynamic) gives the sense that he is imitating himself.

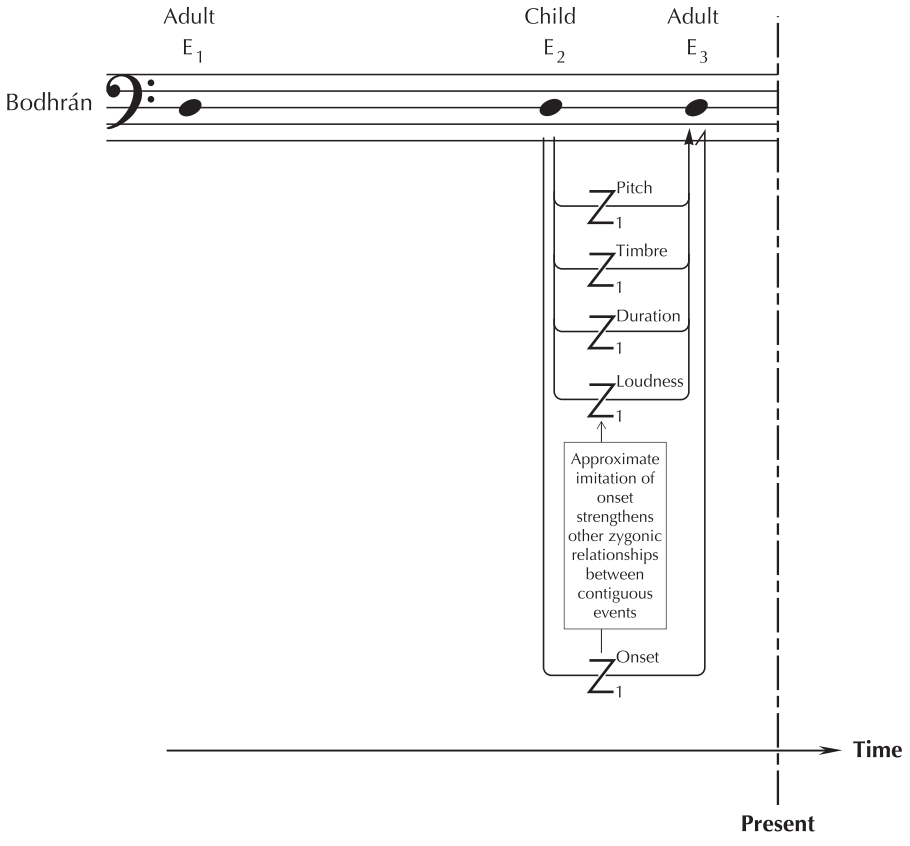


Fig. 3.10 Potential impact of the temporal disposition of events on the perception of imitation.

Here, other things being equal, it would be the potential imitative relationship between E_2 and E_3 that would be likely to be emphasized in cognition at the expense of that between E_1 and E_3 (see Fig. 3.10). Conversely, let us imagine that

> the pattern of temporal adjacency was reversed, and the inter-onset interval between E_1 and E_2 was shorter than that between E_2 and E_3.

Here it is likely that relationship between E_1 and E_3 would have greater cognitive prominence. This is because, being relatively close together in time, E_1 and E_2 would be more likely to be heard as a group in Gestalt terms (cf. Lerdahl and Jackendoff, 1983, p. 40), and E_3 as the first element in a reiteration of that group (Fig. 3.11). If, however,

> E_1, E_2, and E_3 were equally spaced in time

then it is likely that E_3 would be heard as deriving from both E_1 and E_2, since we can surmise that the inter-onset interval $E_2 \rightarrow E_3$ would be heard as imitating the interval $E_1 \rightarrow E_2$, which would

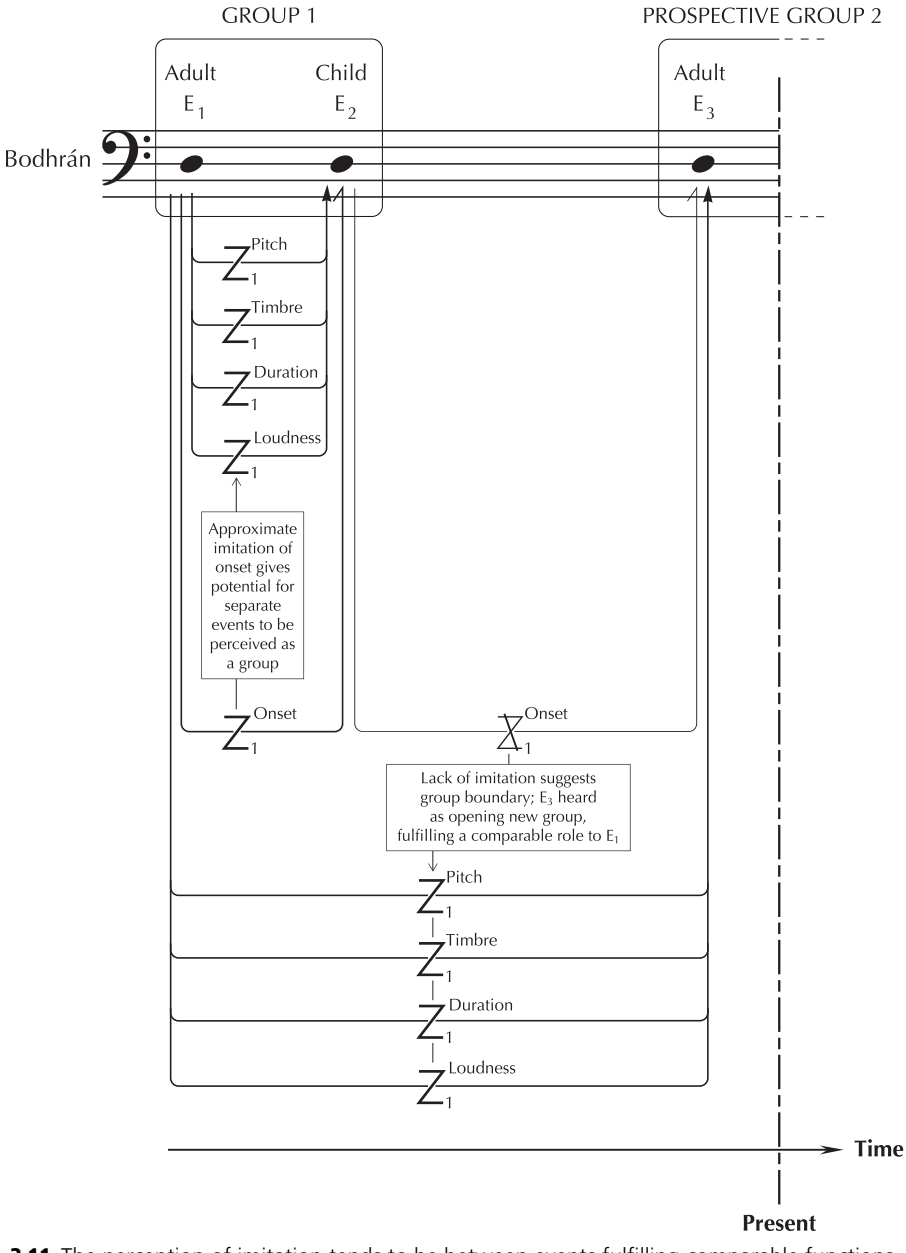


Fig. 3.11 The perception of imitation tends to be between events fulfilling comparable functions in groups.

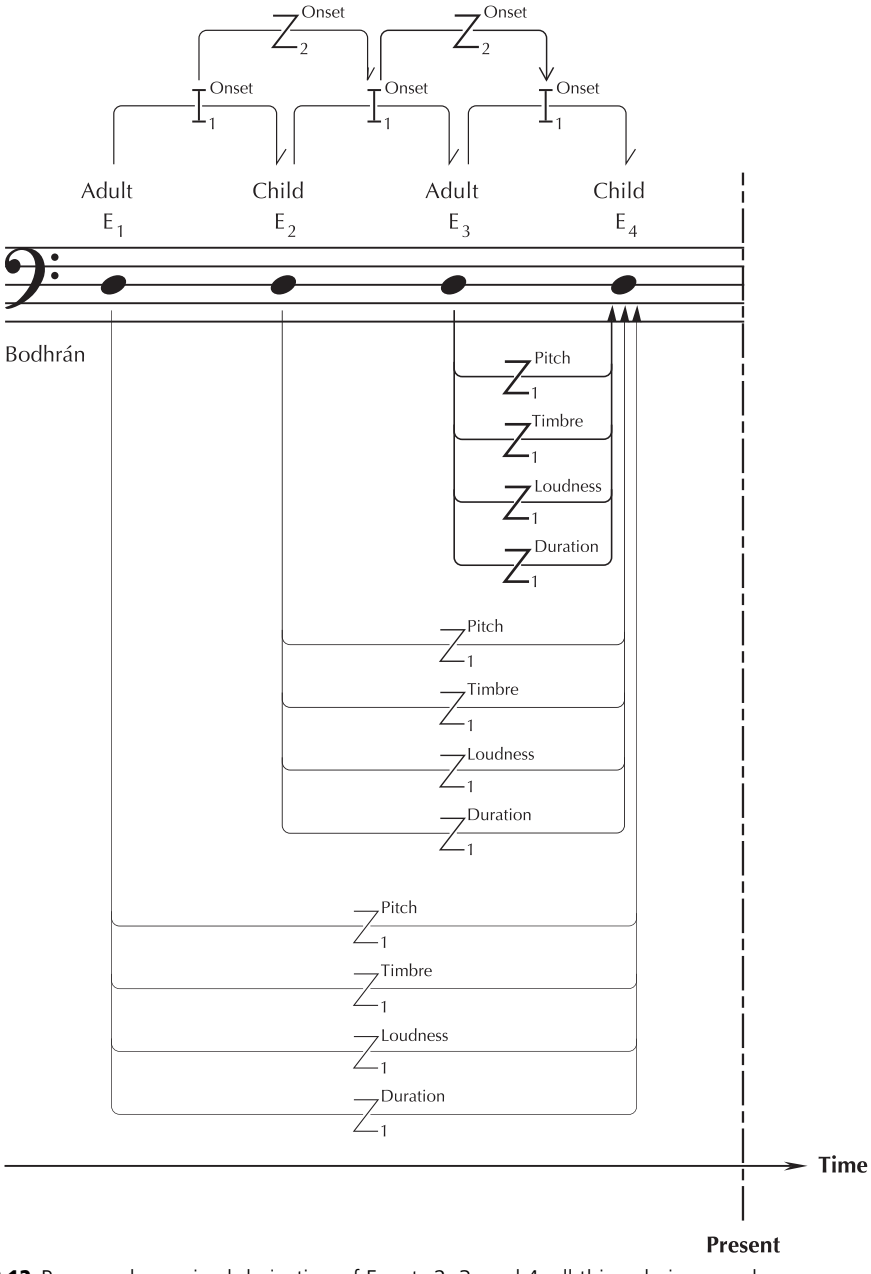


Fig. 3.12 Presumed perceived derivation of Events 2, 3, and 4, all things being equal.

be rooted in both the first and second events. As was the case in the Beethoven, it is reasonable to speculate that E_2 would exert the more powerful imitative influence on account of its greater salience.

Let us assume, for now, that

E_1, E_2, and E_3 do indeed occur at equal temporal intervals and are of similar loudness and duration, and that the child strikes the bodhrán again (E_4) in the same way as before, such that, in terms of perceptual qualities, $E_1 = E_2 = E_3 = E_4$, and the inter-onset interval between E_3 and E_4 is the same as those preceding between successive events, such that $E_1 \rightarrow E_2 = E_2 \rightarrow E_3 = E_3 \rightarrow E_4$.

Following the principles set out above, and given no other contextual information, zygonic theory predicts that the observer, with her critical musical faculties engaged, would tend to hear the pattern of derivation as shown in Fig. 3.12. But, as we have observed, this may not be a reasonable assumption to make in relation to the thinking and actions of the child. It could be that the observer was imposing an auditory logic that was not present, or was different, in the original interaction, and therefore misinterpreting the child's intentions (if any were indeed present). As the child is non-verbal, how could we know? In order to answer this question, let us explore further how *repetition* and *intentionality* work together to form *imitation*, which fulfills a range of functions in early communication, as well as lying at the heart of musical structure.

Gauging intentionality in musical improvisation

As we have seen, adults *intentionally repeat* the gestures and sounds of very young children and those who are developmentally delayed, and, from birth, "neurotypical" babies intuitively do the same thing. We are, it appears, born to copy one another, and this *imitation* lies at the heart of early communication (Nagy, 2006; Hart, 2006) and forms the foundation of social interaction within a shared interpersonal space (Heimann *et al*., 2006; O'Neill and Zeedyk, 2006)—fostering an evolving sense of self and other, a relationship between a "me" and a "you," at once different and yet with a common understanding and consciousness (Caldwell, 2006; Ockelford and Welch, 2012). The imitation of patterns of sound in such contexts has not traditionally been regarded as "music," although as Stephen Malloch and Colwyn Trevarthen have so persuasively shown, it actually forms the bedrock of human musicality (Malloch, 1999/2000; Malloch and Trevarthen, 2008; Trevarthen, 2008). This accords with the zygonic conjecture: that musical structure will be created or cognized when imitation is devised or detected (albeit non-consciously) (see Chapter 2). But, as human beings, we are constrained in the sounds we can make, and so, within an extended interaction, repetition is almost inevitable. Therefore, the key question is this: how do we know when repetition constitutes imitation (and, by implication, when a stream of sounds becomes music)?

Zygonic theory holds that an observer's confidence that the repetition of a sound (or feature thereof) is intentional—that there is a sense of imitation—is inversely proportional to the degree of freedom thought to exist in the production of the sound that potentially echoes the first (Ockelford, 2009a). This is because, the greater the range of values available in any given domain, the less likely it is that two the same will occur by chance. To consider what this means in practice, let us consider a further scenario.

Scenario 3.3

An adult is working with a blind child, who has severe learning difficulties and is on the autism spectrum. Teacher and pupil are each sitting at a piano, with the full 88 keys available. The child has previously orientated himself in relation to the keyboard, so he has a physical sense of where the notes are. Without saying anything, the teacher plays a note, 4th octave B♭, quietly and briefly. The pupil reaches forward, and with no hesitation pushes down the same key on his piano with some force, then holds it while the sound dies away.

Despite the differences in dynamic and duration, since the probability of striking the same key twice by chance is remote, it seems reasonable, on the evidence available, to assume that the pupil intended to echo the B♭ played by his teacher. Hence there is more than repetition here, there is *imitation*: a sense that the second note derives from the first. This can be taken as a proxy indicator of the child's musical intentionality (Fig. 3.13).

Now let us change the parameters somewhat, and see how our view of an ostensibly similar reactive behavior may alter as a result.

Scenario 3.4

The teacher and another non-verbal pupil with autism each have access to identical small toy keyboards, with just five notes (C, D, E, F, and G), whose dynamic and duration are mechanically predetermined. Making sure the pupil is not able to observe what he is doing, the teacher plays "C" on his keyboard. The pupil strikes the same note on hers.

What can we deduce about the pupil's intentions with regard to pitch? Here, although there is repetition, because of the limitations of the keyboard it is impossible to be sure whether imitation was meant or not: environmental constraints limit our capacity to discern the child's musical intentions.

To take a more extreme example, consider Scenario 3.2 (the interaction with the bodhrán), where only one note was available. Here we have no sense at all of either participant's intentions in relation to pitch.

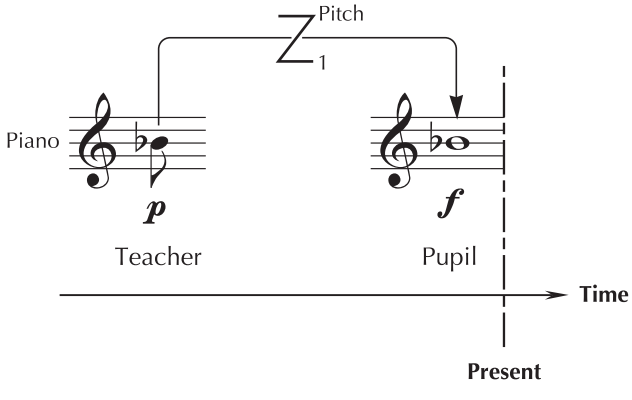


Fig. 3.13 Presumed derivation of the pupil's choice of note from the teacher's.

Finally, there may be circumstances in which:

Scenario 3.5

The teacher and a pupil with very limited communication skills each have a different chime bar: one tuned to A and the other F♯. The teacher plays a single note on his chime bar. There is a pause and then the pupil plays hers.

Again, in this scenario it is impossible to ascertain what the pupil's intentions are *apropos* pitch: since repetition is not possible, imitation is not feasible either. The child may or may not have wished to engage in a coherent musical dialog; we are unable to tell.

Scenarios 3.2, 3.4, and 3.5 provide examples of *environmental* limitations on the production of sounds that interfere with an observer's capacity to identify potential *zygonic* constraints. They do this in one of two ways: in Scenarios 3.1 and 3.2, by producing potentially "false positives" ("Type I" errors), whereby repetition being highly probable or even inevitable leads the listener to hear imitation where none was intended; or, in Scenario 3.5, what is conceivably a "false negative" (a "Type II" error), in which it is impossible to discern whether imitation is intended or not, since repetition is not an option. As we shall see, such interference is one of the key challenges for those seeking to gauge a child's intentionality through sound alone with regard to the creation of music.

However, external constraints such as these can at least be ameliorated through careful planning of a child's learning or therapeutic environment, and the deployment of appropriate resources. More challenging for the analyst are other, *person-based*, constraints. For example . . .

Scenario 3.6

. . . consider again the child described in Scenario 3.3 (blind, with severe learning difficulties, and on the autism spectrum). Let us now assume that, in addition, the child has a motor impairment that limits independent finger movement, making it difficult for him to play individual notes on a standard keyboard; typically he strikes simultaneous clusters of three or four adjacent keys. In response to hearing his teacher's fourth octave B♭, with some awkwardness, the pupil plays a cluster of notes—A♭, B♭, B♮ and C (Fig. 3.14).

Here, because of the child's difficulty in playing one note at a time, it is problematic to gauge whether there was intentional pitch imitation or not.

Now let us revisit Scenario 3.2: the pupil and teacher playing the bodhrán. The video recording continues after the second beat by the child, and the listener observes the following:

After hearing E_4, the adult stays still. There is a short period of silence, followed by another *bang* on the bodhrán by the child (E_5), to all intents and purposes identical to his two previous contributions, whereby the three events are equally spaced in time (inter-onset interval $E_2 \rightarrow E_4 = E_4 \rightarrow E_5$) (see Fig. 3.15).

Again, the adult does not react, and the child hits the bodhrán once more (E_6), with the same qualities of sound and timing as before. This pattern continues for a further three beats (E_7, E_8, and E_9).

Then, the teacher removes the bodhrán, but the child's periodic arm movements persist.

This evidence suggests that the child's actions may represent a stereotypy: a behavior that is persistently repeated irrespective of external stimulus (or the lack of it). It may cause the listener

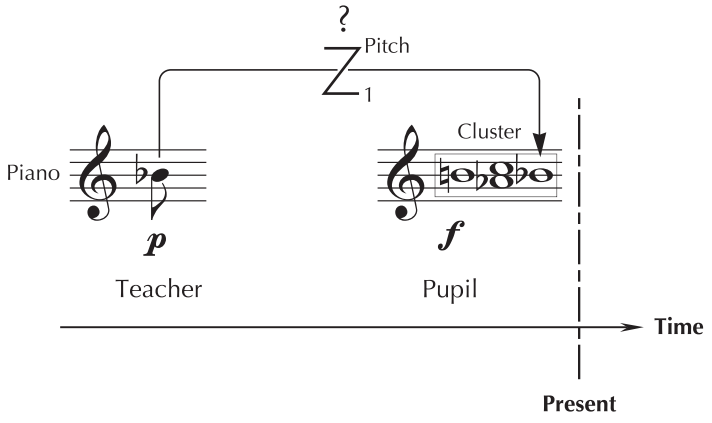


Fig. 3.14 When the pupil's response comprises several notes, the derivation of any one from the teacher's stimulus is less clear.

to re-evaluate her understanding of what she had assumed was an interaction, since it means that imitation may not have figured in the child's thinking after all. But, equally, how could an observer be sure that the pupil did *not* intend to echo what the teacher did, given the potential masking effect of his repeated movements?

So much for *environmental* constraints and *person-based* constraints, and their potential impact on understanding a pupil's musical intentions. However, there is a third group of constraints, which pertain to the *observer*. As we have seen, he or she may have limited evidence on which to draw, and this may affect the way in which a putative musical interaction is interpreted.

For example, let us return to Scenario 3.2, in which a therapist and child are playing the bodhrán, and imagine that the action actually began before the video recording started. In fact

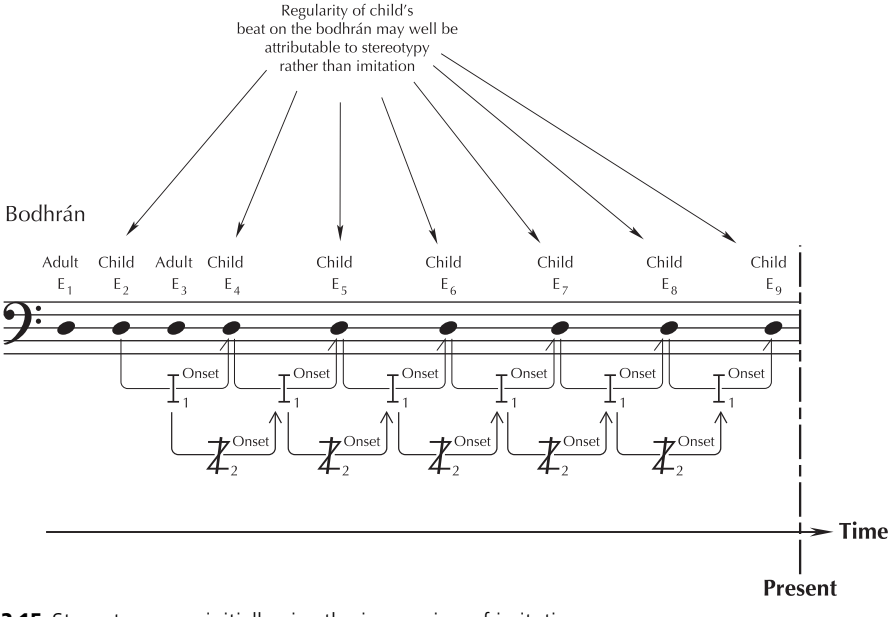


Fig. 3.15 Stereotypy may initially give the impression of imitation.

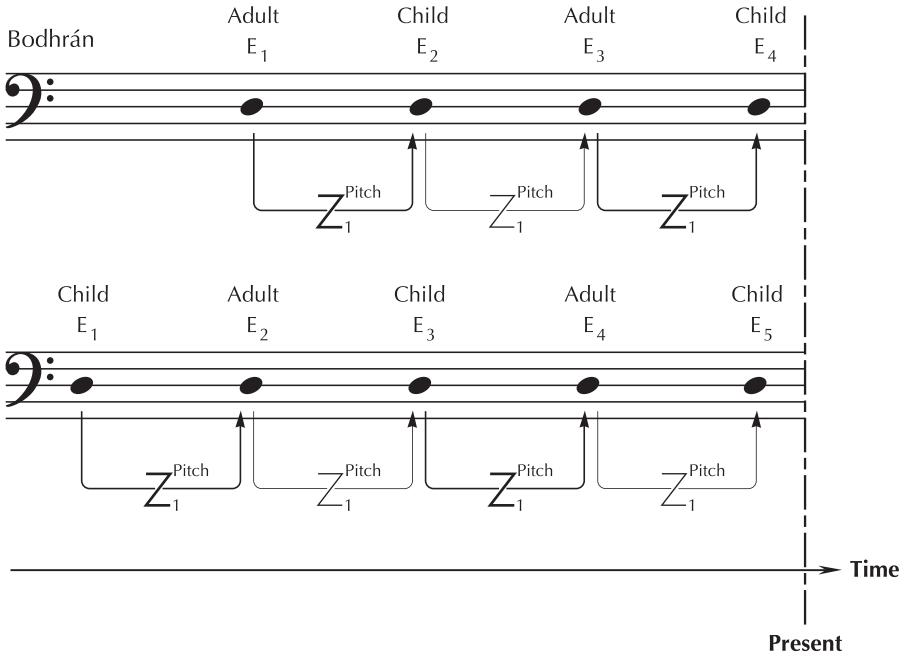


Fig. 3.16 Who initiates an interaction can influence the relative salience of subsequent zygonic relationships.

it was the child who initiated things by banging the drum before the adult. Had this additional evidence been available to the listener, it is likely that she would have arrived at a different interpretation of the polarity of the imitation that appears to drive the pattern of repetition. Instead of the child echoing the adult, it would seem, the adult was consciously copying the child—a sense of derivation that applies not only to the first pair of sounds, but to those that follow (Fig. 3.16).

Given the potentially confounding impact of environmental, person-based, and observer-generated restrictions on the nature of a musical interaction, how can we gauge the potential influence of zygonic constraints that may be present—proxy indicators of a child's musical intentionality? To address this problem, we will present it first in its simplest form. Consider again Scenario 3.2 (in its original version, in which the adult kicks off proceedings). Mentally wind forward to E_2, when the child strikes the bodhrán following the adult's initial contribution (E_1). The observer believes that there are two possible causes of E_2: either imitation of E_1, or the child's stereotypy (or conceivably a combination of the two).

To obtain evidence as to which it may be, it would be necessary to continue the interaction while eliminating one of these two possible causes, and then to observe what the child did (or failed to do). In practical terms (since stereotypy is, by definition, driven from within the child), the easiest way of achieving this would be for the teacher *not* to produce a further event to be imitated. There would be two potential consequences: either the child would strike the bodhrán again or he would not. If he *did* then that would provide evidence that the event was not a product of music-structural intentionality. If he did *not* then that would suggest that the sound was derived through imitation.

Now, if were we dealing with "absolute" constraints in a physical world, then that might well be all the evidence that was required to determine which agency was at work. However, we are concerned with human behavior, which is subject to whim, error, and unpredictable change. Above all, it is important to remember that zygonic relationships (metaphors for the cognitive channels through which imitation is forged or recognized) are *implicative* not *causal* (Ockelford, 2005a, p. 75). That is, one sound may *imply* another in the mind of (in this case) the improvising child, but it does not *cause* it. (Causation comes about through the decision to act on the implication: to engage in the necessary motor activity to produce a sound similar to the one just heard.) However, since implication is a mental construct, in a given musical circumstance (such as the teacher striking the bodhrán), it may be, but need not be, conceived by the child (in the form of hearing potential imitation), who may, but need not, subsequently act upon this (by hitting the bodhrán). Conversely, the child may decide to hit the bodhrán anyway, with no thought of imitating the teacher, or he may simply decide to remain silent. Hence the root of the child's sound or silence is ambiguous and, for the listener, the existence of imitation can only be *probabilistic*, irrespective of the presence of any external constraints, which, as we saw in relation to Scenarios 3.3, 3.4, and 3.5, can add another layer of statistical complexity.

The analysis of events on a probabilistic level is ultimately about taking a broad enough view to prevent moment-by-moment perturbations from obscuring deeper trends and tendencies. The more data one can gather and analyze, the more certain it is possible to be that one's findings are reflective of the bigger picture—and this is where undue observer-based constraints can have a negative impact. There is in any case a balance to be struck between acquiring the resources required for amassing and interrogating large quantities of data and the law of diminishing returns that will operate in relation to the likely improvement in the validity of one's findings. So most quantitative research makes use of data samples that are judged to be of sufficient size and typicality to allow analysis to be undertaken in a manageable way; the conclusions are nonetheless acceptably secure.

In the context of applied musicology, zygonic theory takes these principles of statistical research in the social sciences and places them within a new framework, seeking to gauge the patterns of human influence behind the spontaneous creation of music. Here, "intentionality" in the production of shared musical structures is a key driving force, whose zygonic derivation and analysis will be introduced through a number of worked examples.

To this end, let us return, once more, to the interaction with the teacher and pupil using the bodhrán (Scenario 3.2), and on this occasion situate the observation of their actions in a fuller temporal context (around 2 minutes). What occurs can be represented graphically (Fig. 3.17). In total, the child plays the bodhrán eight times, and the adult 12.

In order to take things further, we need to determine the granularity of our analysis: the "units of activity" upon which our investigation will be based. Listening to what occurs, it is evident that the basic building block of the musical interaction is a stroke on the bodhrán, which usually stands alone, although sometimes such events occur in pairs. On this basis, the units of activity occur with the following frequencies: adult playing alone, $n = 7$; child playing alone, $n = 3$. There are also times when the adult strikes the drum and the child plays immediately afterwards ($n = 5$). Hence the total number of units of activity $= 3 + 7 + 5 = 15$.

In addition, there are there are periods of silence, when neither participant actively contributes, and in order to obtain a complete picture of what is going on it is important that these are taken into account in the analysis. To enable comparisons to be drawn, we somehow need to apply a comparable granularity to these intervals of inactivity as we have to the events themselves. To achieve this, we will use the notion of "frames" or "slots": a representational system borrowed

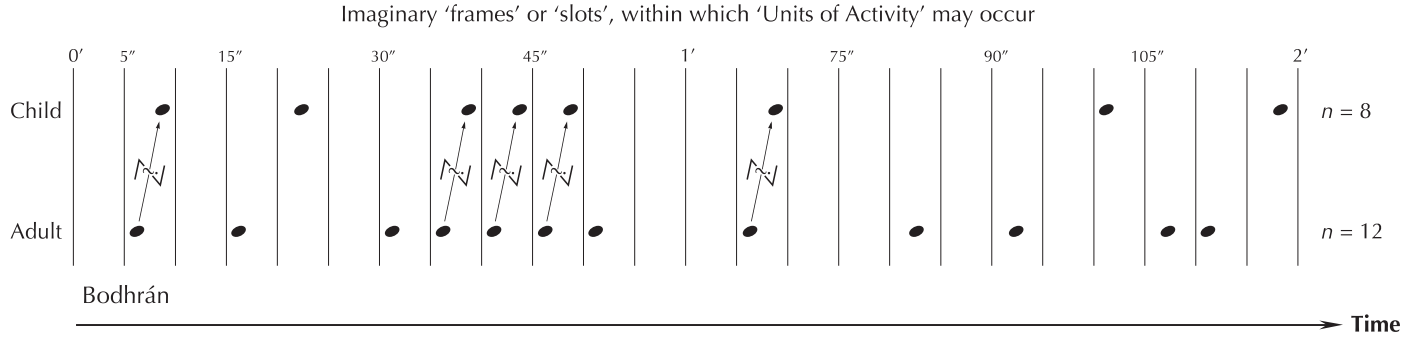


Fig. 3.17 An interaction on the bodhrán involving a child and an adult that lasts for 2 minutes.

from the sphere of artificial intelligence, in which the time dimension is quantized, and relevant facets of the musical experience are captured in each frame (West *et al.*, 1987, p. 14). Here, the temporal quantum amounts to around 5 seconds: the smallest interval between each participant's strokes on the bodhrán. This yields 24 frames in the 2-minute sample (see Fig. 3.17). Nine of them are entirely silent.

With this information to hand, we can begin the analysis. First, we need to know the ratio of repetition to non-repetition, and the proportion of strokes on the bodhrán that are immediately reiterated by the child ($R = 5/15 = 0.33$). In order to take the further step of estimating the child's *intentionality* in creating these patterns, we need to ascertain the likelihood of this number (5/15) occurring by chance. This can be computed using the following formula (3.1):

$$\begin{aligned}&\text{probability of 5 repetitions occurring by chance } (P)\\ &= \frac{\text{no. of permutations involving 5 repetitions}}{\text{total no. of permutations of child's events/empty frames}}.\end{aligned} \tag{3.1}$$

To make this calculation, let us hypothetically reconfigure the interaction so that the adult's bodhrán strokes ($n = 12$) occur sequentially, and five of the child's strokes (that number that, in the original sample, are repetitions of adult events) occur at the same time. This leaves seven frames of inactivity on the part of the child to set against the remaining strokes made by the adult (Fig. 3.18).

In this scenario, the number of permutations of adult's and child's strokes is given by Formula (3.2)

$$\frac{(\#\mathrm{E_A})!}{(\#\mathrm{REP})! \times (\#\mathrm{E_A} - \#\mathrm{REP})!} \tag{3.2}$$

where

$\#\mathrm{E_A}$ is the number of events generated by the adult and #REP is the number of repetitions made by the child.

This leaves the remaining 12 frames in which the adult is inactive, which need to be set against the residual three strokes by the child (see Fig. 3.18). Here the number of permutations is

$$\frac{(\#\mathrm{F} - \#\mathrm{E_A})!}{(\#\mathrm{E_C} - \#\mathrm{REP})! \times (\#\mathrm{F} - \#\mathrm{E_A} - \#\mathrm{E_C} + \#\mathrm{REP})!} \tag{3.3}$$

where

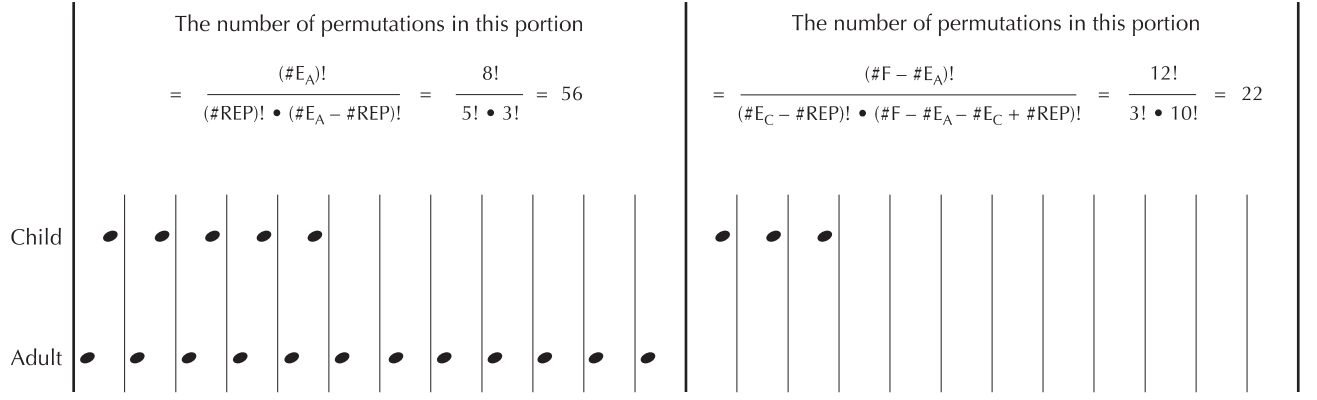
#F is the number of frames and $\#\mathrm{E_C}$ is the number of events generated by the child.

Hence the number of permutations involving five repetitions is given by the product of Formulae (3.1) and (3.2), which equals

$$\frac{(\#\mathrm{E_A})! \times (\#\mathrm{F} - \#\mathrm{E_A})!}{(\#\mathrm{REP})! \times (\#\mathrm{E_A} - \#\mathrm{REP})! \times (\#\mathrm{E_C} - \#\mathrm{REP})! \times (\#\mathrm{F} - \#\mathrm{E_A} - \#\mathrm{E_C} + \#\mathrm{REP})!}. \tag{3.4}$$

The total number of permutations of the child's events/empty frames is given by

$$\frac{(\#\mathrm{F})!}{(\#\mathrm{E_C})! \times (\#\mathrm{F} - \#\mathrm{E_C})!}. \tag{3.5}$$



Where $\#E_A$ is the number of events generated by the adult, $\#E_C$ is the number of events generated by the child, #F is the number of frames, and #REP is the number of repetitions made by the child.

Fig. 3.18 Preliminary calculations used to compute the number of permutations involving five repetitions of bodhrán strokes by the child.

The probability of five repetitions occurring by chance (P) is given by substituting Formulae (3.4) and (3.5) into (3.1):

$$P = \frac{(\#\mathrm{E_A})! \times (\#\mathrm{E_C})! \times (\#\mathrm{F} - \#\mathrm{E_A})! \times (\#\mathrm{F} - \#\mathrm{E_C})!}{(\#\mathrm{F})! \times (\#\mathrm{REP})! \times (\#\mathrm{E_A} - \#\mathrm{REP})! \times (\#\mathrm{E_C} - \#\mathrm{REP})! \times (\#\mathrm{F} - \#\mathrm{E_A} - \#\mathrm{E_C} + \#\mathrm{REP})!} \quad (3.6)$$

In the case of the 2-minute sample from Scenario 3.2 (Fig. 3.14)

$$P = \frac{12! \times 8! \times 12! \times 16!}{24! \times 5! \times 7! \times 3! \times 9!} = 0.24. \quad (3.7)$$

Intentionality (I) is given by R (the proportion of repetition to non-repetition) multiplied by the probability that this will *not* occur by chance ($1 - P$):

$$I = R(1 - P)\,. \quad (3.8)$$

In our case

$$I = 0.33(1 - 0.24) = 0.33 \times 0.76 = 0.25. \quad (3.9)$$

This means, according to zygonic theory, that there is around a 25% chance that the child repeated the adult's material intentionally—through imitation.

To gain a sense of what this figure means in a broader context consider Table 3.1, which lists comparable scenarios in which the number of repetitions of events by the child ranges from zero to eight (the maximum). These data are presented graphically in Fig. 3.19. Observe that the probability of the child repeating what the adult does by chance rises and falls as the number of repetitions increases—the most likely number being four reiterations ($P = 0.33$). And note that while it is extremely unlikely that seven or eight repetitions would occur by chance, there is a similarly vanishingly small probability of one repetition or none occurring other than intentionally. Hence, such results could indicate that a child were deliberately avoiding imitating an adult—quite conceivable in the case of a pupil on the autism spectrum, for example. As the probability of repetition occurring by chance grows, so the gap between R and I widens too; conversely, as the probability decreases, so R and I converge. This variation notwithstanding, overall, intentionality increases as the number of repetitions rises.

It is important to appreciate that it is only possible to gauge the intentionality of a person creating musical structure in the course of a bimodal interaction with another (that is, of one party imitating the fact that the other made, or did not make, a sound) when *at least one change occurs in the behavior of both*. Without this, the probability of repetition occurring (or not occurring) by chance is invariably 1, and so intentionality is 0. Consider, for example, a situation in which, during a sample of six frames of activity, the adult strikes the bodhrán six times. Whenever the child plays, repetition is inevitable, and so intentionality cannot be measured, irrespective of the number of reiterations (see Table 3.2).

The analytical position is the same if the child plays constantly, or if either or both participants do not contribute at all. Hence practitioners who wish to assess a child's capacity and willingness to imitate them need to ensure that there is variation in what *they* do as a first step. Even a minimal change on the part of the child can then be used to gauge his or her intent.

The zygonic measure of imitation—of intentionality in the creation of musical structure—is of particular value since it that it allows observers to compare quite different scenarios on equal terms. Consider, for example, the following samples of interaction, taken from 10 hypothetical sessions with the bodhrán over a school term. As one would expect in complex human activities

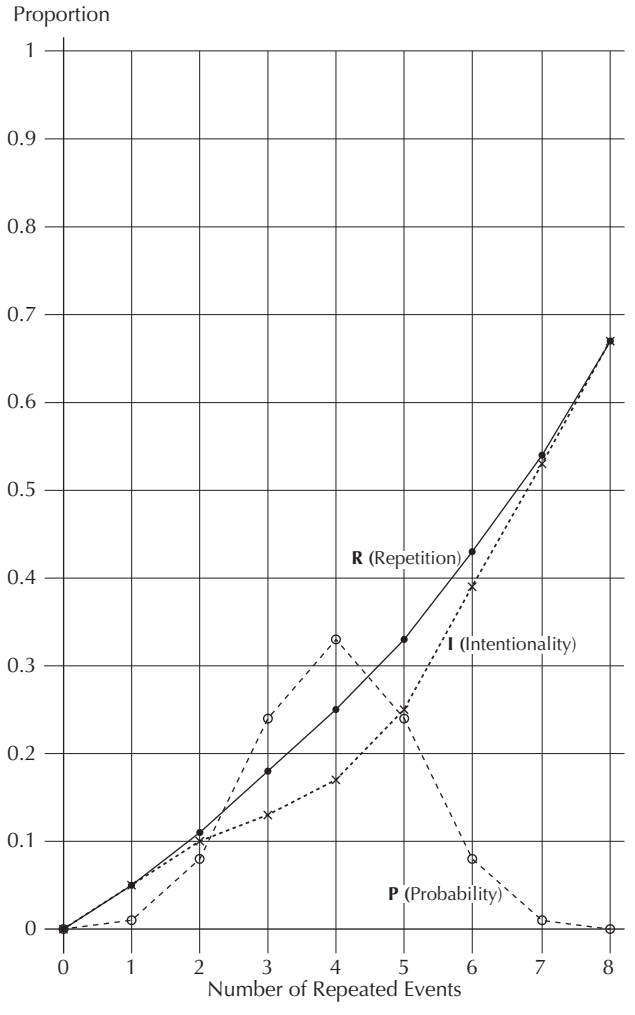


Fig. 3.19 Graph showing how intentionality varies with repetition (given 24 frames and 12 adult-generated events).

of this nature, there is a good deal of variation and, judged by the proportions of occasions upon which the child repeats the adult's strokes on the drum, it may seem as though there is a discernible negative trend of around 4.5% in which the child gradually comes to interact less with the adult (Fig. 3.20, Table 3.3).

However, when one takes into account the probability of repetition occurring by chance—which falls by around 96%—the analysis looks very different: there is an increase in intentionality of around 98%; and the probable level of *imitation* on the part of the child appears to have doubled (see Table 3.4 and Fig. 3.21).

The same principle of intentionality can be applied in other, more sophisticated, music-interactional contexts too. For example, consider Scenario 3.3 once more, in which an adult working with a blind child with autism and learning difficulties plays a note on the piano (4th octave B♭). The pupil immediately copies the note. How certain can the teacher be that this repetition is intentional, that it constitutes imitation? This is evidence that the child may possess

Table 3.1 Varying degrees of repetition (*R*) result in a range of probabilities (*P*) and, therefore, intentionality (*I*)

#F	#E_A	#E_C	#REP	*R*	*P*	*I*
24	12	8	0	0.00	0.00	0.00
24	12	8	1	0.05	0.01	0.05
24	12	8	2	0.11	0.08	0.10
24	12	8	3	0.18	0.24	0.13
24	12	8	4	0.25	0.33	0.17
24	12	8	5	0.33	0.24	0.25
24	12	8	6	0.43	0.08	0.39
24	12	8	7	0.54	0.01	0.53
24	12	8	8	0.67	0.00	0.67

#F, number of frames; #E_A, number of events generated by the adult; #E_C, number of events generated by the child; #REP, number of repetitions made by the child.

"absolute pitch": the capacity to recognize or reproduce pitches in isolation from others (see, for example, Takeuchi and Hulse, 1993).

Consider again Formula (3.8), $I = R(1 - P)$. To calculate *P*, the probability that the pitch concerned would occur by chance, we will invoke the principle of "octave equivalence," whereby, in possessors of absolute pitch, notes with the same letter name are regarded as equivalent, irrespective of the octave in which they occur (Rakowski, 1993). This equates to $1/12 = 0.08$. There is a single event which is repeated exactly, so $R = 1$. Hence $I = 1 - 0.08 = 0.92$. That is, according to the zygonic measure of intentionality, there is a 92% chance that the B♭ occurred through imitation, which, in the absence of neighboring pitch stimuli would be a strong indication of the presence of absolute pitch.

This is straightforward enough. However, the theory is of greater service in the more complex situations typical of work in the classroom. Take Scenario 3.3 once more, and let us extend this action in time.

Table 3.2 Invariance in a stimulus does not allow intentionality to be measured. Definitions as in Table 3.1

#F	#E_A	#E_C	#REP	*R*	*P*	*I*
6	6	6	6	1	1	0
6	6	5	5	0.83	1	0
6	6	4	4	0.67	1	0
6	6	3	3	0.50	1	0
6	6	2	2	0.33	1	0
6	6	1	1	0.17	1	0

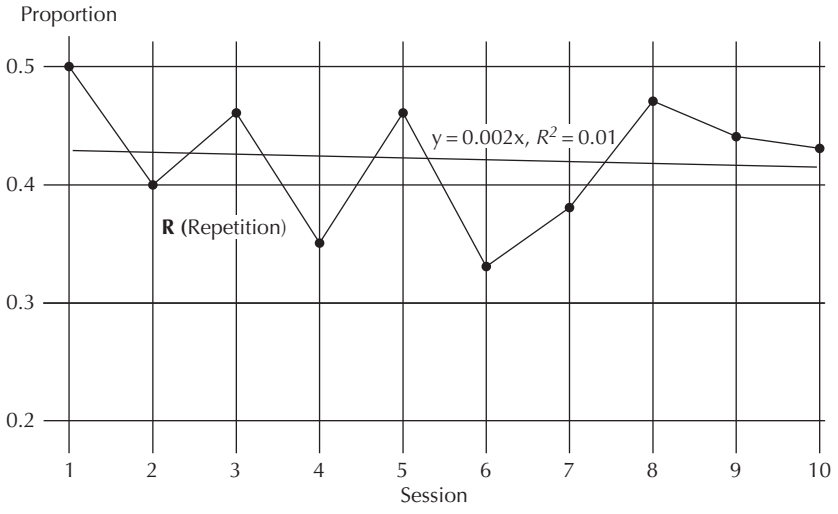


Fig. 3.20 Small decrease in the proportion of repetition over time.

A minute or so after the pupil's initial response (during which time the teacher interacts playfully with the pupil with a rhyme), the teacher plays another note on the piano—3rd octave A (see Fig. 3.22). On this occasion, however, the pupil appears not to be concentrating, and does not react. A further playful rhyming game ensues, then the teacher plays the same note again, and this time the pupil responds rather hastily with F in the 3rd octave. After a further minute or so of non-musical activity, the teacher plays F♯ in the 5th octave, and the pupil plays the A♭ a tone away. A further break, and then the teacher plays 4th octave C♯. The pupil plays it back immediately. After a further minute or so, the teacher plays B♭ in the second octave, and again the pupil does not respond.

Table 3.3 Hypothetical data from bodhrán sessions over a period of 10 weeks. Definitions as in Table 3.1

#F	#E_A	#E_C	#REP	*R*
11	10	5	5	0.50
12	9	5	4	0.40
30	21	17	12	0.46
26	13	14	7	0.35
30	21	17	12	0.46
24	12	8	5	0.33
22	14	15	8	0.38
26	11	14	8	0.47
36	18	21	12	0.44
28	19	21	12	0.43

Table 3.4 The diminishing probability of repetition occurring by chance has a positive effect on intentionality. Definitions as in Table 3.1

#F	$\#E_A$	$\#E_C$	#REP	*R*	*P*	*I*
11	10	5	5	0.50	0.55	0.23
12	9	5	4	0.40	0.48	0.21
30	21	17	12	0.46	0.31	0.32
26	13	14	7	0.35	0.30	0.24
30	21	17	12	0.46	0.31	0.32
24	12	8	5	0.33	0.24	0.25
22	14	15	8	0.38	0.14	0.33
26	11	14	8	0.47	0.09	0.43
36	18	21	12	0.44	0.16	0.37
28	19	21	12	0.43	0.04	0.41

What is the observer to conclude from these apparently unsystematic responses? It seems that at times the pupil may not have been attending to the task at hand, and on other occasions it appears that he may have been making errors—hardly surprising given his blindness and learning difficulties, and the unpredictability of the desultory "musical dialog" in which he was intermittently engaging. Indeed, it is reasonable to expect more inaccuracies (in the sense of a participant not producing the sound or sounds that he or she intended) in the context of freely improvised musical interactions than in pre-planned and rehearsed performances. But, as in the case of the interaction with the bodhrán, this leaves the analyst with the challenge of knowing whether the repetition of pitch that did occur was intended to be imitative or not, and whether, on some or all of the occasions that repetition did *not* occur, it had actually been contemplated. And, given the number of incorrect responses (or no reaction at all), what is the probability that the child has absolute pitch? Let us see what the zygonic formula of intentionality, $I = R(1 - P)$, tells us. The results are given in Table 3.5—observe that the probability of a nil response is set at 11/12 (since pitches with the same letter name but in a different octave would have been considered to be equivalent):

$$R = \frac{2}{6} = 0.33 \tag{3.10}$$

$$P = \left(\frac{1}{12}\right)^2 \times \left(\frac{11}{12}\right)^4 \times \frac{6!}{2! * 4!} = 0.07 \tag{3.11}$$

$$I = 0.33 \times (1 - 0.07) = 0.31. \tag{3.12}$$

These figures tell us that, since the probability of two pitches out of six being imitated is low (around 7%), the likelihood is that the child has absolute pitch (93%). However, the intent with which he imitated the teacher's notes is rather lower (0.31).

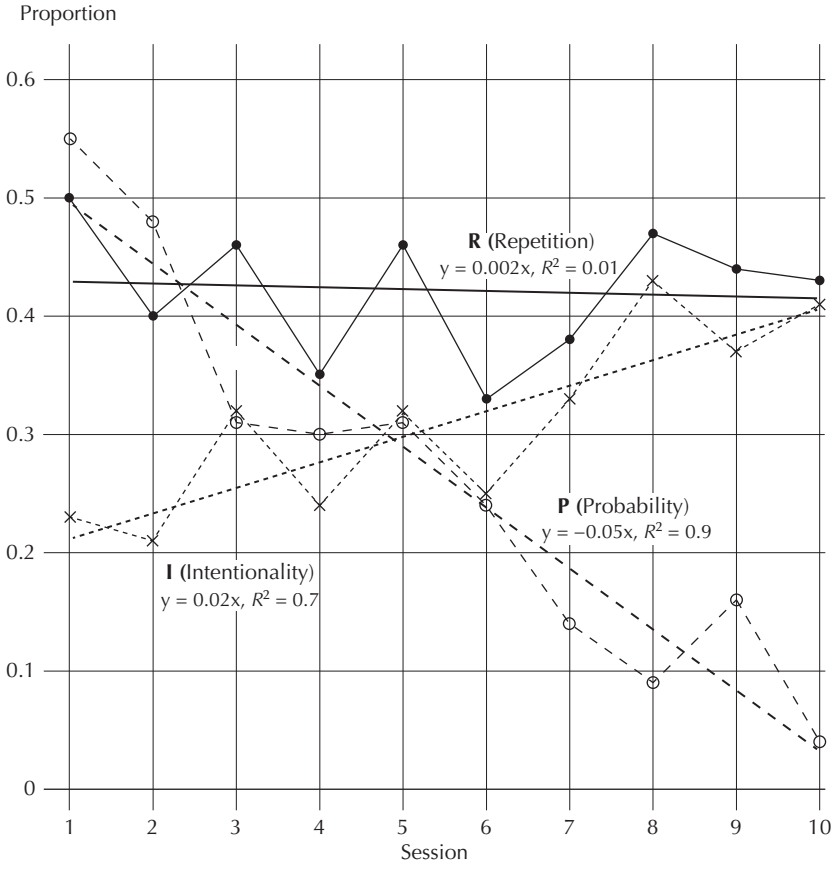


Fig. 3.21 Graphical representation of the impact that the probability of repetition occurring by chance has on intentionality.

Now let us revisit Scenario 3.4, in which only five notes (C, D, E, F, and G) were available to both teacher and pupil. Even with relatively few notes available, with (say) 20 replications, the results can be a powerful indication of a child's musical intentionality (see Table 3.6). Here,

$$R = \frac{9}{20} = 0.45 \tag{3.13}$$

$$P = (0.2)^9 \times (0.8)^{11} \times \frac{20!}{9! * 11!} = 0.007 \tag{3.14}$$

$$I = 0.43 \times (1 - 0.007) = 0.43. \tag{3.15}$$

That is, the probability of the repetition occurring by chance is vanishingly small (less than 1%), whilst the child's intentionality is 0.43.

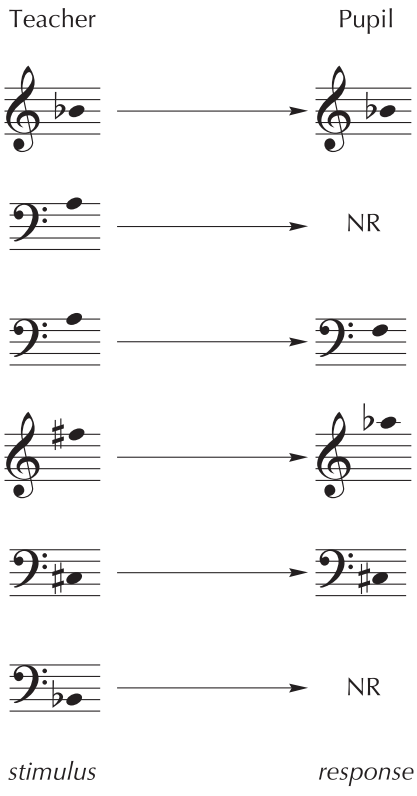


Fig. 3.22 A series of pitches played on the piano, and a pupil's responses (NR = no response).

Finally, consider Scenario 3.6, in which a child who is blind and has severe learning difficulties and a motor impairment that limits independent finger movement strikes clusters of adjacent keys in response to single notes played by the teacher. The stimuli (E_A) and responses (E_C1, E_C2, E_C3 and E_C4) are shown in Table 3.7. Over six attempts, the average proportion of repetition (*R*) is 0.4, the average probability (*P*) of this occurring by chance is 0.22, and the intentionality (*I*) is 0.32.

Table 3.5 Pitches played by an adult (E_A) on the piano, a child's responses, and the probability of these occurring by chance

E_A	E_C	Repetition?	*P*
B♭	B♭	Yes	1/12
A	–	No	11/12
A	F	No	11/12
F♯	A♭	No	11/12
C♯	C♯	Yes	1/12
B♭	–	No	11/12

Table 3.6 A child's responses (E_C) to pitches played by an adult (E_A) from a selection of five available

E_A	E_C	Repetition?	*P*
C	C	Yes	0.2
G	E	No	0.8
F	D	No	0.8
E	E	Yes	0.2
G	F	No	0.8
D	C	No	0.8
C	C	Yes	0.2
E	E	Yes	0.2
G	C	No	0.8
F	G	No	0.8
D	F	No	0.8
C	G	No	0.8
F	E	No	0.8
E	E	Yes	0.2
G	F	No	0.8
D	D	Yes	0.2
C	C	Yes	0.2
E	D	No	0.8
F	F	Yes	0.2
G	G	Yes	0.2

Table 3.7 Analysis of the pitch clusters played in response to individual notes on the piano

E_A	E_C 1	E_C 2	E_C 3	E_C 4	*R*	*P*	*I*
B♭	A♭	B♭	B♮	C	0.25	0.33	0.17
A	G	A	B	–	0.33	0.25	0.25
A	G	A	–	–	0.50	0.17	0.42
F♯	F♯	A♭	B♭	–	0.33	0.25	0.25
C♯	C♯	E♭	–	–	0.50	0.17	0.42
B♭	B♭	A♭	–	–	0.50	0.17	0.42
				Means	0.40	0.22	0.32

From theory to practice: two examples

In the previous section, by working through a series of hypothetical scenarios, we developed a theory of how intentionality in musical interaction may be gauged purely by observing and analyzing patterns of sound: through calculating the degree of patterning present (R) (in terms of the proportion of repetition to non-repetition), assessing the probability of such patterning occurring by chance (P), and through this, conversely, the likelihood of it having been created through human design ($1 - P$). The product of the two, $R(1 - P)$, was deemed a measure of "intentionality" (I). We will now apply this thinking to two "real-life" examples, that have until now have resisted the analysis of musical intent through more informal methods.

The first example involves a musical dialog between Sally Zimmermann, a music and communication specialist, working with Matthew, who is 6 years old, and is cortically blind with cerebral palsy and multiple learning difficulties. The video recording is available on the *Sounds of Intent* website <http://www.soundsofintent.org>.

We are in mid-session. Matthew is seated in his wheelchair and Sally is kneeling in front of him, with a lollipop drum in her right hand and a small shaker in her left, which she holds in front of Matthew a little above his head height. For the second time, Sally sings a song from *All Join In!* (Ockelford, 1996): *Slowly and Quickly*. Each downbeat is accompanied by a bang on the drum with the shaker, alternating from left to right in front of Matthew (Fig. 3.23).

Matthew is alert throughout the first section of the song ("Slowly, slowly . . ."), though without showing any particular or consistent response. As Sally sings "Quickly, quickly . . .", the tempo changes abruptly, and the rate of beating on the drum increases dramatically. Matthew shows a powerful reflex reaction to the increase in volume of sound, and he becomes rigid for a few seconds. However, in the silence that follows that "quick" section of the song, he relaxes, smiles broadly, and makes a high-pitched cry of pleasure as he inhales. Sally responds with a yodeling vocalization that falls and rises over a range of around an octave and a half.

A vocal dialog ensues in which the two participants alternate with bursts of vocalization, that largely comprise pitch glides and swoops, though Sally introduces some more stable pitches too. It appears initially as though she is imitating Matthew (Contribution 3, Fig. 3.23b), but subsequently, as the material of teacher and pupil converges, it is difficult to tell whether he also echoes some of what Sally does. In particular, in Contribution 7 (Fig. 3.23c), Matthew produces a contour that rises then falls, which sounds very much like the ending of Sally's contribution that immediately precedes. But does the evidence support an interpretation of imitation here, or is Sally's skilful scaffolding of Matthew's efforts giving the impression of intentionality on his part where none, in fact, exists? As noted above, we are intuitively programmed to imitate each other and to expect imitation in return—particularly in our interactions with children in the early stages of development. It is part of being human. And to hear *repetition* in such dialogs and not unthinkingly to interpret it as *imitation* requires a willing suspension of belief that is likely to feel counterintuitive. To resolve this issue, we need to turn to the principles set out in the previous section of gauging intentionality in the production of musical structures. The most salient feature of each vocal contribution is its *contour*—the pattern of ups and downs that it traces over time in the domain of pitch (cf. Dowling and Fujitani, 1971; Adams, 1976)—and it is to this characteristic that we will first turn to look for repetition and potential imitation.

By representing elements of a contour simply as a "negative" (that is, downwards) or "positive" (that is upwards) change in pitch, and taking into account only the relative disposition of *successive* peaks, troughs or periods of stability, the following series emerges from Fig. 3.23 (see Table 3.8, column 3). Some movements in pitch are more substantial than others, which appear to be more

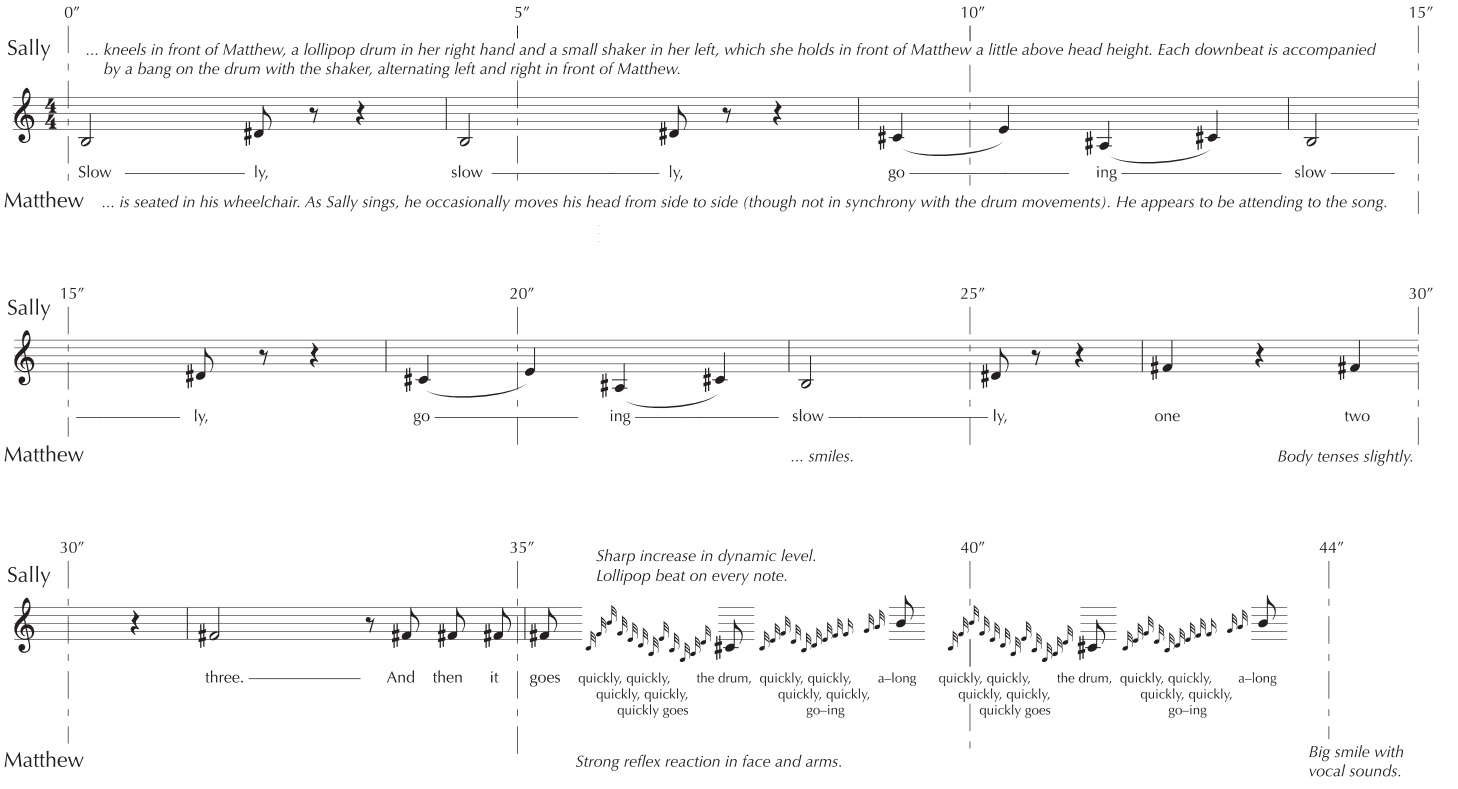


Fig. 3.23 (a)–(c) Interaction between Sally and Matthew using the song *Slowly, Slowly*, from *All Join In!*.

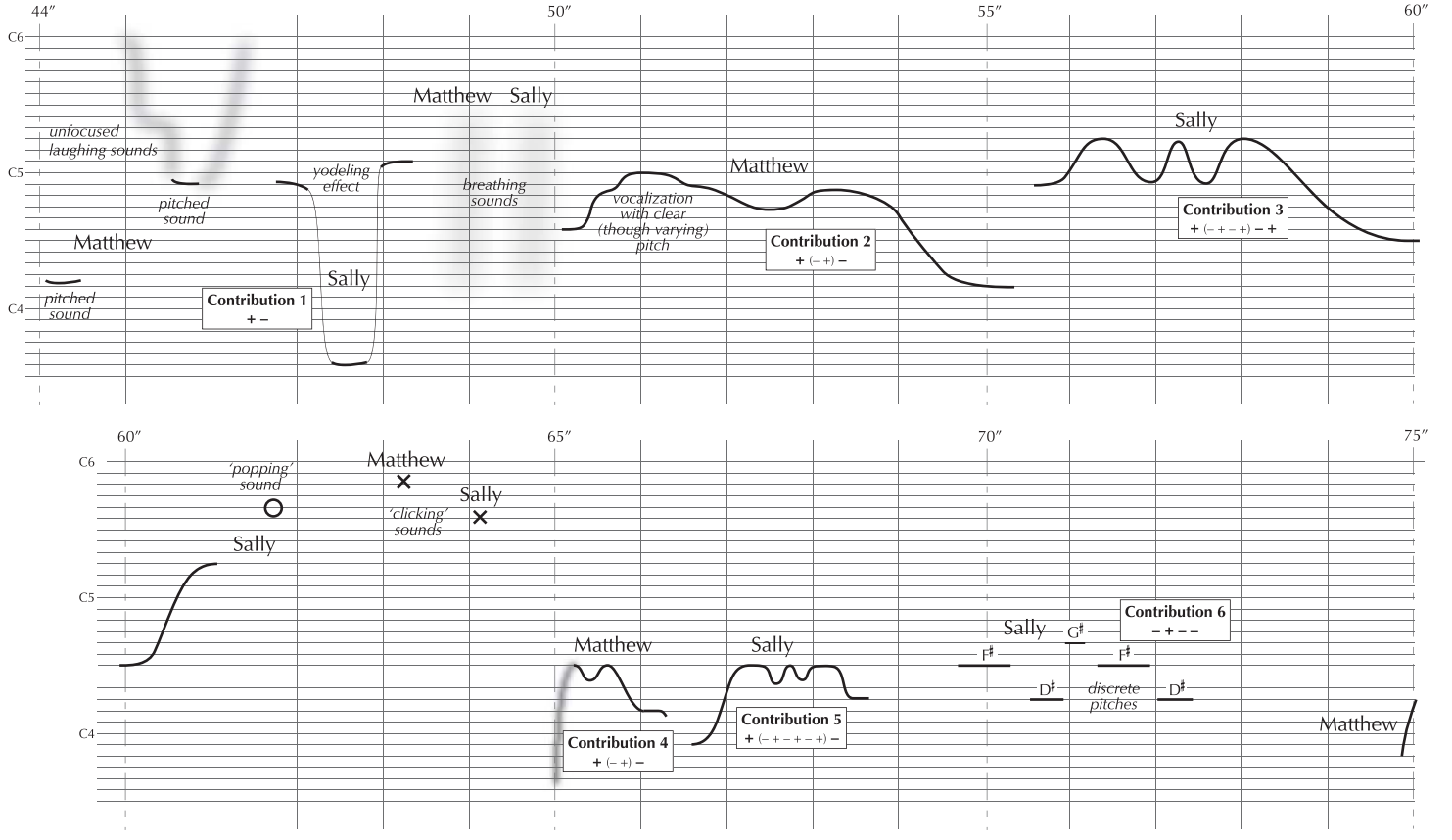


Fig. 3.23 (continued).

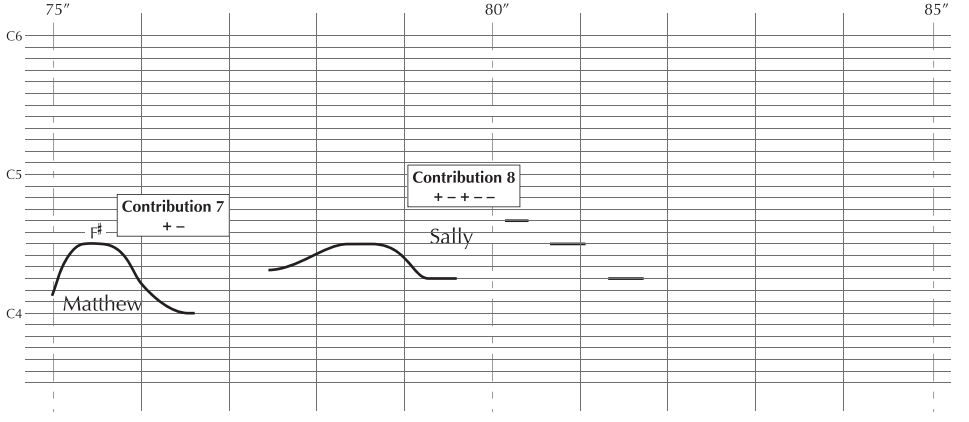


Fig. 3.23 (continued).

Table 3.8 Pitch contours of the vocalizations used by Matthew (M) and Sally (S)

Contribution number	Participant	Full contour	Underlying contour	Reference number
1	S	− +	− +	$_1S_1$
2	M	+ (− +) −	+ −	$_2M_1$
3	S	+ (− + − +) − +	+ − +	$_3S_2$
4	M	+ (− +) −	+ −	$_4M_2$
5	S	+ (− + − + − +) −	+ −	$_5S_3$
6	M	− + − −	− + − −	$_6S_4$
7	M	+ −	+ −	$_7M_3$
8	S	+ − + − −	+ − + − −	$_8S_5$

ornamental. Taking into account only the more "structural" (larger) changes will facilitate the process of comparing contours—see column 4 in Table 3.8.

In terms of gauging repetition (R), probability (P), and intentionality (I) in relation to these contributions, there are many possible relationships that need to be taken into account—each contour potentially repeating or imitating those that came previously. Here, our initial interest is in the extent to which Matthew may have intentionally repeated—imitated—Sally. We can approach this issue systematically by setting up matrices as shown Fig. 3.24. The proportion of repetition between each pair of contours is calculated as the number of *identical* successive + or – pairs as a ratio of the number of *different* + or – pairs, when the two sequences are aligned to give maximum congruence. That is:

$$R = \frac{\text{no. of successive matches}}{\text{no. of potential relationships}}. \tag{3.16}$$

Examples are shown in Fig. 3.24.

This process is comparable to the algorithm derived by Müllensiefen and Frieler (2004, p. 10) and cited in Müllensiefen and Wiggins (2011, p. 174). Here, given the permitted operations of insertion, deletion, and substitution, similarity is calculated as the "Levenshtein" distance between two series of notes: that is, the minimum number of operations ("edits") needed to transform one string into another (Müllensiefen and Wiggins, 2011, p. 175) expressed as a ratio of the "maximal" distance (the length of the longer string). In the current context, however, the "maximal" distance is taken to be the number of *potential* relationships, which, when sequences overlap, may be greater than the length of the longer string (see Table 3.9). In each case, the probability of such repetition occurring by chance is given by the number permutations that result in the given degree of repetition divided by the total number of permutations. That is:

$$P = \frac{\text{no. of permutations resulting in } R}{\text{no. of permutations}}. \tag{3.17}$$

For example, given $_1S_1$ (− +), and a response from Matthew comprising two contour components, then the possibilities are − +, − − −, + −, and − +, and the probability of $R = 0$ is $3/4 = 0.75$. Given $_6S_4$ (− + − −), the probability of $R = 0.5$ is also $3/4 = 0.75$.

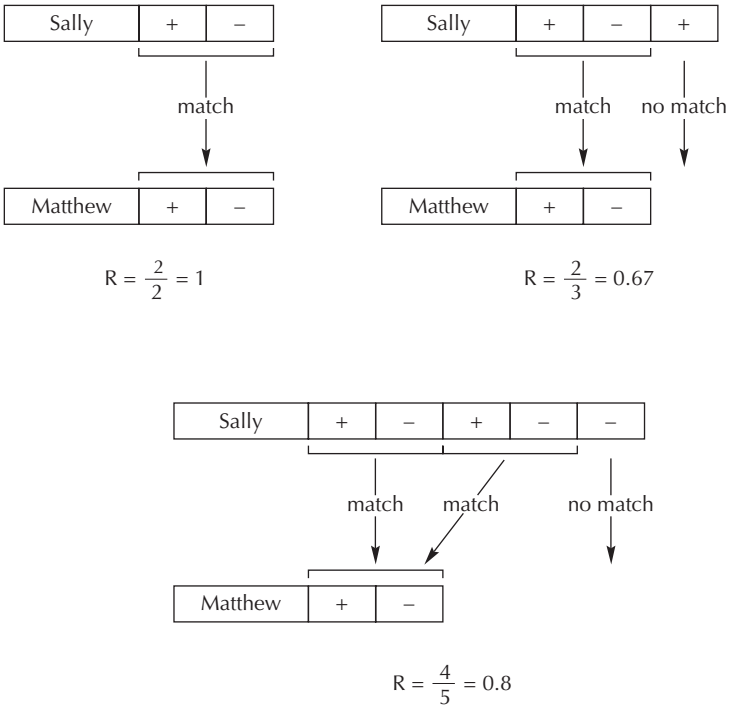


Fig. 3.24 Calculations of *R* in relation to Sally's and Matthew's vocal contours.

On the assumption that (within the relatively short space of time in which the vocal interaction takes place) a given contribution can potentially exist in imitation of any of those that precede, it seems reasonable to assert that the mean values of repetition, probability, and intentionality are broadly reflective of Matthew's musical motivations and behaviors over the period. These are $R = 0.40$, $P = 0.61$, and $I = 0.16$. That is, the probability of Matthew's repetition of Sally's contours occurring by chance is relatively high (over 60%), while his intentionality, as measured by the zygonic formula, is correspondingly low (around 16%). Contrast these with Sally's scores, which are a testimony to her adroit scaffolding of Matthew's efforts: $R = 0.76$, $P = 0.18$, and $I = 0.63$.

Table 3.9 Repetition, probability, and intentionality deemed to be functioning between Sally's (S) and Matthew's (M) contributions

		$_2M_1$	$_4M_2$	$_7M_3$
		+ –	+ –	+ –
$_1S_1$	– +	$R = 0$, $P = 0.75$, $I = 0$	$R = 0$, $P = 0.75$, $I = 0$	$R = 0$, $P = 0.75$, $I = 0$
$_3S_2$	+ – +		$R = 0.67$, $P = 0.5$, $I = 0.17$	$R = 0.67$, $P = 0.5$, $I = 0.17$
$_5S_3$	+ –			$R = 1$, $P = 0.25$, $I = 0.75$
$_6S_4$	– + – –			$R = 0.5$, $P = 0.75$, $I = 0.13$
$_8S_5$	+ – + – –			

However, there is a further characteristic of the interaction in addition to the pure relativity of contour: the "absolute" values of pitch which become increasingly evident in Sally's contributions from ${}_6S_4$ (as she sustains certain pitches to form a distinct three-note motif, universally familiar in children's chants) and which observers report hearing imitated in Matthew's final vocalization (${}_7M_3$). What does zygonic analysis suggest that the position is here?

In ${}_6S_4$ (Contribution 6, Fig. 3.23b) there are three stable pitches, F♯, D♯, and G♯, while ${}_7M_3$ (Contribution 7, Fig. 3.23c) has one, which occurs at the melodic peak, namely F♯. Here, $R = 0.33$ and $P = 0.25$ (assuming 12 available pitch-classes[2]), yielding $I = 0.25$. Although the evidence is limited, this suggests that Matthew's capacity (or propensity) to imitate individual pitches may be greater than his ability (or desire) to reproduce different contours. This is a finding of potential importance for those engaging musically with Matthew. Clearly, further interactions, in which he was presented with a range of different vocal stimuli with which he could potentially interact, would need to be analyzed in order to substantiate these preliminary findings (or to suggest others).

The second "real-life" scenario to which the analysis of intentionality developed in this chapter will be applied occurred in my work with a young woman in the final stages of juvenile Tay–Sachs disease—Abigail Lee. Abby has since died, aged 19, and it is to her that this volume is dedicated, since it was in seeking to fathom her engagement with music towards the end of her life that the notion of "intentionality" presented here was first formulated.

Juvenile Tay–Sachs is a form of GM2 gangliosidosis, a degenerative condition caused by the shortage of an enzyme that normally clears up fatty deposits that would otherwise accumulate in the brain. Over time, this leads to the loss of mental and physical functions and, in due course, premature death. Abby's sister, Charlotte, died when she was only 10.

The girls' illness did not start to take effect until they were 2 years old, so they both enjoyed a normal early infancy. Abby's parents report that, as a young child, she was very bright and talkative. Like her mother, Sue, who learnt to play the piano as a child, Abby was fond of music—especially singing. She had many tapes and CDs of nursery rhymes and childhood and popular songs, which she liked to hear over and over again in the car. Her father, Duncan, recalls her asking repeatedly for the Spice Girls!

Over a period of 5 years, Abby lost her power of speech, but she was still able to sing nursery rhymes for some time after she was no longer able to talk. Duncan reports that "Here we go round the nardy dush" (mulberry bush) were probably the last words that she could ever produce—and she would sing them loudly, and tunefully, on her way to and from school.

One day, her class were played a song that "got Abby very excited and vocal," according to her carer. It was Burt Bacharach's *Raindrops Keep Falling on my Head*. This was a song that Duncan had regularly sung to Abby at night when she was a baby. He decided to get her a recording, which he could only obtain as part of a compilation of Bacharach's work. Each song has a distinctive introduction, and Abby would give a little laugh every time she realized that a number she particularly liked was coming up. Subsequently, Sue and Duncan bought Abby an iPod, upon which they put all the music that she had ever shown a liking for, and they report that she derived a lot of fun and comfort from it late in her life.

My issue, as Abby's music teacher in her last 2 or 3 years, when she was unable to vocalize or grasp a conventional musical instrument in order to manipulate it, was how to enable her to engage with music proactively—for during music sessions, she often displayed sustained, rapt attention. This focus, together with her love of songs and singing earlier in life, meant that it was

[2] That is, notes with the same "letter name"—A, B, C, etc. (see p. 63 above).

hard to imagine that Abby did *not* want to participate in the music-making that was going on around her.

Working with her teachers and carers at Linden Lodge School in London, where Abby was a pupil, it was decided to see whether a technological solution—OptiMusic®—could enable Abby to take part in music sessions once more. OptiMusic® works by emitting beams of light, which, when broken at different points by a reflective surface, are detected by a sensor, and cause corresponding MIDI signals to be sent to a digital library of sounds. The beauty of this and comparable beam systems, others of which, such as Soundbeam®, use ultrasound as the switching medium, is that they can be adjusted so that *any* movement can be made to cause *any* sound.

In Abby's case, given her previously observed capacity and enthusiasm for singing, it was decided to set things up so that a series of pitches were available to her that were melodically pleasing irrespective of the sequence in which they are played, and we opted for the notes of a C major chord (C, E, G) spaced over two octaves, using the sound of an acoustic guitar. The intention was for the group of supporting staff to improvise a song that used those notes, and for me to provide a keyboard accompaniment such that Abby's pitches, C, E, and G, were always concordant with the underlying harmonies. This arrangement meant that if Abby was able to operate the system at all, though with little or no control, her efforts would still be congruent in pitch terms with the wider improvisation, and so a pleasing musical product was guaranteed. However, the triad of available pitch-classes also meant that Abby had the scope to offer musically more sophisticated material should she find this possible and desirable.

The necessary reflective surface was provided by a lightweight plastic paddle, which, with some preliminary assistance, Abby could grasp with her left hand, which initially rested on her lap. The beam was set up so that a lateral movement of only 2 or 3 cm in the paddle was sufficient to trigger a note. All six notes were captured in the range of around 15 cm, diagonally upwards and to the right.

It was explained to Abby that in order to join in the song she needed to move the paddle . . . and then the music got under way. To everyone's great pleasure, Abby was indeed able to participate, and produced sounds with increasing vigor as the song progressed over a couple of minutes. The improvisation was designed to be simple and predictable, with the melody based on a rocking/descending triadic motif, using Abby's three notes: G, E, and C. This was treated as an ostinato—a melodic fragment that is persistently repeated. The thinking was that, by providing a pattern in sound that was continually reiterated, it would give Abby the best possible chance of predicting what was coming next, potentially enabling her to tailor her contribution to match the unfolding improvisation.

The first attempt at the song was successful in that Abby made an active contribution to an improvised musical structure that was both coherent and pleasing. However, in the context of live music making, it was difficult to discern the level of intentionality lying behind patterns of pitches she produced (since, as we noted above, the texture was designed to "work" musically whatever her input). Hence it was decided to perform the song again, and video Abby's endeavors for further analysis. The result can be seen on the *Sounds of Intent* website <http://www.soundsofintent.org>.

After a brief rhythmic introduction, the melodic ostinato appears 10 times without a break. The whole song lasts around 1 minute 45 seconds. Because of the strong tendency of listeners to impose a logic on any stream of sounds deemed to constitute (or potentially to constitute) music, when one watches the video it is very difficult to discern whether there is an underlying intentionality in Abby's choices of pitch or not. One indication would be the extent to which she repeats notes that have just occurred or (possibly) are just occurring, since they could be predicted from previous iterations of the melody (see Fig. 3.25). If such repetition is found, and is significantly above the level of chance, then that would be a fair sign of music-structural intentionality.

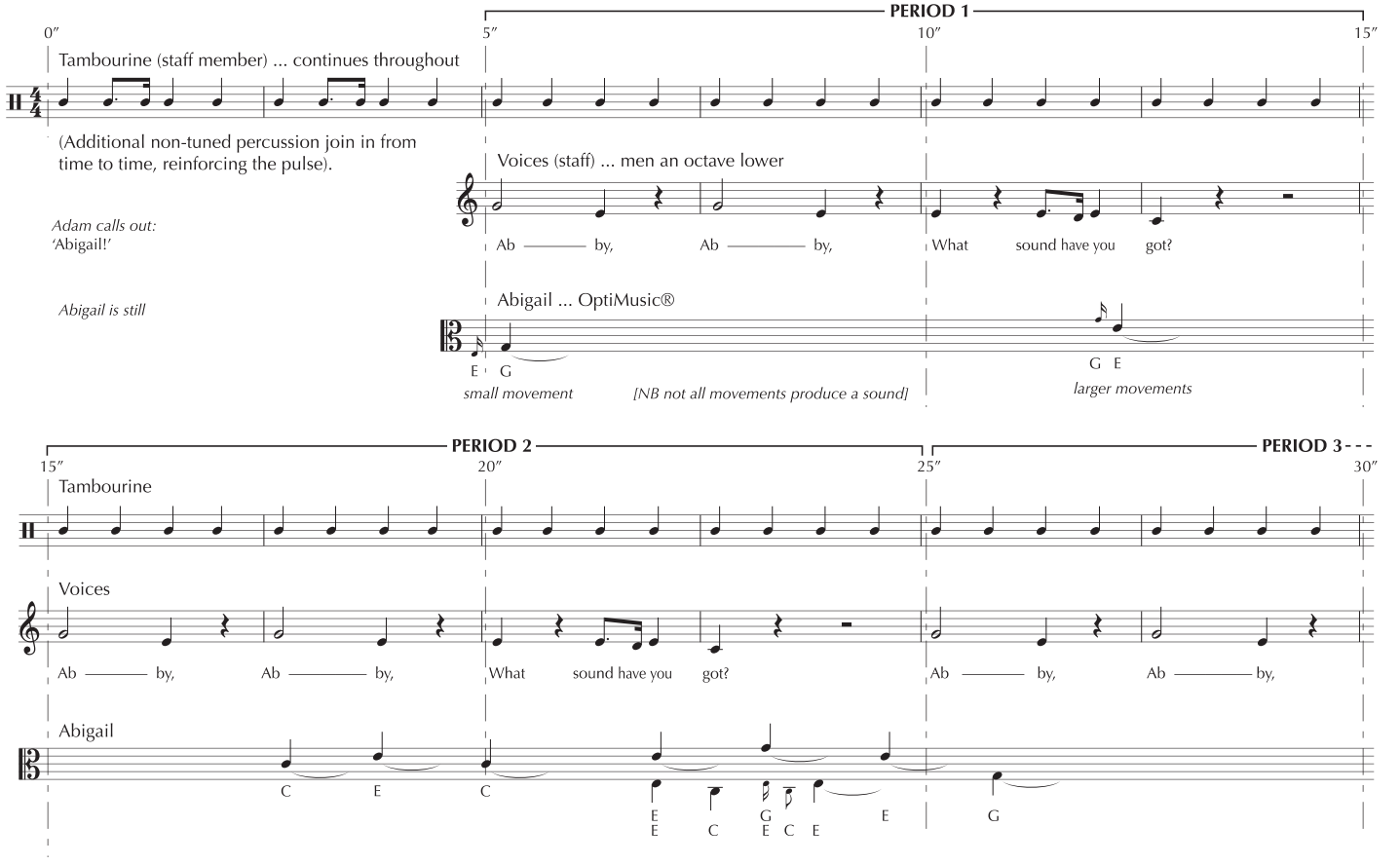


Fig. 3.25 (a)–(d) Improvised piece with Abby and a group of staff.

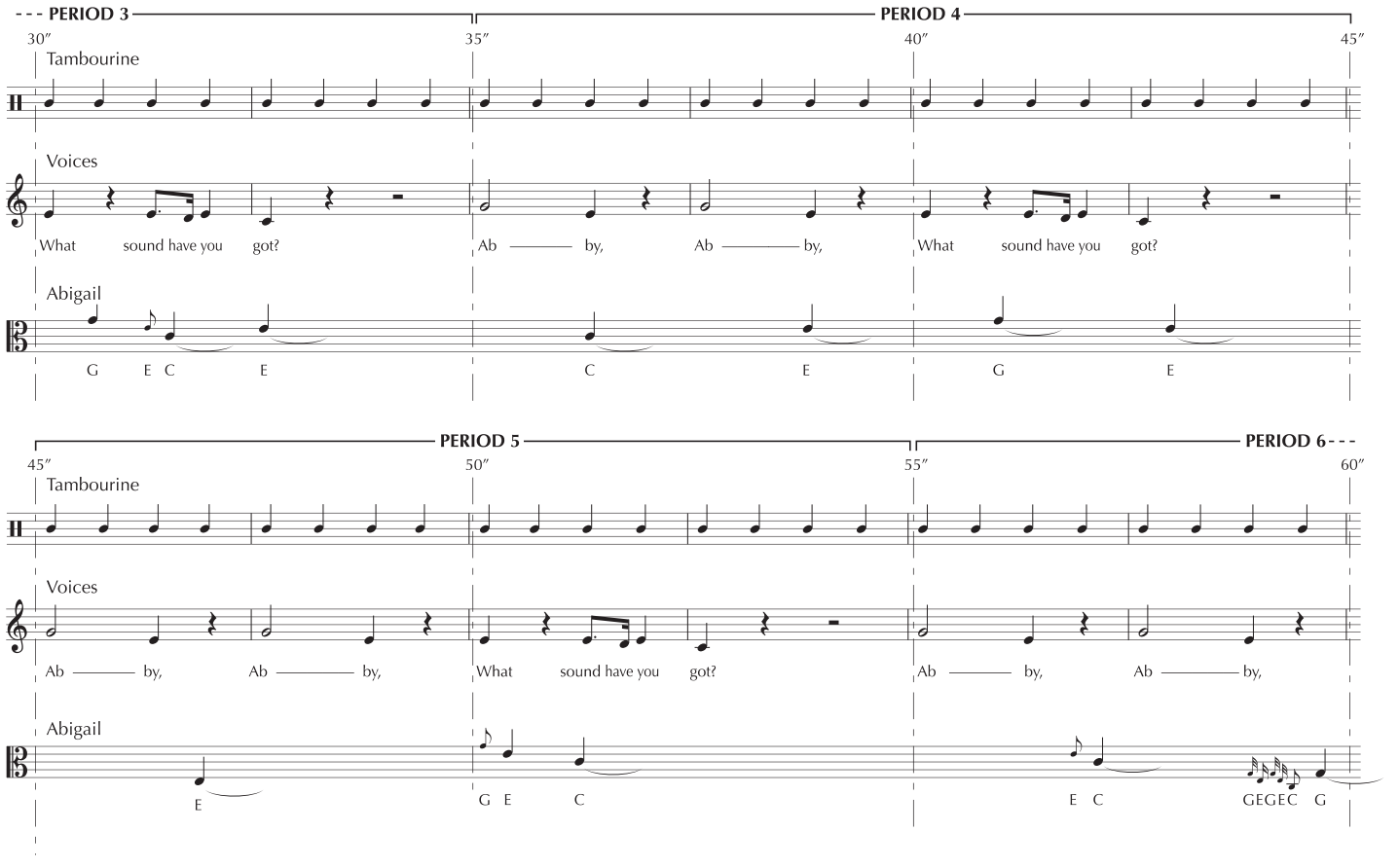
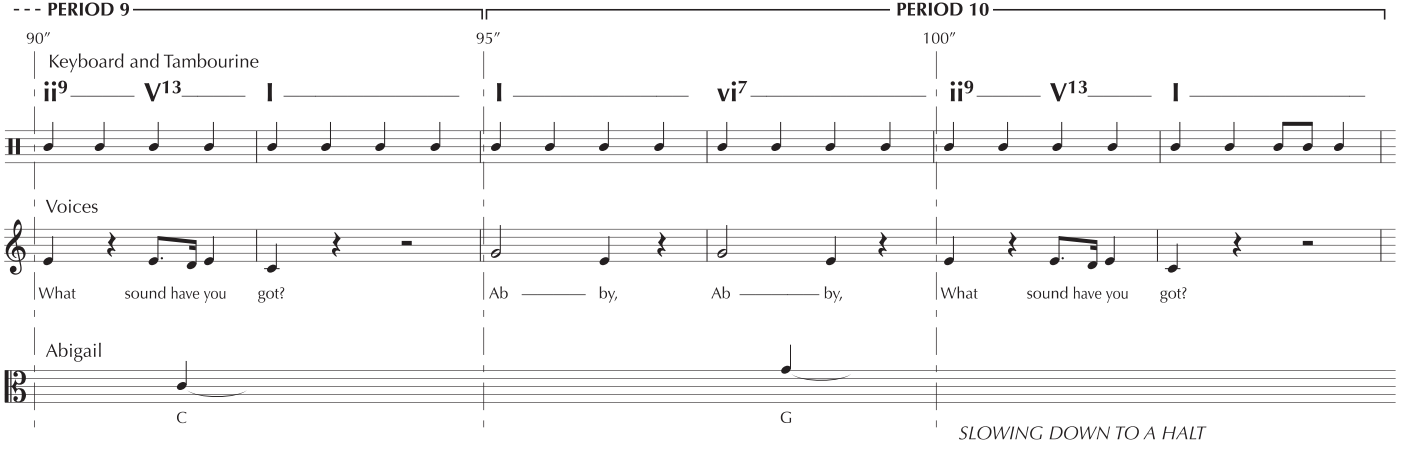



Fig. 3.25 (continued).

Fig. 3.25 (continued).



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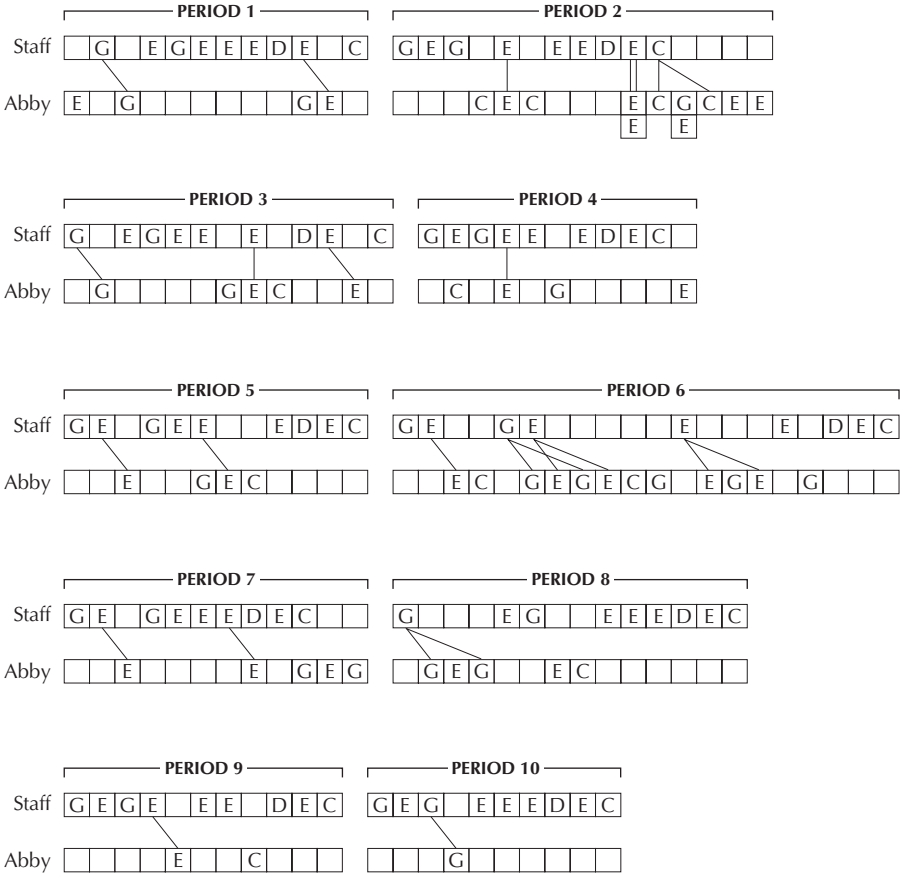


Fig. 3.26 Abigail's use of pitch-class in relation to the melody.

Figure 3.26 records the whole of Abby's contribution in terms of pitch-class and the sequentiality of events. These are mapped onto the nearest available preceding or simultaneous pitch-class in the melody (which was sung in octaves, with female and male voices). The results can be summarized as follows. Of the 53 notes that Abby played, 23 were repetitions of proximate notes[3] (or pairs of notes) occurring in the melodic ostinato. Hence

$$R = \frac{26}{53} = 0.49. \tag{3.18}$$

The probability of this proportion occurring by chance is

$$P = \left(\frac{1}{3}\right)^{26} \times \left(\frac{2}{3}\right)^{27} \times \frac{53!}{26! * 27!} = 0.007. \tag{3.19}$$

[3] Some were virtually simultaneous, implying anticipation based on previous hearings of the ostinato (see Fig. 3.29).

Period	Event #	before 39–30ms	before 29–20ms	before 19–10ms	before 9–0ms	after 0–9ms	after 10–19ms	after 20–29ms	after 30–39ms
1	1				•				
	2						•		
	3					•			
	4						•		
2	5							•	
	6							•	
	7			•					
	8					•			
	9					•			
	10					•			
	11					•			
	12					•			
	13						•		
	14					•			
	15			•					
3	16	•							
	17						•		
	18		•						
	19	•							
	20				•				
4	21					•			
	22					•			
	23						•		
	24							•	
5	25								•
	26					•			
	27							•	
	28					•			
6	29								•
	30					•			
	31					•			
	32					•			
	33						•		
	34							•	
	35								•
	36			•					
	37						•		
	38							•	
	39				•				
	40							•	
7	41					•			
	42		•						
	43				•				
	44				•				
	45	•							
8	46								•
	47		•						
	48							•	
	49				•				
	50					•			
9	51					•			
	52							•	
10	53					•			
	Totals	3	3	3	6	18	7	9	4

24 'repetitions'

29 'non-repetitions'

Fig. 3.27 The placement of Abigail's contributions relative to the beat.

Intentionality is therefore

$$I = 0.49(1 - 0.007) = 0.49. \tag{3.20}$$

That is, virtually half of Abby's contribution in the domain of pitch can be interpreted as constituting musical structure that she intended to occur. Given the very considerable physical challenges that she faced in using the paddle to operate the OptiMusic® system, and given her inexperience in manipulating it, this is a powerful indication that, despite the profound impact of her deteriorative condition, her musical mind was still active and, given the appropriate means, she was still able to engage in sophisticated musical interaction with others.

Turning to the temporal domain, analysis of Abby's contribution provides equally compelling evidence of her capacity and intent to process and produce musical structure. Subjecting the audio track of the improvised song to temporal frequency analysis (using WavePad 4.54) confirms the presence of a regular beat (reinforced throughout on the tambourine) at ♪ = 96, that is, one beat (transcribed as having the duration of a quarter note) every 0.63 seconds. The notes that Abby produces (sounding like a plucked guitar) have clearly defined onsets, and it is possible to assign these to eight categories, each 10 ms in duration, occurring before or after the beat (see Figs. 3.27 and 3.28). (The assignment of events to the categories spanning 39–30 ms before the beat, and 30–39 ms after the beat, which overlap, is made on the basis of which forms the more persuasive connection in musical terms—largely through forming part of a cluster that either stems from the previous beat or leads the ear to the next one. Note the numbers of such events are in any case relatively small, and not material to the analysis that follows.)

The results are startling, with 24 of the 53 events (45%) occurring less than 10 ms from the beat and 34 (64%) occurring within 20 ms (well within the asynchrony encountered in typical

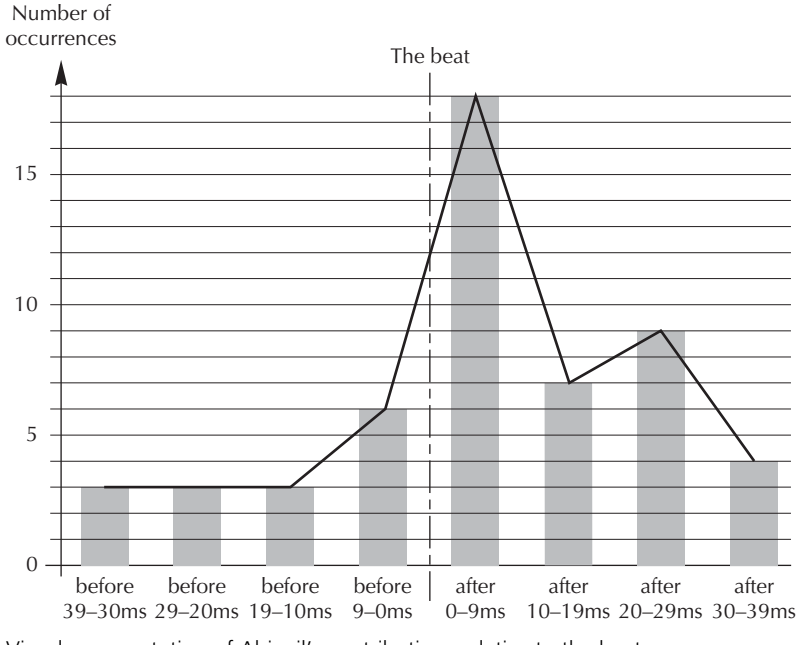


Fig. 3.28 Visual representation of Abigail's contributions relative to the beat.

professional performances; see Rasch, 1979), and the asymmetry of events before and after the beat is also telling. Repetition here is at *secondary* level, with the relationships between inter-onset intervals that are the same enabling future beats to be predicted (see Fig. 3.29). Even taking the stricter (<10 ms) boundary,

$$R = \frac{24}{53} = 0.45 \tag{3.21}$$

$$P = \left(\frac{1}{4}\right)^{24} \times \left(\frac{3}{4}\right)^{29} \times \frac{53!}{24! \times 29!} = 0.0007 \tag{3.22}$$

and

$$I = 0.45(1 - 0.0007) = 0.45. \tag{3.23}$$

These findings, in relation to pitch and rhythm, indicate that, despite the severity of her disabilities in the last few months of her life, Abby's capacity to process musical structure and, given the opportunity, to provide a coherent strand in the complex act of improvising a piece as a group, were intact.

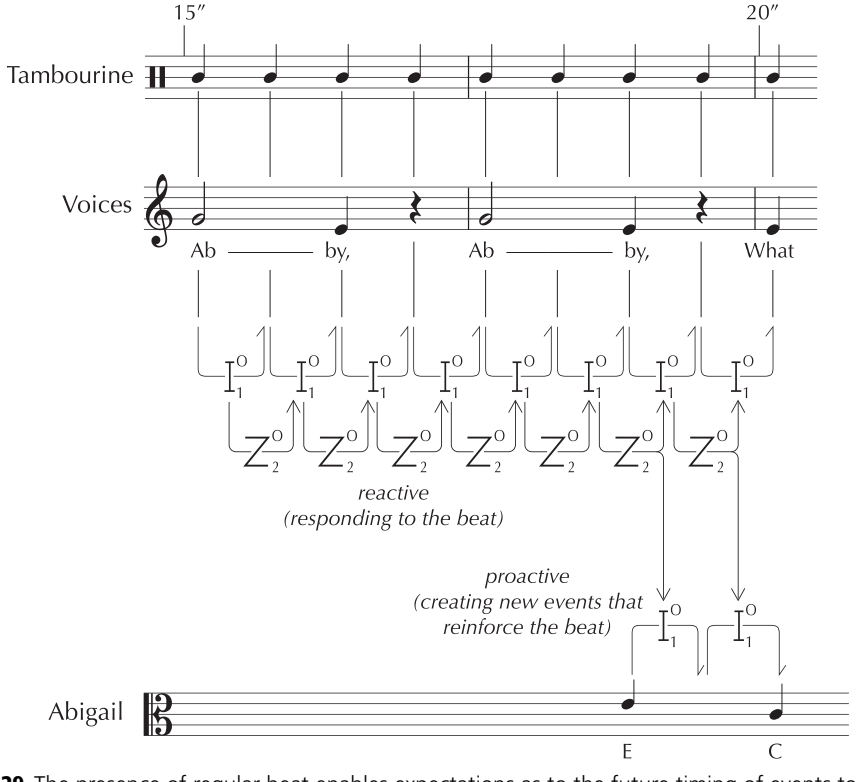


Fig. 3.29 The presence of regular beat enables expectations as to the future timing of events to occur through secondary zygonic relationships.

Conclusion

It seems, then, that the algorithm developed in this chapter for gauging the intentionality with which children and young people with severe or profound disabilities engage in musical interaction may potentially be of value to practitioners and researchers in a range of educational, therapeutic, and diagnostic scenarios—both musical and, perhaps, pertaining to other areas of human engagement. For example, there is no reason why the principles of repetition (R), the probability of this occurring by chance (P), and imitation as a proxy indicator of intentionality (I) should not apply in a variety of domains of human activity. For example, if a baby moves her hand in the same way as mine, or makes the same facial expression, did she mean to do it or not (amid the welter of similar gestures)? For medical practitioners seeking to ascertain whether a patient who has experienced severe brain trauma, and whose apparently random tapping with the fingers of his right hand seem to change in response to tapping made by another, is in a vegetative or low-awareness state (cf. Royal College of Physicians, 2003), the $I = R(1 - P)$ formula may indicate whether intentionality—a key indicator of the capacity for self-reflective thought—is present. Conversely, other (non-musical) signals may be interpreted as indicating musical intentionality: for example, smiling consistently as certain sounds are made may suggest that repetition is intended to function imitatively (cf. Magee, 2007, p. 597). Such holistic approaches to evaluating engagement may be essential in people with multisensory impairment.

Chapter 4

From intentionality to influence: gauging the impact of one performer on another in improvised musical dialogs

Introduction

In Chapter 3, we considered how zygonic analysis could provide a measure of *intentionality* in improvised musical interactions by gauging the extent to which one participant could be considered to imitate another. Such circumstances imply a relationship of *influence* between the two performers, whereby the music created by one has an impact on that generated by the other (see Fig. 3.1). Such relationships are fundamental in music education and therapy—and, indeed, in ensemble playing in general. Until recently, however, most analysis has been *indirect*, with data obtained by interviewing participants (teachers, pupils, therapists, clients, and musicians) and asking them to reflect on what they believe occurred. However, by adopting similar zygo-analytical techniques to those used to gauge a participant's intentionality, we can gauge influence in improvised musical dialogs *directly* (through analysis of the music itself) with some rigor and precision. This chapter sets out the theory of musical influence from a zygonic perspective, and leads us through a number of worked examples of this proposition in action.

The theory of musical influence

In Fig. 2.6 we saw perceived influence in action in Bach's B minor Mass, as the soprano and alto enter in the duet *Et in unum Dominum* and the melody of the latter is heard as *deriving* from that of the former. A sense of derivation can operate in a similar way in the context of *improvised* musical interactions as well (Ockelford, 2012b). Here, if one performer (A) introduces musical material "A(♪)" and a second participant (B) imitates it "B(♪)", then there may be a transfer of thinking over and above the purely auditory information that is conveyed: A may be heard to exert an effect on B—to be perceived as *influencing* B. In phenomenological terms (cf. p. 40) this influence will be felt from the point at which B's contribution is recognized as being imitative.

Furthermore, if A influences B, then A can be said to *control* the musical dialog, to a greater or lesser extent, from the juncture at which the imitation occurs. The nature and perceived strength of such control will depend on the manner in which A's ideas influence B, and B derives material *other than* from A. The extent to which B produces musical ideas that do *not* stem from A's contribution is a measure of his or her dialogic *autonomy* (Fig. 4.1).

Elsewhere, I hypothesize that the ratio between B's control and autonomy is proportional to the ratio between B's derivation of material from A and from "not A" (A′) (Ockelford, 2012b, p. 301). That is:

$$\text{B (control : autonomy)} \propto \text{A}(\♪) \text{—}\not{\text{Z}}\longrightarrow \text{B}(\♪) : \text{A}'(\♪) \text{—}\not{(\text{Z})}\longrightarrow \text{B}(\♪) \qquad (4.1)$$

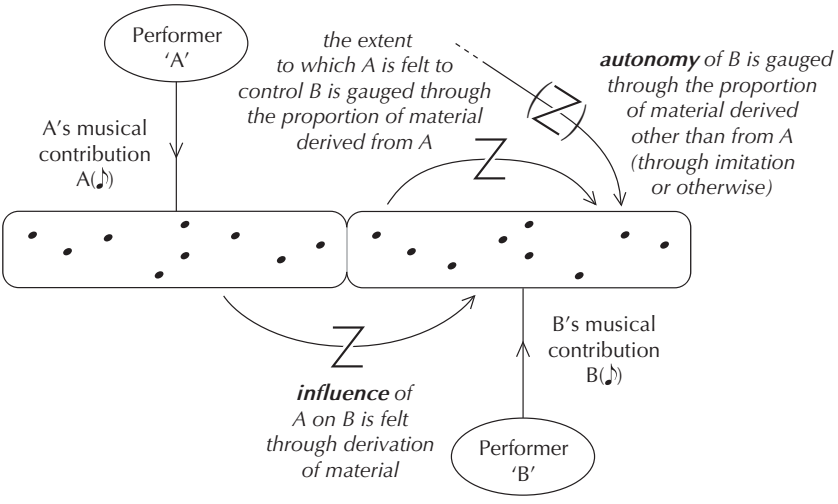


Fig. 4.1 Zygonic model of influence and autonomy occurring in an improvisation involving two performers.

As Formula (4.1) suggests, although control and autonomy are functionally opposite, and while complete control would necessarily imply zero autonomy and vice versa, due to the multi-dimensional nature of music the two can coexist in a virtually limitless variety of ways, as we shall see.

Two preliminary examples

First, though, let us consider an example of complete control (where one participant's contribution is judged to be entirely influenced by that of another). The context was a one-to-one music session I had with B—a 5-year-old girl who was blind through retinopathy of prematurity. As usual, we were working on two pianos. Initially, in our work together, B had displayed a high degree of introversion, and she had neither spoken nor played at all in the first eight of our weekly lessons (Ockelford and Matawa, 2009, pp. 82–91). She had, nevertheless, appeared to be listening intently to the music I had played for her and, as I subsequently discovered, had absorbed a good deal of what she had heard [no doubt assisted by her acute sense of absolute pitch (AP)—the ability to recognize and reproduce notes in isolation from others; see p. 13]. But my aim, after her 2 months of chronic inhibition, was simply to entice B to interact at all.

To this end, I adopted a number of different strategies, including playing pieces up to the final tonic chord, but stopping before it sounded, and leaving a silence that I hoped B would fill. Eventually, the desire for musical closure proved irresistible, and, from tentative and musically monosyllabic beginnings, B increasingly participated in our sessions. Initially, her contributions were exclusively musical, though gradually verbal language pertaining to the music that we were creating or re-creating came to figure increasingly in the equation too. Within only a few more weeks, in a way that I could never have anticipated, B came to be the dominant musical partner in sessions, exerting the greater influence on the direction of our improvisations (see Fig. 4.2).

The passage shown in Fig. 4.2 occurred during Session 20 of my working with B. The excerpt is around 40 seconds long, and the musical content derives from the children's hymn *Lord of*

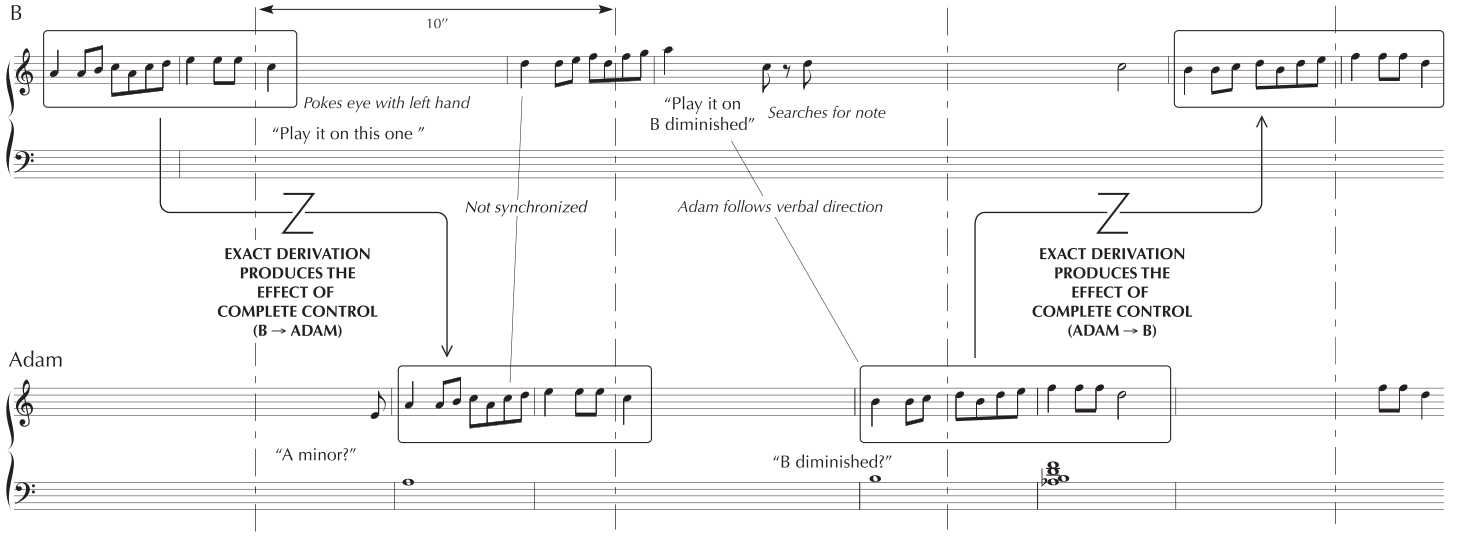


Fig. 4.2 B and Adam improvising on *Lord of the Dance* on two pianos.

the Dance—a preferred source of material for B, with which we would often create extended improvisations together. These would frequently take the form of "conversations" in sound, in which musical fragments would alternate between us, often supplemented with aphoristic verbal contributions from B, describing or dictating the action.

Figure 4.2 shows two occasions when the musical output of one of us is wholly influenced by that of the other. The first occurs when B plays the opening phrase of *Lord of the Dance* in A minor and I imitate what she does exactly, as I sense she intends me to (though for the avoidance of doubt she says "Play it on this one," referring to the key that she has just used). The second takes place as B imitates my rendition of the same motif played on the chord of B diminished. This switch illustrates how the forces of influence functioning within an improvised musical dialog can rapidly change direction with no sense of incongruity.

In the case of total *autonomy*, where A is felt to have no influence on B:

$$\begin{aligned} &\mathrm{A}(\text{♪}) \not\longrightarrow \mathrm{B}(\text{♪}) \\ \Rightarrow\ &\mathrm{B}\ (\text{control}) = 0, \text{ and } \mathrm{B}\ (\text{autonomy}) = 1 \end{aligned} \tag{4.2}$$

A(♪) and B(♪) are not logically connected, and the musical dialog is necessarily incoherent at the point where the complete lack of influence occurs.

Of course, this very disjunction may be what was intended, as was often the case with 8-year-old Romy. Romy is on the autism spectrum, and although she has no expressive language, she evinces exceptional musicality, including AP. Whilst, aged 8, her keyboard technique was at a rudimentary level (she preferred to play with the middle three fingers of her right hand alone, without using her little finger or thumb) she could nonetheless transpose fluently (if, as we shall see later, idiosyncratically) into all keys whatever she heard and was minded to reproduce. Then, as now, Romy exuded an irrepressible passion to engage with music, and she continues to use her musical talents to communicate and socialize with others.

The excerpt shown in Fig. 4.3 is around 45 minutes into an early session with Romy (to be found on the *Sounds of Intent* website <http://www.soundsofintent.org>), and there is no sign yet of any diminution of her frenetic musical energy. I begin to play what I know to be one of her favorite pieces, Beethoven's *Für Elise*, whose opening section was programmed into the first keyboard that she owned. Romy listens and watches intently. I continue playing into the second section of the piece to see how she will react, since her father made me aware that her *new* keyboard included this additional material, and that Romy found it disconcerting, quickly turning the machine off whenever this point was reached. What would she do in the context of a human performer? Would she seek to influence the course of events, and, if so, how?

The answer becomes clear only a few seconds into my rendition of the second section of *Für Elise*. Romy introduces a "rocking" motif, comprising two alternating notes a third apart, which she typically uses to terminate a musical conversation whose drift she does not care for. It means, "Change the subject!" The motif is usually transformed so that it is distinct from what has just occurred or is occurring, tonally and rhythmically. With no sense of derivation from the surrounding material, Romy's rocking patterns are thus completely autonomous in the contexts in which they are introduced; the thread of any musical conversation is lost, and attempts at interaction grind temporarily to a halt.

On this occasion, however, Romy misjudges things, in that the constituents of her alternating figure, A and C, can be heard as deriving from elements of *Für Elise* (that is, resulting from "unintentional" zygonic relationships) and the effect is not as deleterious in musical terms as she would have liked. Romy endeavors to remedy this accidental congruence and exert her authority

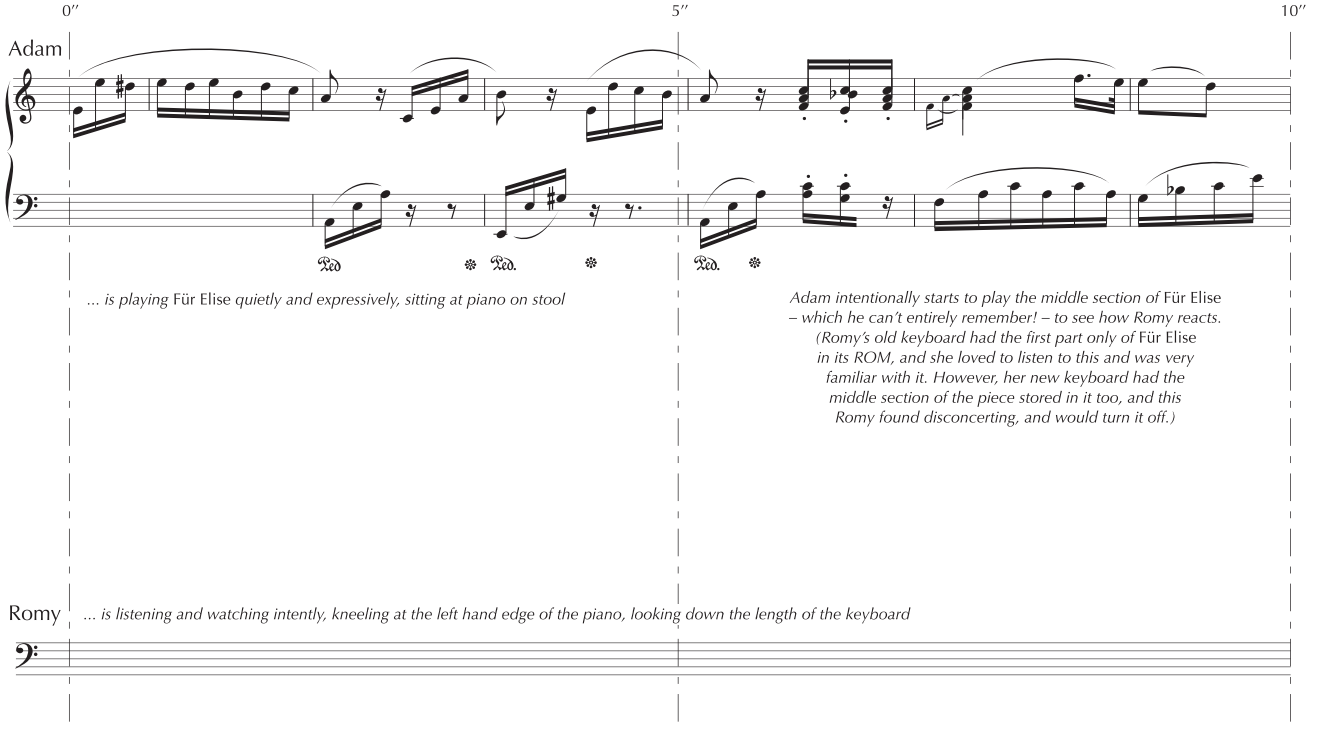


Fig. 4.3 (a)–(c) Romy and Adam interacting on a single piano keyboard, using material from *Für Elise*.

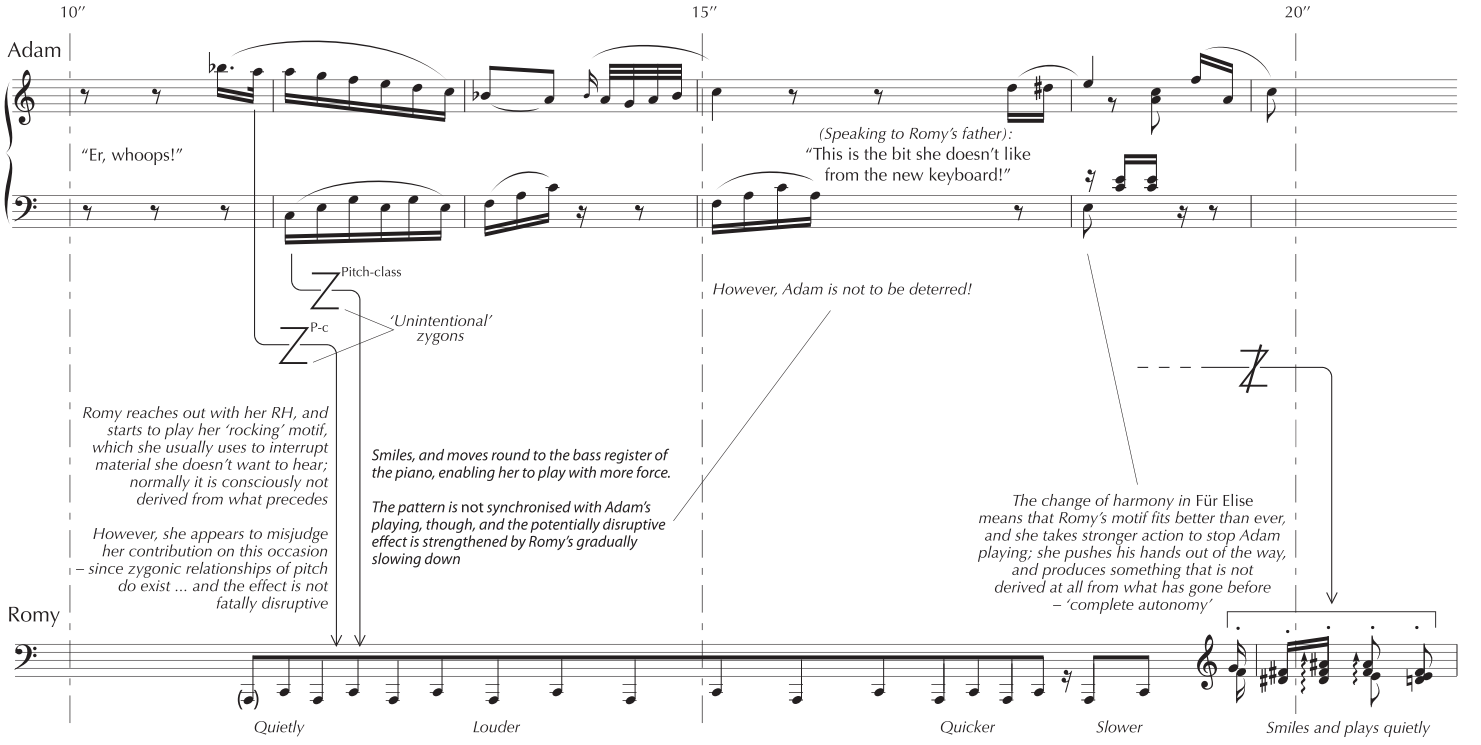


Fig. 4.3 (continued).

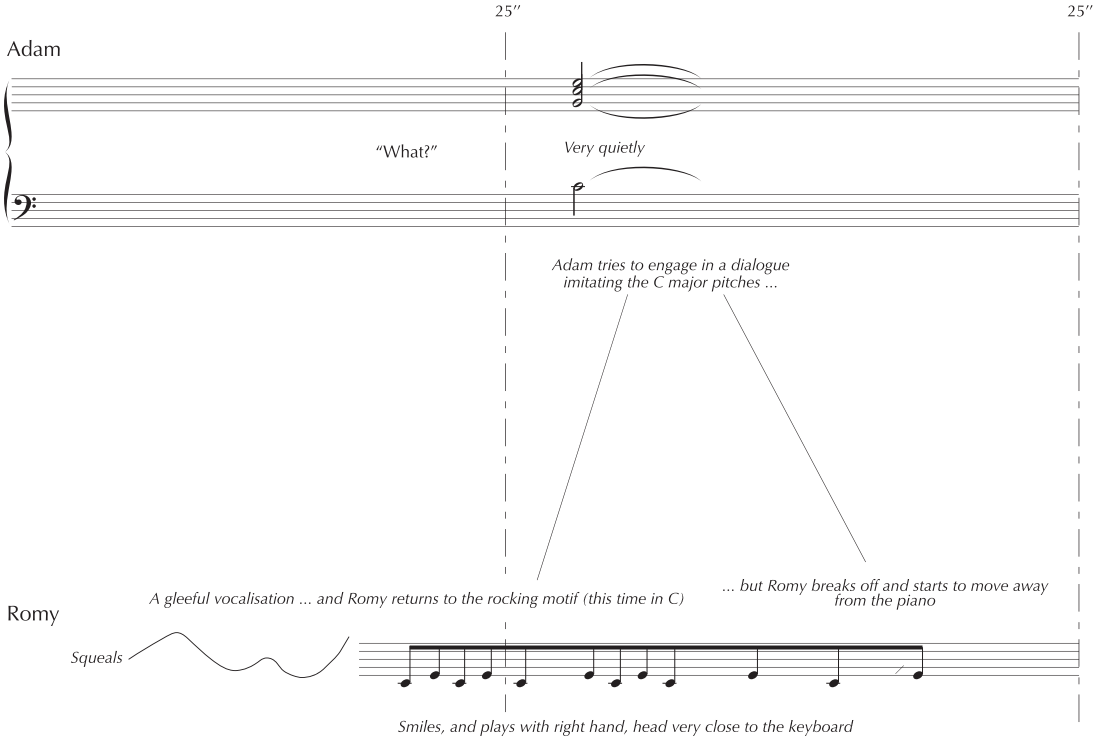


Fig. 4.3 (continued).

by playing more loudly, but this has no effect, and a critical point is reached when *Für Elise* moves back to A minor. Here, Romy's two notes become fully compatible with those used by Beethoven, and her strategy of calculated discord is subverted by harmonic happenstance.

Her efforts at disruption in the domain of pitch having been foiled, Romy abruptly changes tack and modifies the tempo twice in rapid succession as she strives to avoid conformance with, and so unsettle, the regular beat of the Beethoven. This tactic too is ignored. Romy is not to be deterred, however, and she proceeds to take more direct action, pushing my hands off the keyboard with her right elbow, while, through a considerable contortion, simultaneously playing a series of chromatic chords, including D♯ minor (which, tonally, is as far removed from A minor as it is possible to get) with her right hand.

At this point, all logical connections with preceding material are lost: there is no sense of the music I was playing exerting any influence on Romy, and the interaction is momentarily halted. Having succeeded in her aim of terminating the middle section of *Für Elise*, Romy squeals with delight, before setting off once more with her familiar rocking motif, this time on C and E. The intentionality behind her self-influence is clear: "This is me again, and I am in charge." But will she allow me to be influenced by her? As discreetly as possible, I play a C major chord above in an attempt to inveigle myself back into our musical dialog by imitating her (and thus demonstrating I have ceded control), but evidently this was not on Romy's agenda: my advances are spurned, she stops playing and moves (temporarily) away from the piano.

These two excerpts from lessons with B and Romy show just how complicated even a short musical exchange between two people can be, as patterns of influence wax and wane capriciously. However, it is essential for teachers and therapists seeking to gauge a child's capacity to engage in and influence the course of a musical interaction to know the nature and extent of the ebb and flow of autonomy and control. This is by no means straightforward, though. For example, how can one be sure that what appears to be the influence of one participant on another is, in fact, nothing more than the result of repetition occurring by chance? Then, where there are potentially multiple sources of derivation, how is one to assess their relative import? And how far back in a dialog should one go in tracing potential sources of material? Finally, what units of analysis should one choose?

We will deal first with the problem of similar or identical patterns occurring by chance: the other issues will be tackled in the course of the examples that follow.

The matter of chance repetition masking intentionality was tackled at some length in Chapter 3, where an algorithm was developed to mitigate its effects, and this can be used in assessing potential musical *influence* in simple improvised interactions. The extent of Sally's impact on Matthew, for example, in their vocal exchange (see pp. 69–75), is the same as the calculated intentionality with which Matthew was judged to copy her. Similarly, the degree of influence of the group working with Abby (pp. 75–84) is reflected in the intentionality with which she is reckoned to copy the pitches of the melody and play on the beat. In such cases, because each stimulus and response contains a small amount of musical information, the likelihood of repetition occurring randomly is relatively high, and it is essential to factor in probability to the intentionality equation in order to gauge the significance of a person's actions appropriately. Most improvised musical dialogs use more complex musical materials than those taken up by Matthew and Abby, however, and involve clusters of notes forming distinct melodic and rhythmic musical motifs. Here the chances of repetition occurring other than deliberately are vanishingly small, and Formula (4.1) can be used as it stands to provide a metric of influence ranging between complete autonomy and total control. Moreover, as we shall see, the formula can accommodate *reciprocity* of influence.

The case of K

Formula (4.1) was first used in the context of a music assessment I undertook with K, a $4\frac{1}{2}$-year-old who was totally blind due to septo-optic dysplasia, elements of which are reported elsewhere (Ockelford, 2006b, 2007c). Septo-optic dysplasia is a rare condition that occurs in approximately 1 in 16,000 children, and is defined as a combination of optic nerve hypoplasia (absent or small optic nerves), pituitary abnormalities, and the complete or partial absence of the septum pellucidum or the corpus callosum or both (Mehta and Dattani, 2004). Visual impairment is among the likely effects of septo-optic dysplasia, and in K's case her condition resulted in no perception of light.

As part of K's assessment (when it had quickly become evident that she had AP and a great enthusiasm for singing), I invited her to make up a new song about her pet dogs (Jack and Elisha), in which she had expressed a particular interest. I played four chords on the piano (F major, D minor, G minor 9, and C major) with a gentle swing rhythm, and added a simple vocal melody to set the ball rolling. After only two iterations of the sequence, K took the lead and, against the continuing four-chord ostinato, made up a song that utilized a further 15 repetitions of the harmonic pattern, and lasted 90 seconds in all (Fig. 4.4).

As the accompanist, my initial impression of K's efforts was of an unfolding extemporization of persuasive moment-to-moment expressivity within a continuously evolving but largely coherent musical structure. Behind it, evidently, lay an active musical mind capable of creating new material intuitively, quickly, and confidently within a familiar style. But to what extent was K influenced by my accompaniment and opening vocal line, and to what degree was she acting autonomously? One would expect a balance between the two—between coherence and creativity—but, on this occasion, just where did the equilibrium lie? And was the musical "balance of power" more or less constant throughout the song, or did it vary? Conversely, did K influence me, and, if so, to what extent? (My view at the time was that K largely dominated proceedings, and that, following the introduction, my primary role was of follower rather than leader.)

In order to gauge my influence on K, and vice versa, the first methodological decision to be made was what the unit of analysis should be. It was determined that this should be at the level of individual notes, since K's part was not based on a regular phrase structure, which would have made fair comparisons between motivic chunks difficult since these varied in size between single events, as in Phrase 12, and groups of a dozen tones, as in Phrase 3. Each note was assessed in relation to its possible musical sources, which were taken to be:

- *Adam's vocal introduction* (bars 1–4, with notes labelled AV1, AV2, etc.),
- *Adam's piano melody* (the uppermost notes in the right-hand part, identified as AM1, AM2, and so on),
- *Adam's bass part* (AB1, AB2, and so forth), and
- *K's vocal line* (K1, K2, . . .).

(The inner parts in the piano texture were taken into account implicitly through the notion of "harmonic context," as described later.)

For every note, zygonic relationships from those that preceded were considered in relation to:

- pitch,
- melodic interval,
- harmonic context, and
- rhythm.

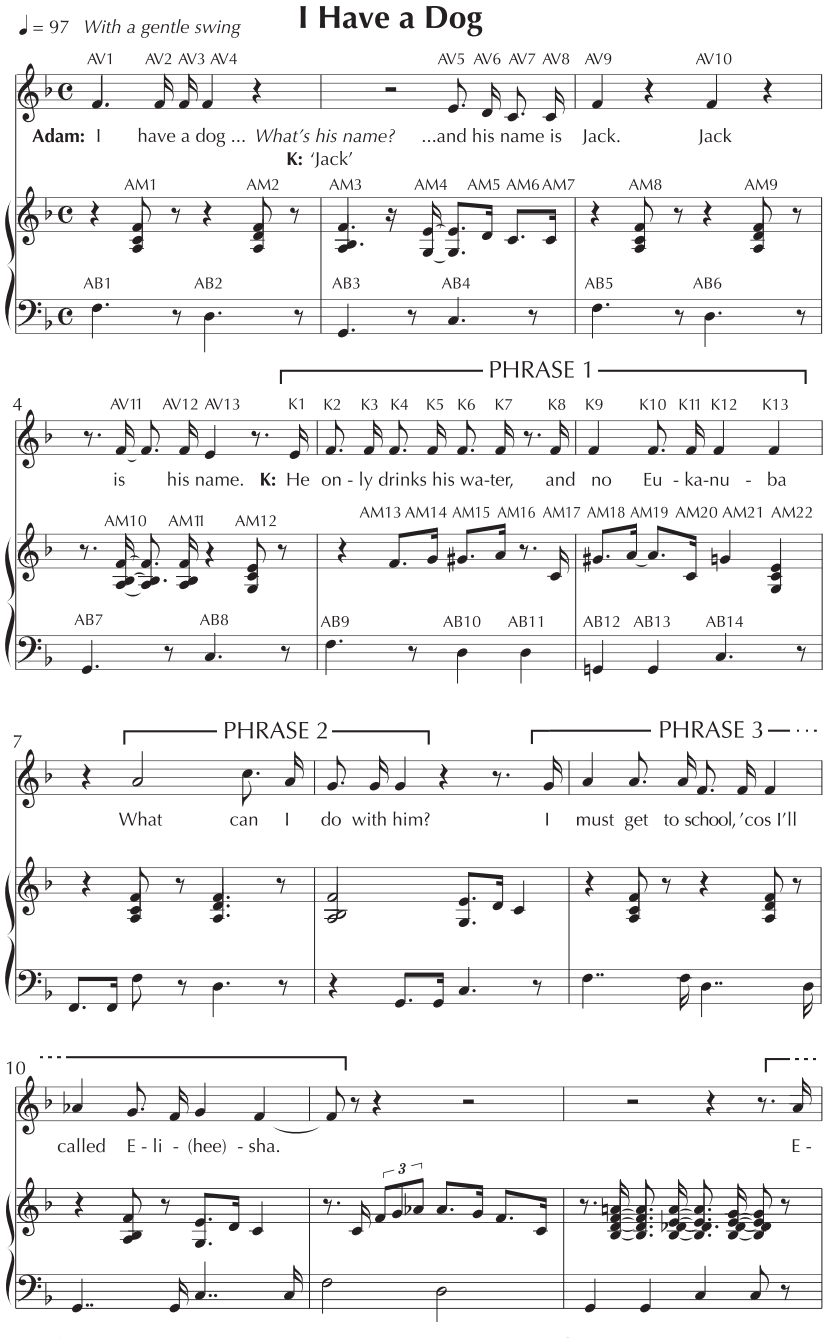



Fig. 4.4 (a)–(c) K improvises a song over a harmonic and rhythmic framework provided.

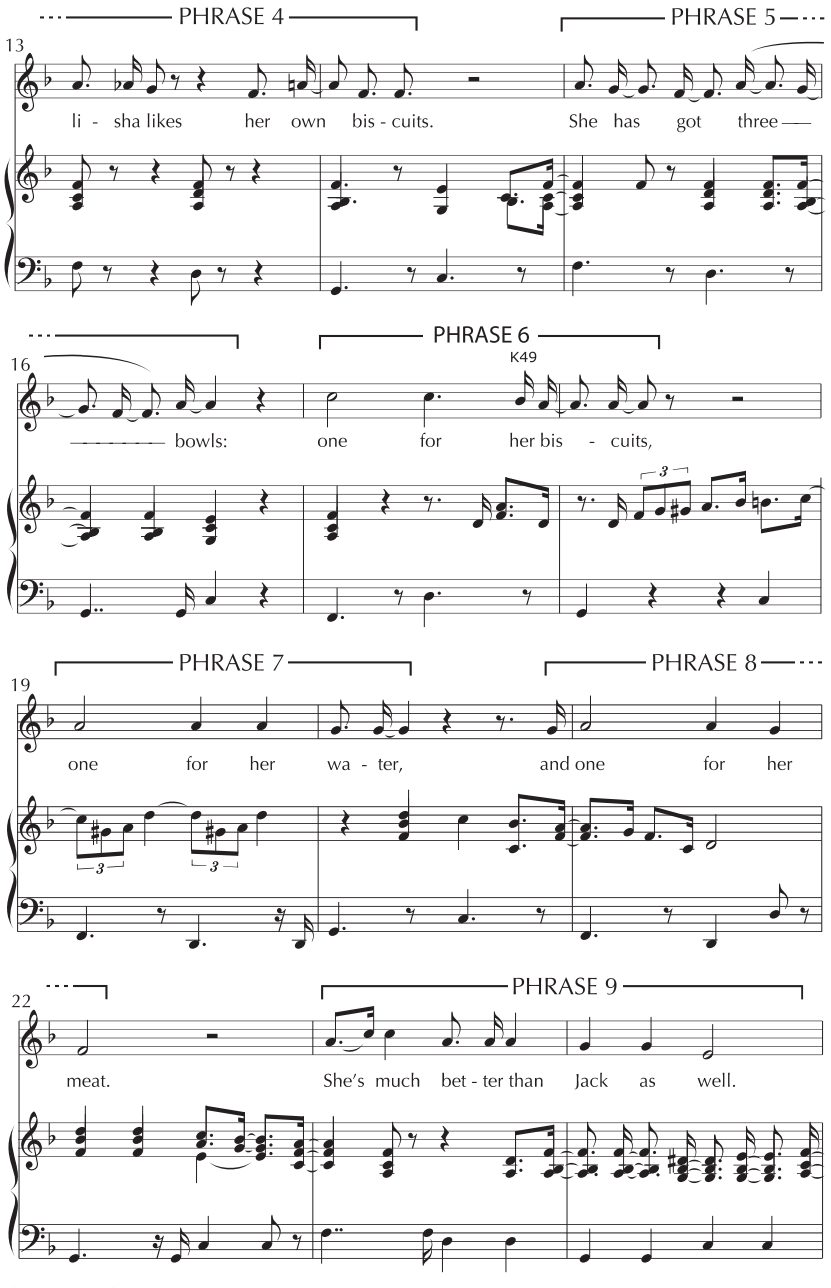



Fig. 4.4 (continued).

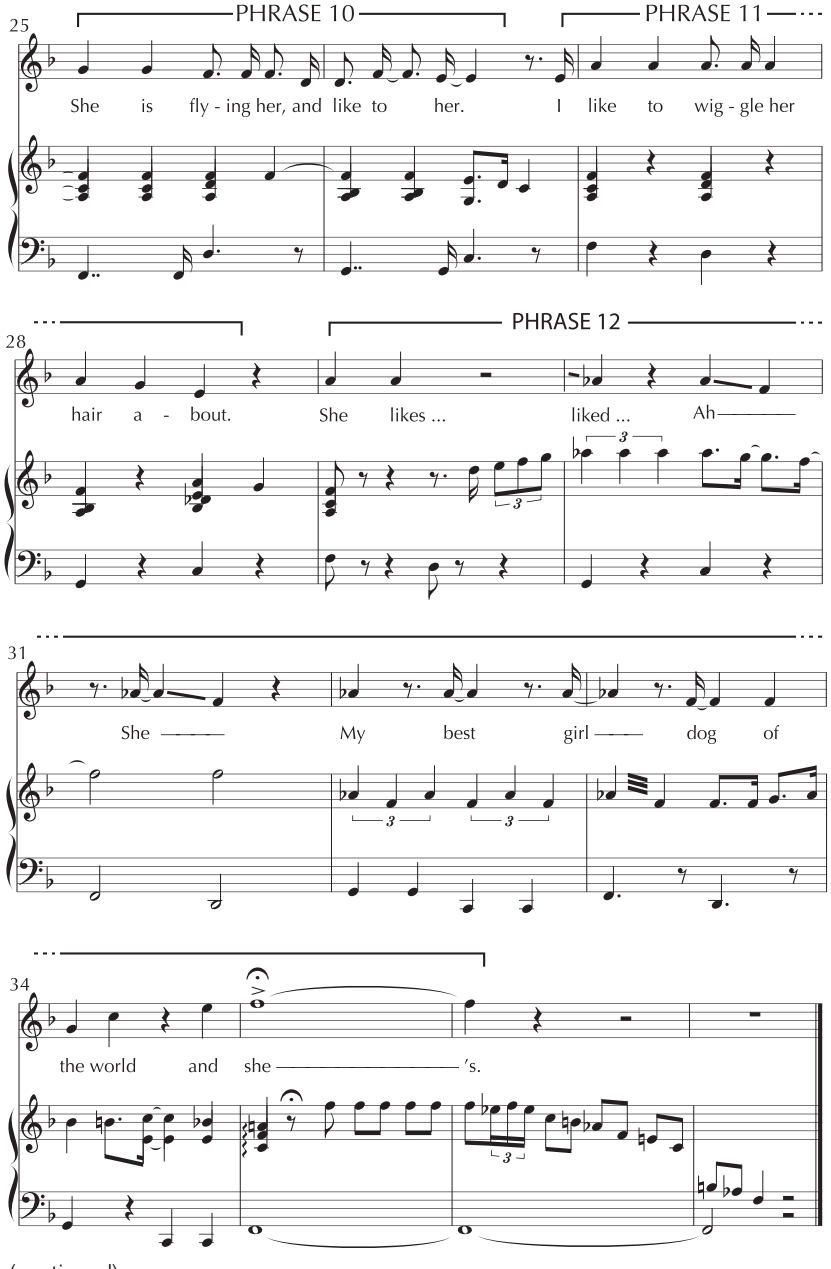



Fig. 4.4 (continued).

These were weighted as follows:

- *pitch* scored 2 for exact repetition, and 1 for the transfer of pitch-class to a different octave;
- *melodic interval* scored 2 for identity, 1.5 for approximate imitation, 1 for inversion or retrogression, and 0.5 for approximate transformations of this type;
- *harmonic context* scored 2 for exact repetition, 1.5 for variation, 1 for transposition and 0.5 for transposed variation; and
- *rhythm* scored 4 for identity, 3 for approximate derivation (including a change of position within the metrical framework), 2 for repetition of duration or inter-onset interval only, and 1 where the sole connection was the variation of duration or inter-onset interval.

The most important thing about these indices is less their absolute values (which, of course, are arbitrary) than their consistent application throughout the analysis.

It was decided that each aspect of every note could be considered to be derived from up to 10 others. Again, this was something of a theoretical leap in the dark, since no data were available to indicate how extensive networks of zygonic relationships might have been in the minds of the performers, and, inevitably, it was something of a simplification too, since each note, irrespective of its position in the musical texture, or tonal or metrical function, was treated the same. However, this very equality of treatment was also a methodological strength, since it ensured a consistency of approach, and meant that fair comparisons could be drawn: in the final analysis, it is the relationship of one score to another that is important rather than any individual value.

Taking into account up to 10 zygonic connections for each aspect of every note meant that a system of weighting was necessary, whereby each "raw" derivation-strength score was modified by a factor based on the theorized salience of the relationship concerned. Since the perceptual salience of musical events is multidimensional and extremely difficult to quantify precisely (Ockelford, 2009b), for this preliminary attempt at analyzing musical influence, one factor only was chosen: sequential adjacency. For example, K's seventh pitch (labelled K7 in Fig. 4.4) could be considered to derive from K6, K5, K4, AM13, K3, K2, AV12, AM11, AV11, and AM10—the order determined by their temporal adjacency to K7 (see Fig. 4.5).

A further pragmatic decision was made to separate each of the factors that were used to moderate the raw scores by a common difference (implying a linear decrease in the strength of their zygonic influence), and normalize them such that the sum of the factors pertaining to a given feature of a particular note was invariably 1. In this case, with 10 factors required, the values used to modify the raw derivation scores were 0.182, 0.164, 0.145, 0.127, 0.109, 0.091, 0.073, 0.055, 0.036, and 0.018, respectively (separated by a common difference of 0.018).

The result of applying these proportions to the raw scores was a series of "derivation indices." The indices for each feature were summed separately in relation to the material improvised by K and me (A). The total potential derivation index for each note ranged between 0 and 10 from either of the two sources, K or A. With regard to the event K7, the subtotals pertaining to K- and A-derived material are shown in Table 4.1: pitch has a derivation index of 0.62 from A and 1.38 from K; melodic interval, 0.33 from A and 1.67 from K; harmonic context, 1.34 from A and 0.67 from K; and rhythm, 1.62 from A and 2.14 from K. This yields a total derivation index of 3.91 from my material, equivalent to 39%—a measure of the *control* I exert at this point. The derivation index from K's own material is 5.85. Given the maximum total derivation index of 10, the sum of these two figures (9.76) leaves a residue of 0.24, reflecting aspects of K7 that cannot be accounted for through derivation from other material in the song. Hence K's musical *autonomy* in producing the event in question (K7) is judged to be just under 61% (since $5.85 + 0.24 = 6.09$).

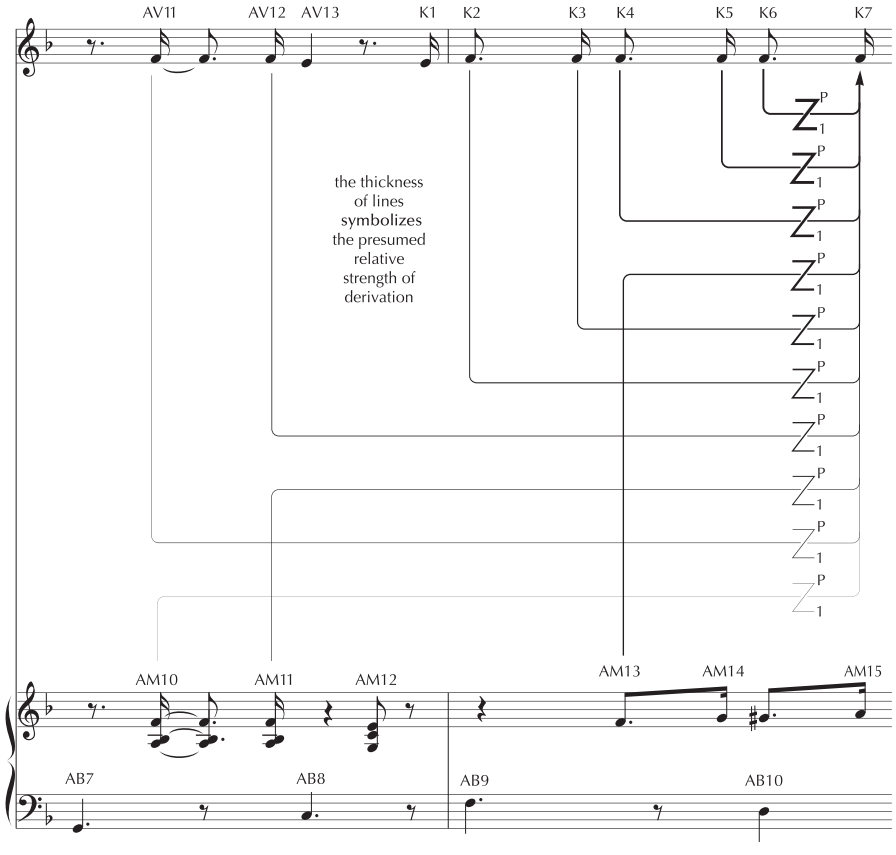


Fig. 4.5 The potential derivation of note "K7" from some of those that precede.

Table 4.1 Quantitative assumptions pertaining to the derivation of note "K7" from others

Pitch									
Derived from A					**Derived from K**				
event number	*relative position*	*raw score*	*weight factor*	*derivation index*	*event number*	*relative position*	*raw score*	*weight factor*	*derivation index*
AM13	4	2	0.13	0.25	K6	1	2	0.18	0.36
AV12	7	2	0.07	0.15	K5	2	2	0.16	0.33
AM11	8	2	0.06	0.11	K4	3	2	0.15	0.29
AV11	9	2	0.04	0.07	K3	5	2	0.11	0.22
AM10	10	2	0.02	0.04	K2	6	2	0.09	0.18
Totals	**5**	**10**	**0.31**	**0.62**	**Totals**	**5**	**10**	**0.69**	**1.38**

Table 4.1 (continued) Quantitative assumptions pertaining to the derivation of note "K7" from others

Interval

Derived from A					**Derived from K**				
event number	*relative position*	*raw score*	*weight factor*	*derivation index*	*event number*	*relative position*	*raw score*	*weight factor*	*derivation index*
AM12	6	2	0.08	0.17	K6	1	2	0.22	0.44
AV12	7	2	0.06	0.11	K5	2	2	0.19	0.39
AM11	8	2	0.03	0.06	K4	3	2	0.17	0.33
					K3	4	2	0.14	0.28
					K1	5	2	0.11	0.22
Totals	**3**	**6**	**0.17**	**0.33**	**Totals**	**5**	**10**	**0.83**	**1.67**

Harmonic context

Derived from A					**Derived from K**				
event number	*relative position*	*raw score*	*weight factor*	*derivation index*	*event number*	*relative position*	*raw score*	*weight factor*	*derivation index*
AM9	2		0.27	0.53	K6	1	2	0.33	0.67
AV10	3	2	0.20	0.40					
AM2	4	2	0.13	0.27					
AV4	5	2	0.07	0.13					
Totals	**4**	**8**	**0.67**	**1.34**	**Totals**	**1**	**2**	**0.33**	**0.67**

Rhythm

Derived from A					**Derived from K**				
event number	*relative position*	*raw score*	*weight factor*	*derivation index*	*event number*	*relative position*	*raw score*	*weight factor*	*derivation index*
AV12	4	3	0.13	0.40	K5	4	1	0.20	0.80
AM11	5	3	0.11	0.33	K3	4	2	0.18	0.71
AV8	6	4	0.09	0.36	K1	4	3	0.16	0.62
AM7	7	4	0.07	0.27					
AV6	8	4	0.04	0.18					
AM5	9	4	0.02	0.09					
Totals	**6**	**22**	**0.47**	**1.62**	**Totals**	**12**	**3**	**0.53**	**2.14**

Totals

autonomy	***control***
5.85 + 0.24 = **6.09**	**3.91**

Table 4.2 Average derivation indices for *I Have a Dog*

	A			**K**		
	Material generated from			Material generated from		
	A	original	K	K	original	A
Sum: derivation indices	1827.04	453.36	329.60	522.77	147.63	369.59
Number of events		261			104	
Average derivation index	7.00	1.26	1.74	1.42	5.03	3.55
	Autonomy		**Control by K**	**Autonomy**		**Control by K**
	83%		**17%**	**65%**		**35%**

The usefulness of these figures in interpreting the relationship between K's and my contributions lies principally in the ratios between them, taken either as averages over a given period or in terms of event-by-event patterns of variation. For example, the derivation indices for the piece as a whole are given in Table 4.2, suggesting that 87% of my production was autonomous (being generated from other of my material in the piece or from elsewhere), with only 13% controlled by K. In contrast, 65% of K's melody is autonomous, with approximately 35% controlled by me: a somewhat sobering statistic for a music educator who at the time felt that he was providing a responsive foil for K's efforts, when, in fact, zygonic analysis indicates that the flow of musical influence was greater from teacher to pupil than vice versa to a degree that is statistically highly significant: $t(363) = 14.04$, $P < 0.0001$.

The derivation indices also enable us to track how the influence of one performer on another varied over time. For example, during K's first phrase (notes K1–K13), the derivation index from my material falls from 9.48 to 0.93, a trend which closely matches a linear descent ($R^2 = 0.82$), the principal exceptions being K9 and K10, where K introduces a rhythmic pattern similar to one used in my introduction (see Fig. 4.6). This decline in my influence on K through the phrase seems to reflect her growing self-assertion and, as one would expect, is matched inversely by an increasing use of her own improvisation to generate further ideas. At the same time, K's use of original material fluctuates at a low level (see Fig. 4.7).

Subsequent phrases show different patterns of influence that cannot be reported in detail here. However, the mean derivation indices pertaining to phrases will be used to give an overview of patterns of influence vary at a deeper structural level. These show K drawing significantly on my material in her first phrase, less so in the second, and more again in the third and the fourth (Fig. 4.8). Subsequently, there is a gradual decrease in my influence over phrases five to nine—the central part of K's improvisation with the descending sequence at its heart—during which her efforts become ever more self-sufficient. In contrast, I influence K's 10th phrase more strongly. Here, a lack of verbal coherence suggests that K may be flagging. Indeed, after rallying briefly in the 11th phrase, K's creative flow almost completely dries up at the beginning of the 12th, and she draws heavily on material in the accompaniment to sustain her vocal line (although in the concluding notes she finally wrests back the initiative). The global pattern of my influence on K, invariably lower than her influence on me, is inversely related to it with a striking consistency [using Formulae (3.10) and (3.11), inverse repetition = 0.82, $P < 0.03$]. That is to say, during

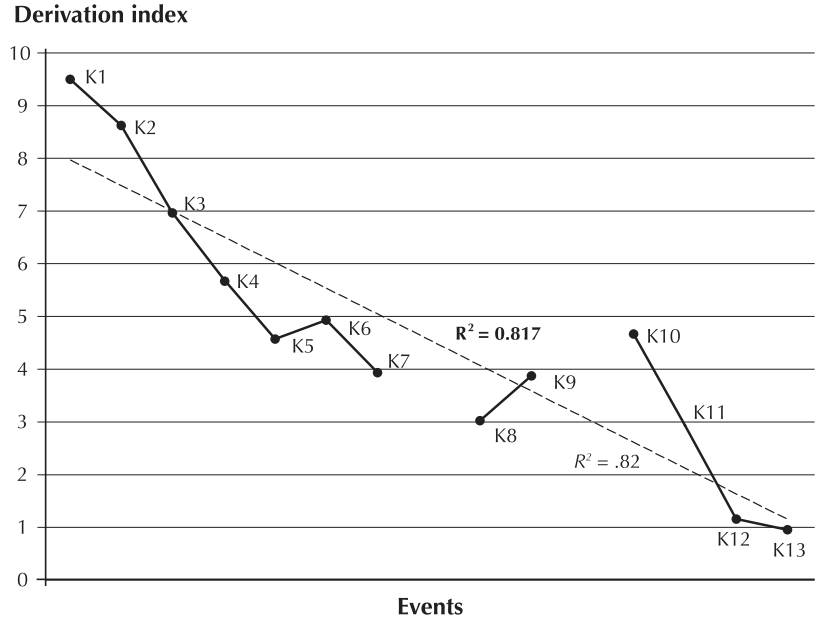
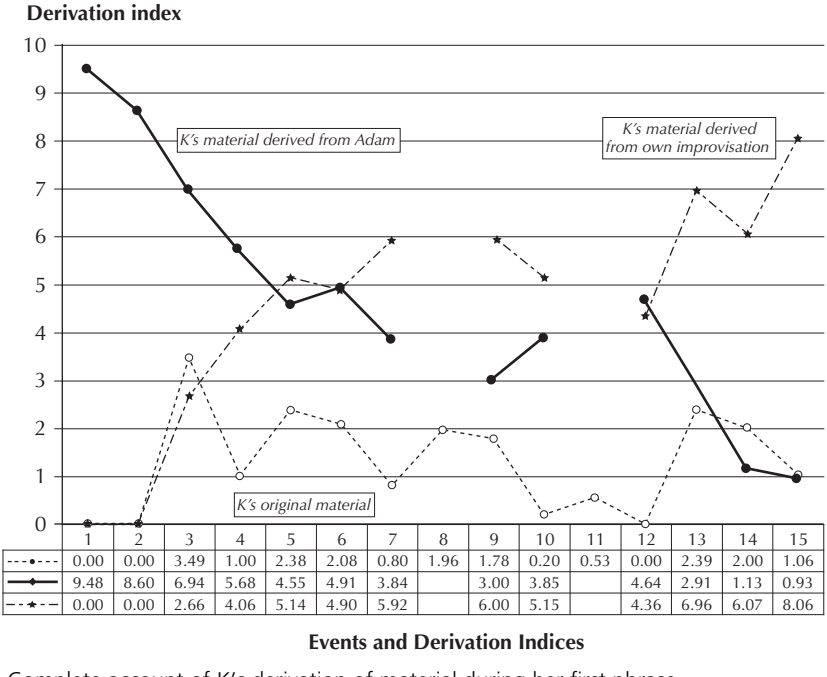


Fig. 4.6 K's diminishing derivation of material from Adam during her first phrase.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
---•---	0.00	0.00	3.49	1.00	2.38	2.08	0.80	1.96	1.78	0.20	0.53	0.00	2.39	2.00	1.06
——♦——	9.48	8.60	6.94	5.68	4.55	4.91	3.84		3.00	3.85		4.64	2.91	1.13	0.93
– – ★ – –	0.00	0.00	2.66	4.06	5.14	4.90	5.92		6.00	5.15		4.36	6.96	6.07	8.06

Fig. 4.7 Complete account of K's derivation of material during her first phrase.

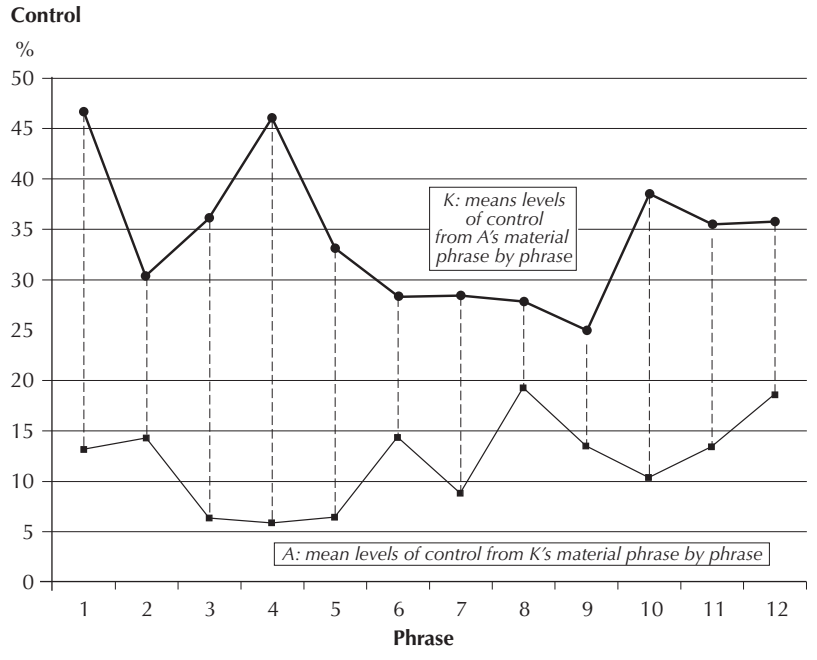


Fig. 4.8 The changing patterns of influence between K and Adam in *I Have a Dog*.

the improvisation, as K chose to rely less on me for material, I tended to rely more on K, and vice versa—perhaps through an intuitive desire on the part of one performer or both to ensure coherence by balancing autonomy and control in the improvised texture as a whole.

Analysis such as this potentially presents practitioners with a precise and powerful tool for gauging how patterns of influence, control, and autonomy function in their musical activities with children, and, even more importantly, perhaps, may enable them to plan future music activities with distinct types and levels of interaction in mind. So, for example, if it were felt that a child would benefit through exerting more control in one-to-one improvisation sessions, then different strategies could be tested using a simplified version of the music-analytical technique set out here, in order to ascertain which were most effective in enabling the pupil concerned to influence the course of the musical dialogs.

Gauging influence in group improvisation

The principle of gauging musical influence between those participating in simultaneous improvisation using zygonic theory was extended to *groups* of performers by Kagari Shibazaki, a doctoral student of mine at the Applied Music Research Centre, University of Roehampton (Shibazaki, 2010; Shibazaki *et al.*, under review). Shibazaki undertook a cross-cultural study of Japanese and English schoolchildren in the upper primary phase (ages 9–11). Three schools from each country took part. Working in a total of 18 groups, each comprising four to seven children, 89 pupils were set the task of creating an original piece of music based on predetermined images such as "a journey into space" or "spring." Class percussion instruments, pitched and non-pitched (such as cabasas, rainsticks, maracas, castanets, bells, cymbals, triangles, snare drums, bongos, agogos,

xylophones, and glockenspiels) and keyboards were available to the children to make a selection. Participants in each group worked together for three or four lessons of 45 minutes to plan their piece, before performing it for the rest of the class. Pieces lasted on average 2 minutes, the shortest being 20 seconds and the longest 4 minutes.

Shibazaki was interested to know how the members of each group influenced each other musically, particularly with respect to the two dimensions of autonomy and control identified above: that is, to what extent did pupils imitate each other's musical contributions, and to what extent was their output derived through self-imitation? In particular, did the ratio of group-influence to self-influence vary systematically between the two countries (Japan and England), perhaps reflecting their different (predominantly collectivist and individualist) cultures (Oyserman *et al.*, 2002), with contrasting notions of interdependent as opposed to independent selfhood (Markus and Kitayama, 1991). That is, would the English children tend to display greater autonomy in their playing, with more reliance on individuality, while the Japanese might perhaps be more inclined to allow themselves to be influenced by peers through the more frequent exchange of ideas (cf. Baaren *et al.*, 2003)? Shibazaki wanted to know too how patterns of musical influence compared with the *verbal* interaction that went on during the planning and rehearsal phase: in other words, were those who had taken the lead in spoken exchanges likely to be the musical leaders too?

Although these queries concerning musical influence probe essentially the same issue as that investigated by Ockelford in relation to his session with K described earlier, they differ in certain important respects. As her research questions show, Shibazaki's interest was not in the subtle changes of influence as they occurred, note by note, in the course of an improvisation, but in gauging the impact of one participant on another in pieces taken as a whole. Hence a different algorithm was used: one that considered what proportion of the total number of musical events produced by a child were derived (1) from his or her own material and (2) from each of the other children in the group. Each judgment had a binary outcome ("yes" or "no"), although events could conceivably have two sources of derivation or more.

In mathematical terms, the influence of A on B, $I^{nf}(A \rightarrow B)$, is given by the amount of control A exerts on B, divided by the amount of control A exerts on B plus B's autonomy. That is:

$$I^{nf}(A \rightarrow B) = \frac{B(\text{control by A})}{B(\text{control by A}) + B(\text{autonomy})} \tag{4.3}$$

Substituting from Formula (4.1) gives:

$$I^{nf} = \frac{A(\text{♪}) \text{—}Z\text{⟶} B(\text{♪})}{A(\text{♪}) \text{—}Z\text{⟶} B(\text{♪}) + A'(\text{♪}) \text{—}\cancel{(Z)}\text{⟶} B(\text{♪})} \tag{4.4}$$

In relation to *self*-influence, the formula becomes:

$$I^{nf} = \frac{A(\text{♪}) \text{—}Z\text{⟶} A(\text{♪})}{A(\text{♪}) \text{—}Z\text{⟶} A(\text{♪}) + A'(\text{♪}) \text{—}\cancel{(Z)}\text{⟶} A(\text{♪})} \tag{4.5}$$

To see how these formulae and the zygonic principle of musical influence work in practice, consider the piece called *Fuga in Red* (Fig. 4.9) produced by four children—two boys and two girls—as part of Shibazaki's study (reproduced from Shibazaki *et al.*, under review).

The self-influence of Girl 1

Girl 1 opens the *Fuga* with a rocking figure on the xylophone. It would be possible to evaluate this (and much of the other music in Shibazaki's study) in relation to a number of musical features. However, four were chosen that were deemed to be the most consistently salient:

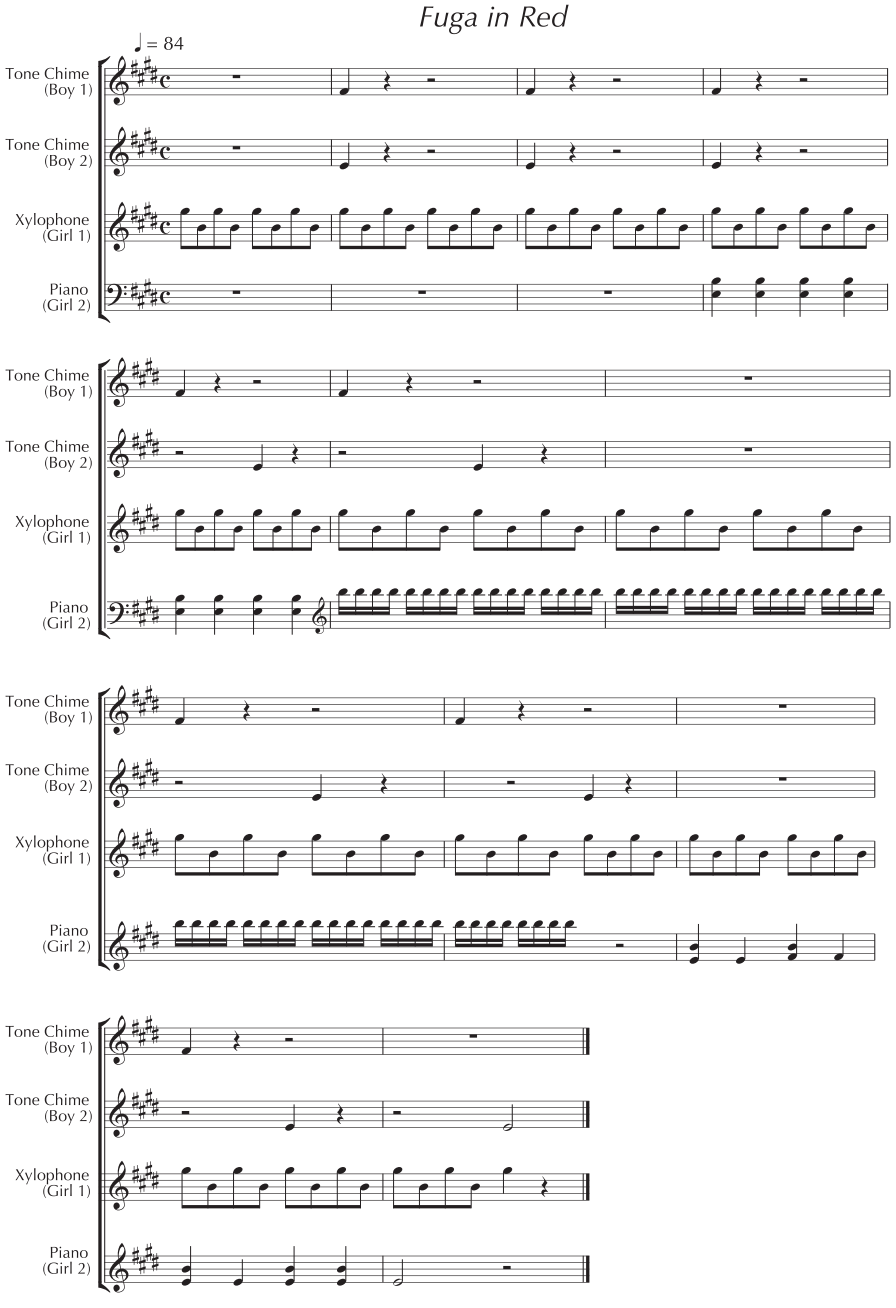



Fig. 4.9 Transcription of *Fuga in Red*.

- pitch
- melodic/harmonic interval
- duration
- inter-onset interval.

In relation to bar 1, using Formula (4.5), the self-influence of Girl 1 can be calculated as follows (see Fig. 4.10), yielding a mean index of

$$\frac{0.88 + 0.79 + 0.88 + 0.86}{4} = 0.85.$$

(Observe that the second melodic interval is deemed to exist in imitation of the first through the repetition of magnitude but not polarity through an "inverse" secondary zygon of pitch. In terms of influence, this is deemed to count 0.5; cf. Ockelford, 2012a.)

Extending these analytic principles to Girl 1's part as a whole yields indices of musical self-influence as follows:

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 1} \mid \text{pitch}) = \frac{91}{91 + 2} = 0.98$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 1} \mid \text{melodic/harmonic interval}) = \frac{90}{90 + 2} = 0.98$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 1} \mid \text{duration}) = \frac{91}{91 + 2} = 0.98$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 1} \mid \text{inter-onset interval}) = \frac{91}{91 + 2} = 0.99.$$

The mean self-influence across the four perceived aspects ("perspects") of sound is:

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 1}) = \frac{0.98 + 0.98 + 0.98 + 0.99}{4} = 0.98.$$

This figure reflects the highly repetitive nature of Girl 1's contribution.

The self-influence of Boys 1 and 2

Boys 1 and 2 enter at the beginning of bar 2. The nature of their self-influence is as follows. In terms of pitch, each boy has only one available (respectively F♯ and E) through their choice of tone-chime. Is it fair to say, therefore, that self-imitation is in play here, since, having selected an instrument with a single pitch, repetition was inevitable? For two reasons, one could argue that it is reasonable to think that the repeated pitches were intended to be heard as deriving from one another through imitation. First, they occur in the context of other parts that exhibit pitch differences as well as repetition, and the sense of imitation that one hears in these strands arguably transfers to the texture as a whole. Second, the boys could have chosen to play two tone chimes or more had they wished to incorporate greater variety in their contributions, and the fact that the pitches were predetermined does not preclude a sense of imitation within the performance. Hence primary zygons of pitch can be considered to function as shown in Fig. 4.11. And since the pitches in each part are identical, the melodic intervals between notes (unisons) are the same too and, through the same reasoning, can be regarded as functioning imitatively.

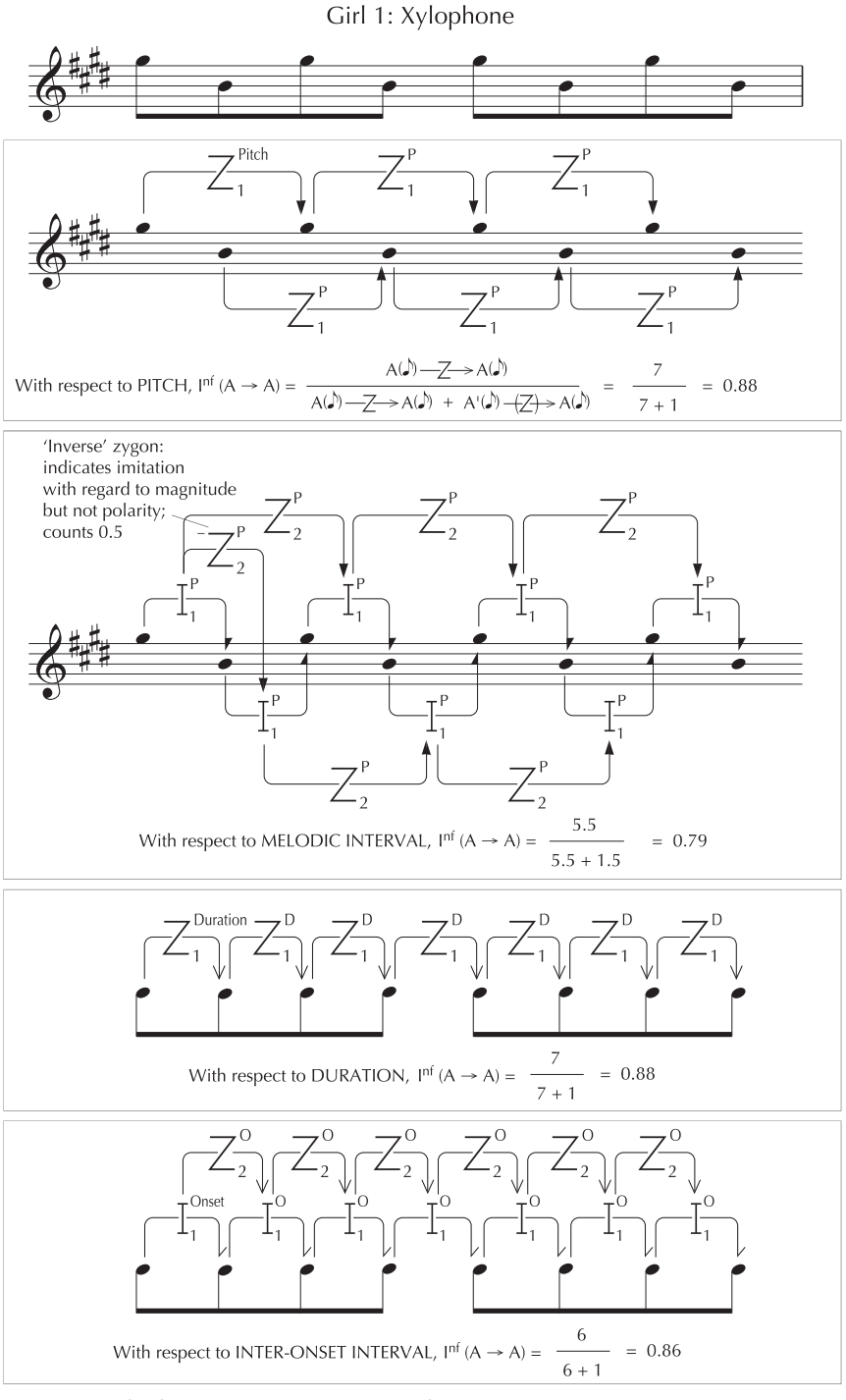


Fig. 4.10 Girl 1: self-influence in the opening bar of *Fuga in Red*.

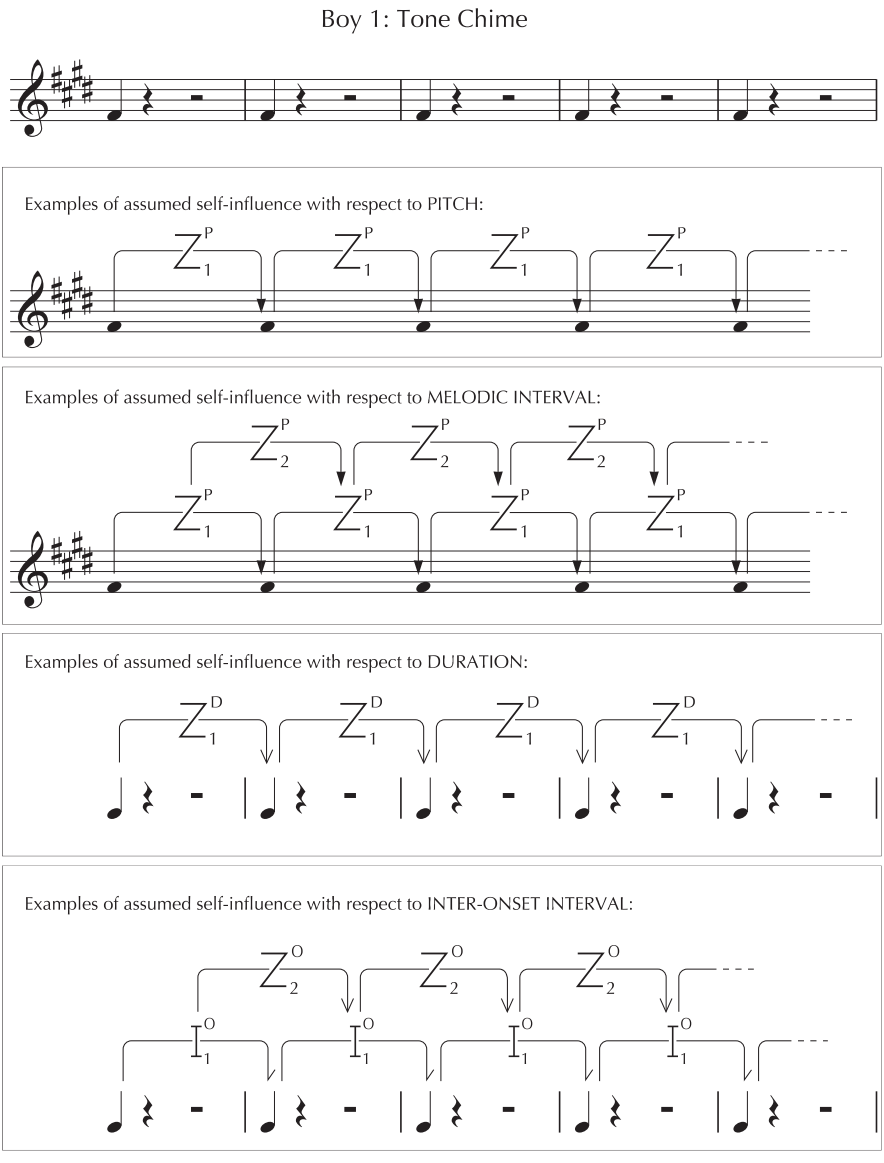


Fig. 4.11 Boys 1 and 2: examples of self-influence assumed to function in the opening bar of *Fuga in Red*.

With regard to duration, again the interpretation of intent is not entirely straightforward. Although the notes on the tone-chimes resonated throughout the bars in which they occurred, extra-musical information indicates that the boys were actually conceiving these as "1, rest, rest, rest," each equating to a quarter note on the first beat of a $\frac{4}{4}$ bar. Hence their transcription as notes a single beat in length, and the understanding (shown in Fig. 4.11) of durational imitation. In contrast, the last note of Boy 2's part was defined as a half note by his saying "3, 4" and then stopping. The inter-onset intervals are unambiguous.

Using the analysis shown in Fig. 4.11, the mean index of self-influence of Boy 1 is

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 1} \rightarrow \text{Boy 1}) = \frac{0.88 + 0.86 + 0.88 + 0.71}{4} = 0.83$$

and that of Boy 2 is

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 2}) = \frac{0.89 + 0.88 + 0.88 + 0.63}{4} = 0.79.$$

The self-influence of Girl 2

Girl 2 enters last, at the beginning of bar 4, playing E3 and B3 together. A zygonic analysis of self-influence is shown in Fig. 4.12. Note that where a pitch has the same letter-name (or "pitch-class", see the case of K discussed earlier) but appears in a different octave, a zygonic relationship between them is judged to have 50% of the derivational strength of a zygon between identical pitches (see Ockelford, 2012a).

Girl 2's mean index of self-influence is

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 2} \rightarrow \text{Girl 2}) = \frac{0.95 + 0.95 + 0.97 + 0.96}{4} = 0.96.$$

Again, her contribution is highly repetitive.

We now move on to consider influence by another (Formula 4.4), since each of the four children potentially has an impact on each of his or her three peers, there are 12 relationships to consider.

The influence of Girl 1 on Boy 1

Here the pitches in each part are different, so there can be no question of one having an impact on the other. In terms of melodic intervals, however, one or more of the unisons in Girl 1's part can be considered to influence Boy 1's use of repeated pitches (see previous comments). The effect is weak, however, and serves only to *establish* the pattern of repetition used by Boy 1, which then appears to be self-sustaining. In the perceived temporal domain, Girl 1's playing does not influence Boy 1 with respect to duration, and there is only a tenuous connection of inter-onset interval, which works in a similar way to the relationships between pitches identified above: the four-beat gap utilized by Boy 1 is present in Girl 1's part, though indirectly and, once established, Boy 1's temporal patterning appears to be maintained through self-influence (see Fig. 4.13).

These interpretations can be quantified as follows:

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 1} \mid \text{pitch}) = \frac{0}{8} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 1} \mid \text{melodic/harmonic interval}) = \frac{1}{1+6} = 0.14$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 1} \mid \text{duration}) = \frac{0}{8} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 1} \mid \text{inter-onset interval}) = \frac{1}{1+6} = 0.14$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 1}) = \frac{0.00 + 0.14 + 0.00 + 0.14}{4} = 0.07.$$

This figure confirms the intuition that the impact of Girl 1's playing on Boy 1 is minimal.

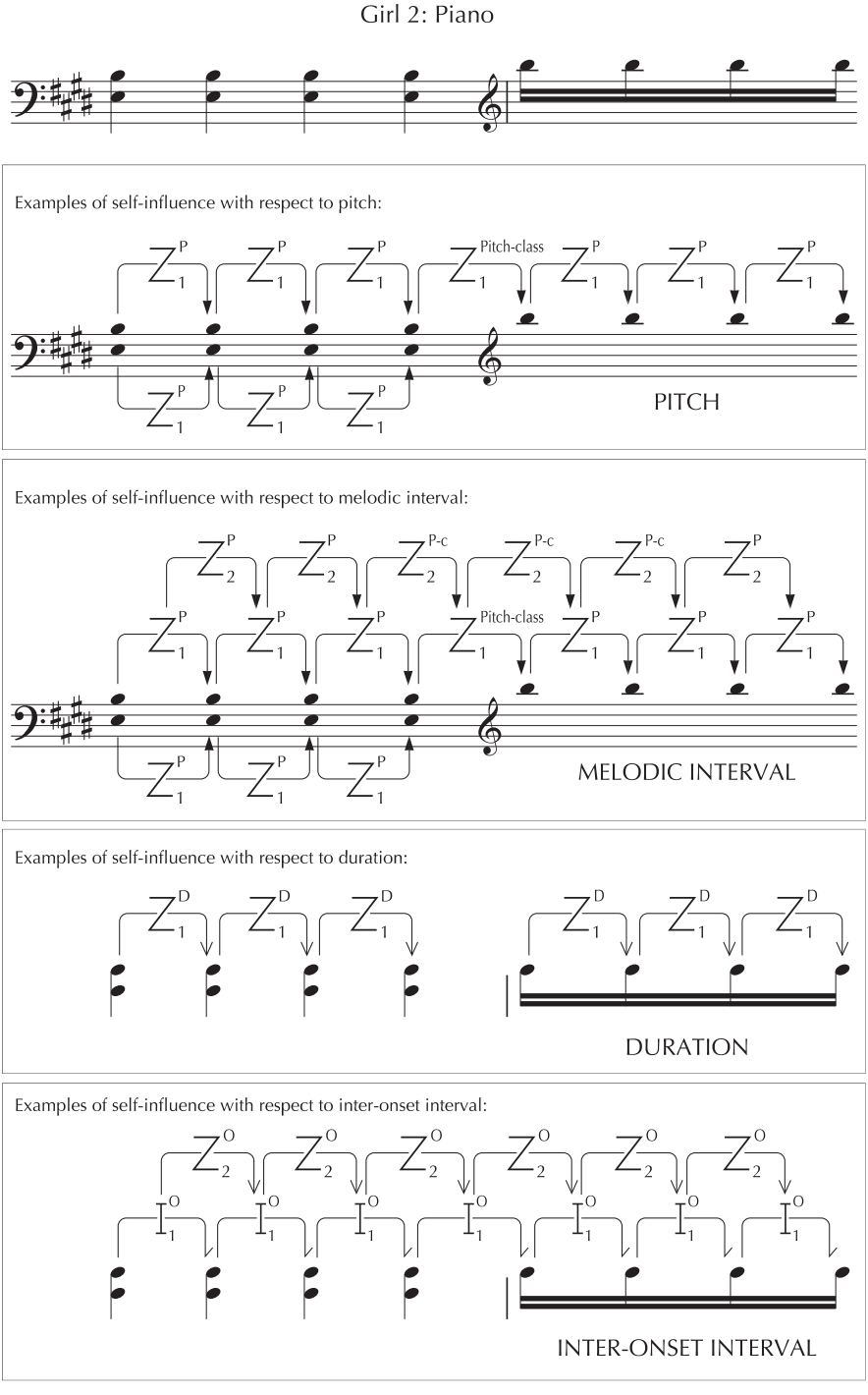


Fig. 4.12 Girl 2: self-influence assumed to function in bars 5 and 6 of *Fuga in Red*.

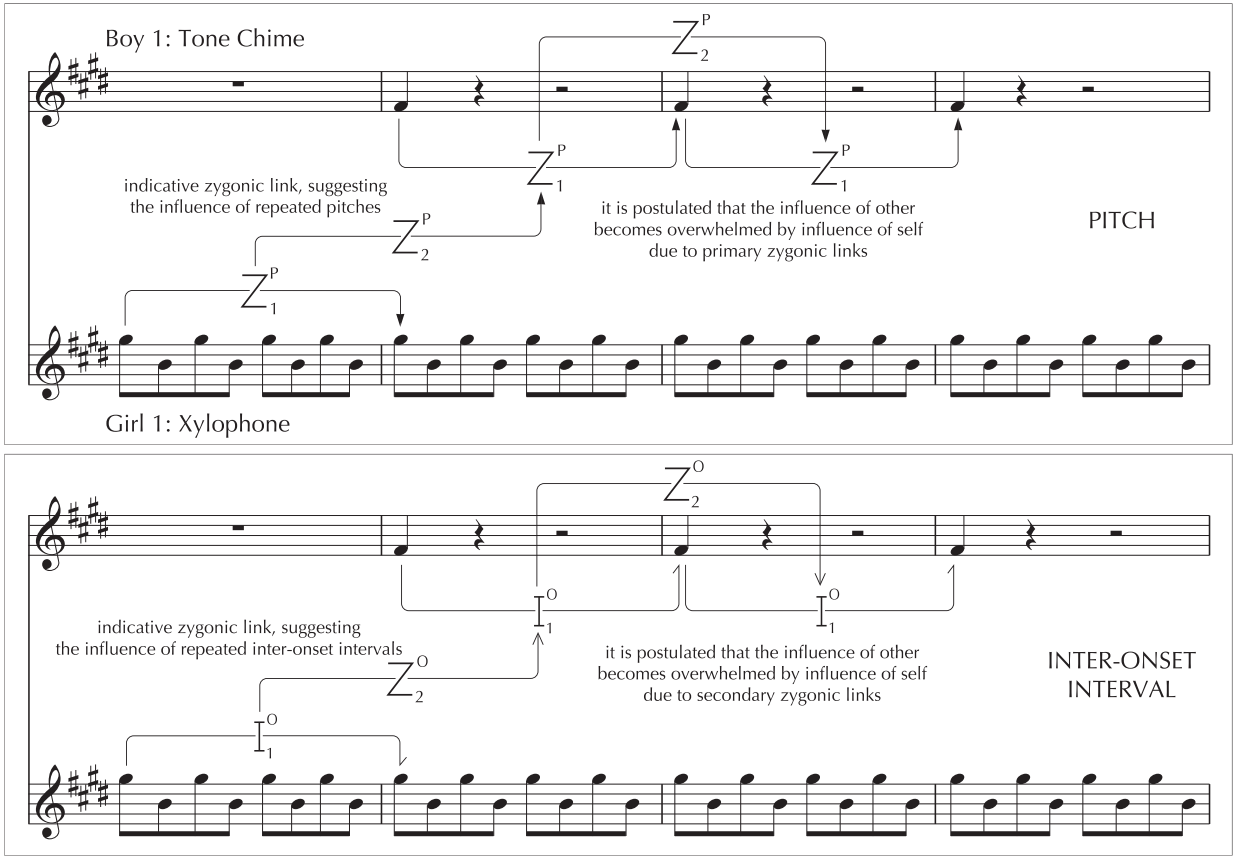


Fig. 4.13 Examples of postulated influence of Girl 1 on Boy 1.

The influence of Girl 1 on Boy 2

The position in relation to Boy 2 is very similar:

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 2} \mid \text{pitch}) = \frac{0}{9} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 2} \mid \text{melodic/harmonic interval}) = \frac{1}{1+7} = 0.13$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 2} \mid \text{duration}) = \frac{0}{9} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 2} \mid \text{inter-onset interval}) = \frac{1}{1+7} = 0.13.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Boy 2}) = \frac{0.00 + 0.13 + 0.00 + 0.13}{4} = 0.06.$$

Again, it is apparent that the effect of Girl 1's playing on Boy 2 is minimal.

The influence of Girl 1 on Girl 2

In terms of pitch, zygonic analysis suggests that Girl 1 influences Girl 2 through imitation of pitch-class on three occasions (at the beginning of bars 4, 6, and 10), as shown in Fig. 4.14. Here, again, the effect is weak, and, it is postulated, only serves to establish one of the pitches used by Girl 2, which is then self-sustaining through repetition. Similarly, the reiteration of pitches in Girl 1's part can be considered to influence Girl 2's contribution on three occasions (again, in bars 4, 6, and 10), the first of which is illustrated. There is no imitation of durations. Four inter-onset intervals are potentially derived through imitation, however (see, once more, bars 4, 6, and 10). Again, the first is illustrated in Fig. 4.14.

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 2} \mid \text{pitch}) = \frac{1.5}{1.5 + 84.5} = 0.02$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 2} \mid \text{melodic/harmonic interval}) = \frac{3}{3+80} = 0.04$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 2} \mid \text{duration}) = \frac{0}{86} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 2} \mid \text{inter-onset interval}) = \frac{3}{4+79} = 0.05.$$

The mean influence (across all four perspects) is:

$$\mathrm{I}^{\mathrm{nf}}(\text{Girl 1} \rightarrow \text{Girl 2}) = \frac{0.00 + 0.13 + 0.00 + 0.13}{4} = 0.03.$$

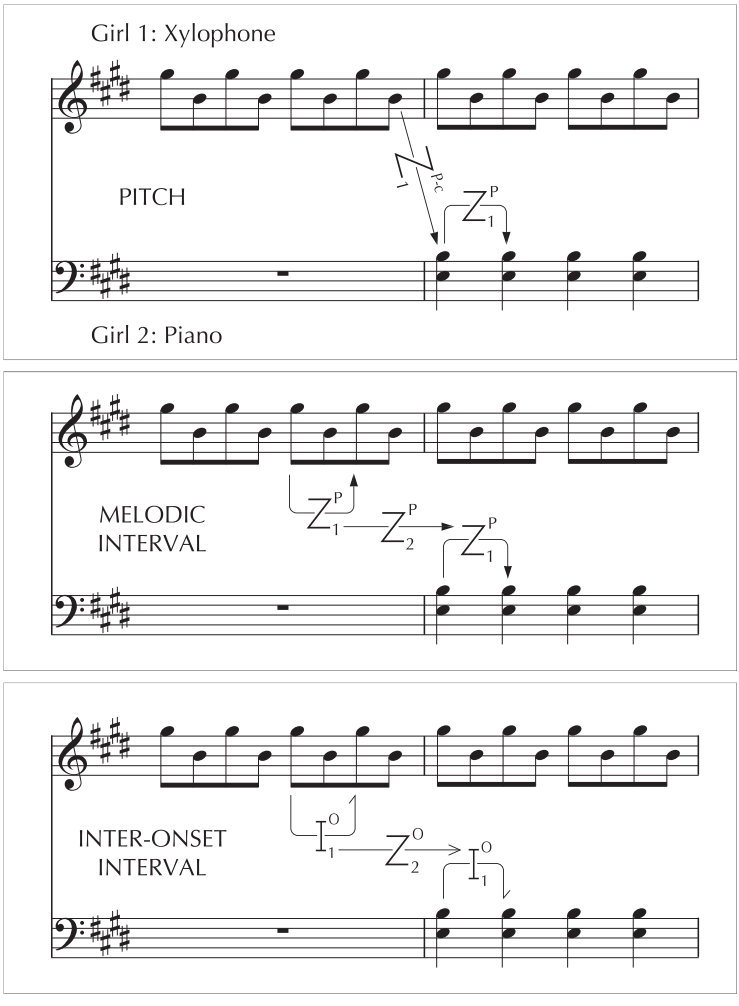



Fig. 4.14 Examples of postulated influence of Girl 1 on Girl 2.

The influence of Boy 1 on Boy 2

The two parts have no pitches in common, so one cannot be considered to influence the other. With regard to melodic intervals, though, it is conceivable that the repetition in one line derives, at least in part, from that in the other (see Fig. 4.15). Again, the effect is slight, however, and could only be considered to play a part in establishing the pattern of repetition used by Boy 2, which is subsequently self-sustaining. Similarly, in the perceived temporal domain, Boy 1 could be considered to influence the duration of Boy 2's second note (an impact that, as we shall see, is potentially mutual), and the inter-onset interval between notes 2 and 3. There are more clear-cut connections between the durations of notes 4, 5, 6, 7, and 8 in each part, as Boy 2 consistently follows Boy 1, and a similar position exists in relation to the inter-onset intervals between notes 4 and 5 of both boys' parts, and notes 6 and 7.

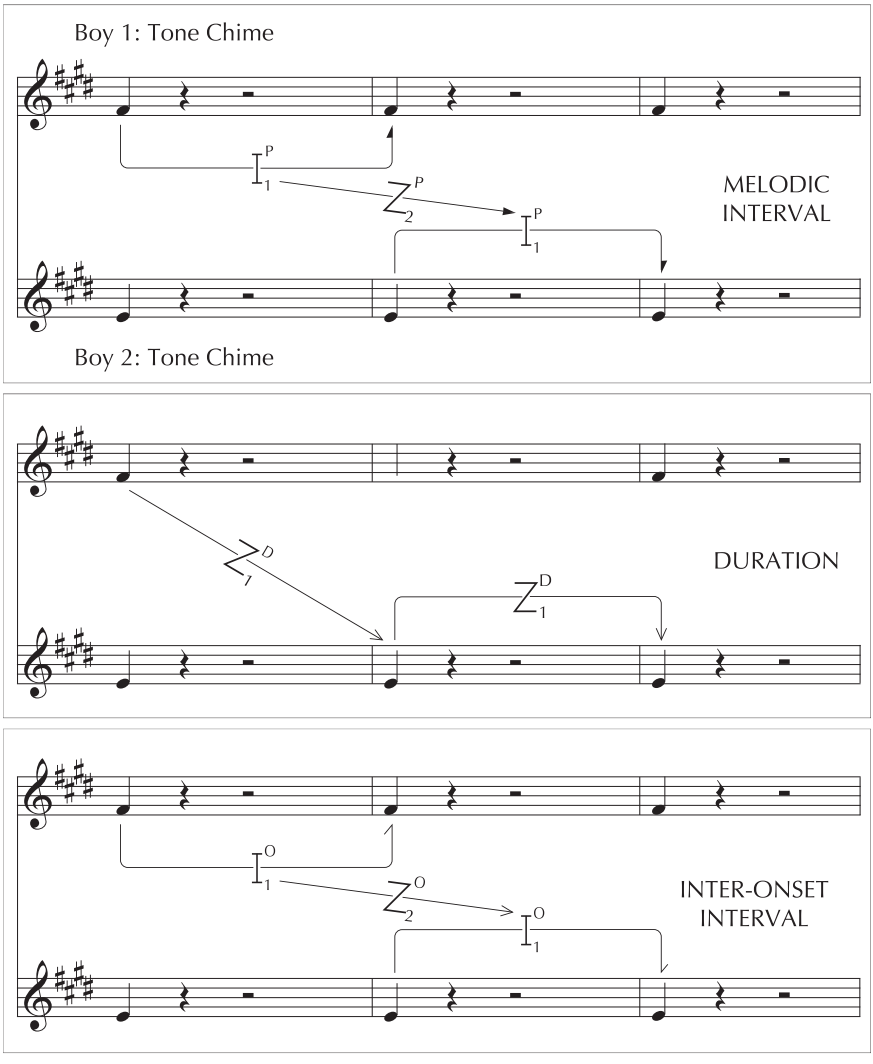


Fig. 4.15 Examples of postulated influence of Boy 1 on Boy 2.

This analysis can be quantified thus:

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 1} \rightarrow \text{Boy 2} \mid \text{pitch}) = \frac{0}{9} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 1} \rightarrow \text{Boy 2} \mid \text{melodic/harmonic interval}) = \frac{1}{1+7} = 0.13$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 1} \rightarrow \text{Boy 2} \mid \text{duration}) = \frac{6}{6+3} = 0.67$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 1} \rightarrow \text{Boy 2} \mid \text{inter-onset interval}) = \frac{3}{3+5} = 0.38.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Boy\,2}) = \frac{0.00 + 0.13 + 0.67 + 0.38}{4} = 0.29.$$

The influence of Boy 1 on Girl 1

Although some similarities exist in relation to melodic and inter-onset intervals (see the previous discussion), as Boy 1 enters after Girl 1 there is no sense of influence of the former on the latter. Hence,

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,1}) = 0.00.$$

The influence of Boy 1 on Girl 2

Here, there appears to be no influence in the domain of pitch, since the parts have no pitches in common, and one does not get a sense that the repetition found in Girl 2's part derives from Boy 1. It is conceivable that duration is imitated (though see my previous comments as to the extent that Boy 1's durations as notated were conceptual rather than perceptual in nature) (see Fig. 4.16). There are no inter-onset intervals in common, however.

Hence, influence in quantitative terms can be deemed to exist as follows:

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,2} \mid \mathrm{pitch}) = \frac{0}{86} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,2} \mid \mathrm{melodic/harmonic\ interval}) = \frac{0}{83} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,2} \mid \mathrm{duration}) = \frac{1}{1 + 85} = 0.01$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,2} \mid \mathrm{inter\text{-}onset\ interval}) = \frac{0}{83} = 0.00.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Boy\,1} \rightarrow \mathrm{Girl\,2}) = 0.00.$$

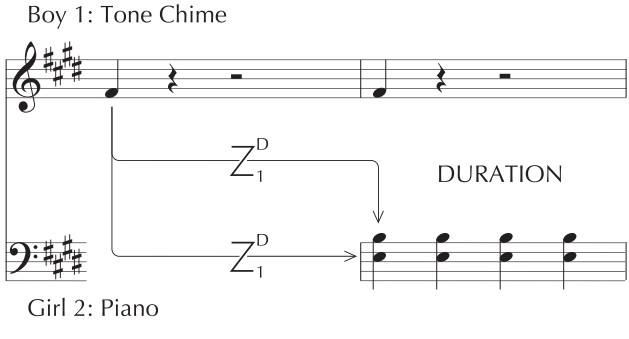


Fig. 4.16 Examples of postulated influence of Boy 1 on Girl 2.

The influence of Boy 2 on Boy 1

Initially, the impact here is the same as that pertaining to Boy 1 in relation to Boy 2 as already discussed, though from bar 5 the mutuality of influence ends as Boy 2 consistently follows Boy 1. This is reflected in quantitative terms as follows:

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 1} \mid \text{pitch}) = \frac{0}{9} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 1} \mid \text{melodic/harmonic interval}) = \frac{1}{1+7} = 0.13$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 1} \mid \text{duration}) = \frac{1}{1+8} = 0.11$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 1} \mid \text{inter-onset interval}) = \frac{1}{1+7} = 0.13.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Boy 1}) = \frac{0.00 + 0.13 + 0.11 + 0.13}{4} = 0.09.$$

The influence of Boy 2 on Girl 1

As is the case with Boy 1 and Girl 1, although there are some similarities pertaining to melodic and inter-onset intervals, as Boy 2 begins to play after Girl 1, there is not a sense of influence of the former on the latter:

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 1}) = 0.00.$$

The influence of Boy 2 on Girl 2

There appears to be limited initial influence in the domain of pitch, and in bars 9 and 10 possible imitation of melodic interval (see Fig. 4.17). It is conceivable too that duration is replicated on two occasions (though see the previous comments in relation to Boy 1's influence on Girl 2). There are no inter-onset intervals in common, however, and hence no sense of influence in this domain.

Quantitatively, the position can be summarized as follows:

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 2} \mid \text{pitch}) = \frac{2}{2+84} = 0.02$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 2} \mid \text{melodic/harmoni interval}) = \frac{1}{1+82} = 0.01$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 2} \mid \text{duration}) = \frac{2}{2+84} = 0.02$$

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 2} \mid \text{inter-onset interval}) = \frac{0}{83} = 0.00.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\text{Boy 2} \rightarrow \text{Girl 2}) = \frac{0.02 + 0.01 + 0.02 + 0.00}{4} = 0.01.$$

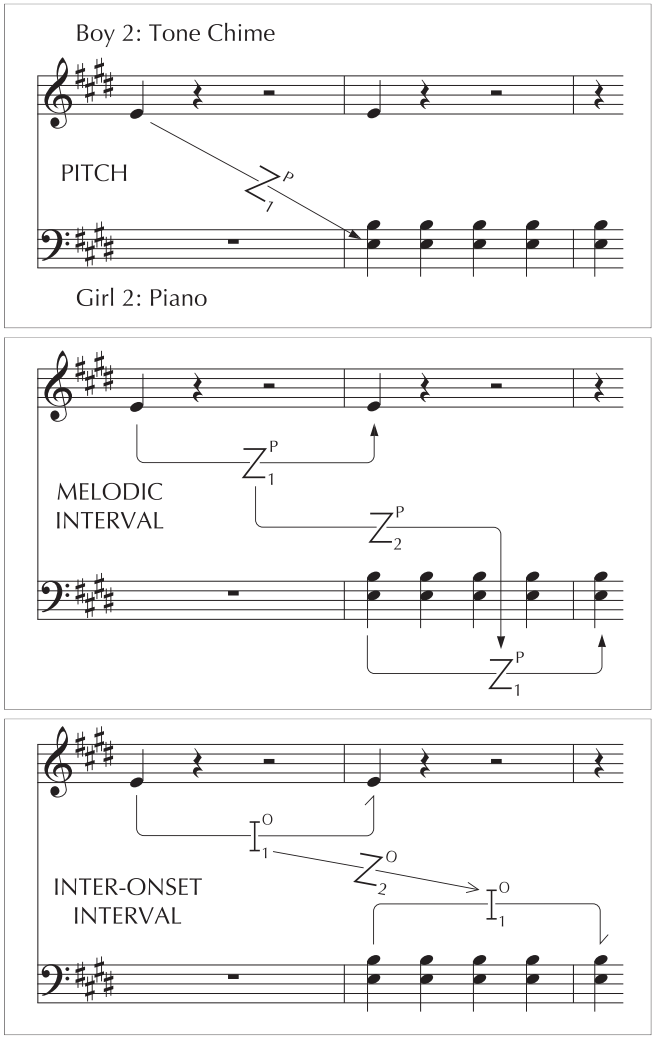


Fig. 4.17 Examples of postulated influence of Boy 2 on Girl 2.

The influence of Girl 2 on Boy 1

Here, there is no sense of influence in the domains of pitch or perceived time. Hence

$$\mathrm{I}^{\mathrm{nf}}\,(\mathrm{Girl}\,2 \rightarrow \mathrm{Boy}\,1) = 0.00.$$

The influence of Girl 2 on Boy 2

Here the only potential influence appears to be between the final notes of each part in terms of pitch and duration (see Fig. 4.18).

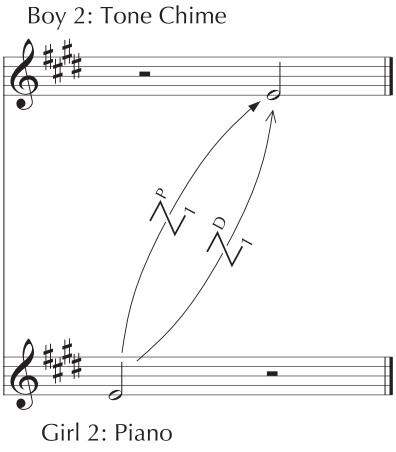


Fig. 4.18 The postulated influence of Girl 2 on Boy 2.

Quantitatively, this yields the following data:

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Boy\,2} \mid \mathrm{pitch}) = \frac{1}{1+8} = 0.11$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Boy\,2} \mid \mathrm{melodic/harmonic\ interval}) = \frac{0}{8} = 0.00$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Boy\,2} \mid \mathrm{duration}) = \frac{1}{1+8} = 0.11$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Boy\,2} \mid \mathrm{inter\text{-}onset\ interval}) = \frac{0}{8} = 0.00.$$

The mean influence (across all four perspects) is

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Boy\,2}) = \frac{0.00 + 0.11 + 0.00 + 0.11}{4} = 0.06.$$

The influence of Girl 2 on Girl 1

Here, there is no sense of influence in play. Hence

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{Girl\,2} \rightarrow \mathrm{Girl\,1}) = 0.00.$$

Summary of interactions

The data for all these interactions are summarized in Table 4.3. The most striking feature is the marked difference between patterns of self-influence and influence by other members of the group. The means are as follows:

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{A}) = \frac{0.83 + 0.79 + 0.98 + 0.96}{4} = 0.89$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{B}) = \frac{0.29 + 0.00 + 0.00 + 0.09 + 0.00 + 0.01 + 0.07 + 0.06 + 0.03 + 0.00 + 0.06 + 0.00}{12} = 0.05.$$

Table 4.3 Degrees of musical influence postulated to be functioning in *Fuga in Red*

influences → / is influenced by ←	Boy 1	Boy 2	Girl 1	Girl 2	**Means**
Boy 1	0.83	0.29	0.01	0.00	**0.28**
Boy 2	0.09	0.79	0.00	0.01	**0.22**
Girl 1	0.07	0.06	0.98	0.03	**0.29**
Girl 2	0.00	0.06	0.00	0.96	**0.26**
Means	**0.25**	**0.30**	**0.25**	**0.25**	**0.26**

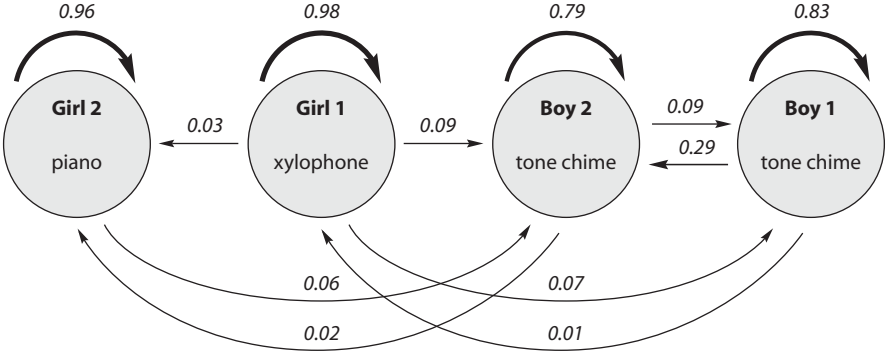


Fig. 4.19 Visual representation of the degrees of musical influence postulated to be functioning in *Fuga in Red*.

Individual differences are apparent too: for example, the most powerful influence of one child on another is Boy 1 on Boy 2, whereas Girl 1 is not influenced by anyone other than herself. These trends and differences are represented visually in Fig. 4.19, where the relative seating positions of the children are reproduced, and the thickness of the lines equates to the degree of influence (cf. Huron, 2006, p. 160; Ockelford, 2006, p. 108).

Combining data from all 18 groups (nine in England and nine in Japan) casts a fascinating light on Shibazaki's research questions. Her first concern pertained to autonomy and control: to what extent did pupils influence one another through imitating each other's musical contributions, and to what extent were their contributions formulated through self-influence? The results are as follows:

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{A}) : n = 88, M = 0.86,\ SD = 0.10$$

$$\mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{B}) : n = 362, M = 0.03,\ SD = 0.05.$$

The difference between the two is significant: $t(448) = 107.24$, $\mathrm{P} < 0.0001$. In summary, pupils' material was around 30 times more likely to be derived through self-influence than as a result of the influence of others.

Turning to Shibazaki's next question: did this tendency differ between the two countries? In terms of self-influence, the results are as follows:

$$\text{England}: \mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{A}): n = 46, M = 0.84,\ SD = 0.11$$

$$\text{Japan}: \mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{A}): n = 42, M = 0.90,\ SD = 0.09.$$

Again, the difference between the two is significant: $t(86) = 3.14$, $P = 0.002$. In Japan, around 7% more of pupil's material was derived through self-imitation than in England. This suggests that the musical contributions of English children tended to show greater internal heterogeneity (while those produced by Japanese pupils were more homogeneous).

In relation to "influence by others," analysis of Shibazaki's data yields the following:

$$\text{England}: \mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{B}): n = 198, M = 0.025,\ SD = 0.047$$

$$\text{Japan}: \mathrm{I}^{\mathrm{nf}}(\mathrm{A} \rightarrow \mathrm{B}): n = 164, M = 0.040,\ SD = 0.058.$$

The difference between the two is significant: $t(360) = 2.59$, $P = 0.009$. That is to say, although both figures are low, the Japanese pupils were influenced by each other's musical ideas a little over 50% more than the English, supporting Shibazaki's postulation that the children in a collectivist culture would evince greater interdependence than those where individualism is valued. This is a striking finding, in which purely musical analysis of individual human interactions lends to support to macro-social constructs.

In her doctoral study, Shibazaki also analyzed children's verbal interaction in the preparation of their pieces. It will be of particular interest to music teachers and music-education researchers to note that even though in each group one pupil tended to dominate discussion, on many occasions this child did not exert most influence *musically*. That is, there was no necessary relationship between verbal and musical leadership. Moreover, while some children did not contribute to group discussions, they nonetheless exerted significant levels of *musical* influence. This underlines the danger of relying on verbal data as a proxy measure of musical engagement and interaction—and reinforces the thesis set out in this book, that music analysis should play a far greater role in much music education, therapy, and psychology research.

Influence through shared musical knowledge

The exchanges with B and Romy discussed earlier exemplified scenarios that are ubiquitous in improvised musical interactions: influence occurring through a *shared knowledge* of given material. Consider again the session with Romy. Let us rewind to the time shortly before the lesson begins. I am waiting in the music room for her, having decided to *initiate* the interaction when she arrives (thereby departing from the normal course of events, in which she dictates what will happen by playing the opening phrase of a piece). Moments later, the door opens, and as Romy runs over to the piano, I play the first line of a piece with which I know she will be familiar. I can't resist giving the music's nose a tweak, though, to see how Romy will react, and I add an ornamental eighth note to the penultimate tone (Fig. 4.20).

From what happens next, it becomes evident that Romy immediately recognizes the melody, the fact that I played it in C major (she has absolute pitch), and the modification to the end of the phrase. But more than this, she appreciates its function as a greeting, and the potential start to an interaction. Pushing me out of the way, she gleefully responds with the second phrase of

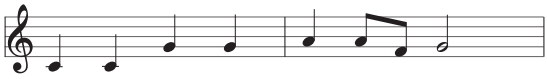



Fig. 4.20 Adam's opening gambit in a music session with Romy.

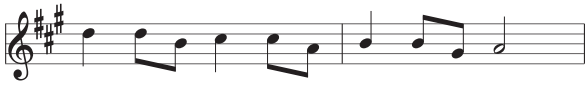



Fig. 4.21 Romy's counter.

Twinkle, Twinkle, but realized in a different key (A major), and with my embellishment adorning every pair of notes (Fig. 4.21). Hence in 4 or 5 seconds of abstract sound production, she manages to acknowledge my presence by allowing herself to be influenced by what I had done, yet through her own wit and imagination trumps what I produced and assumes control. Hence a new musical dialog kicks off; a shared string of sounds. But how did this happen: how did the influence and the transfer of control work, given direct imitation was limited?

Consider the position once more. We can assume that my decision to play the opening of *Twinkle, Twinkle* stimulated in my mind a cognitive representation of the requisite melodic and inter-onset intervals, which I reified starting on C4 and at a tempo of ♪ = 96. We can further suppose that hearing these notes caused Romy to activate a comparable mental model, from which she derived the information necessary to play the second phrase (although, as we know, she consciously opted to use a different tonal centre, namely A major). Hence the primary route of influence was indirect: through patterns encoded in long-term memory (though a secondary feature—my melodic ornament—was directly imitated) (see Fig. 4.22).

As Romy's opening gambit shows, this oblique form of influence can be used to control musical interactions just as effectively as the immediate imitation of sounds. Striking examples are to be found in the "music and communication" sessions that Sally Zimmermann undertook with Shivan, who is blind and autistic, when he was at primary school. Shivan spoke very little, occasionally talking quietly to himself using unrecognizable words and sounds. When conversing with others, although his articulation was louder and clearer, the single words that he used usually restated what he had just heard (so-called "echolalia"), rather than conveying meaning in the semantic sense.

In Shivan's music sessions with Sally, however, things were very different. She observed (Ockelford and Matawa, 2009, p. 63):

> Shivan will continue and sometimes complete lines from familiar songs that are stopped mid-phrase, using both the correct words and notes. He will also fill in the silences at the ends of phrases by repeating the last word or words that have just been sung. Occasionally, he will sing phrases at the same time as someone else. However, he does not sing entire songs from beginning to end unprompted. If he wants a song to be repeated, he sings or hums the starting note. Often, he is happy to hear a song many times over. Shivan's contributions are usually quiet and reserved; occasional periods of higher energy and excitement appear to have more to do with a self-awareness of his participation in a musical dialogue than as a result of recognising or responding to particular features of the music.

These observations are powerfully illustrated in Fig. 4.23, which is a transcription and analysis of 60 seconds of a session with Sally that occurred when Shivan was 9 years old, using the material from the English children's song *London's Burning* (available on <http://www.soundsofintent.org>). The general shape of the song is maintained, although its surface is fragmented, alternating between the two participants. The dialog is made possible by the

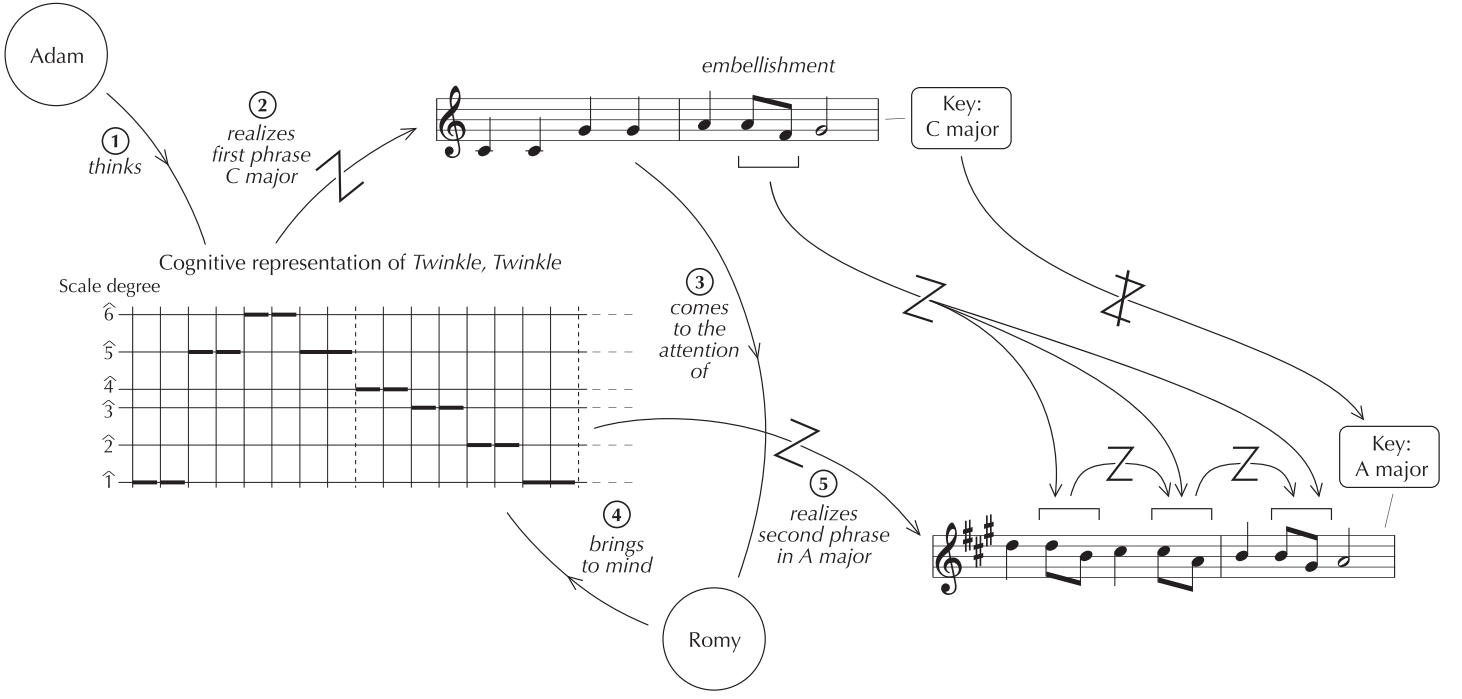


Fig. 4.22 Model of interaction using shared knowledge of a piece.

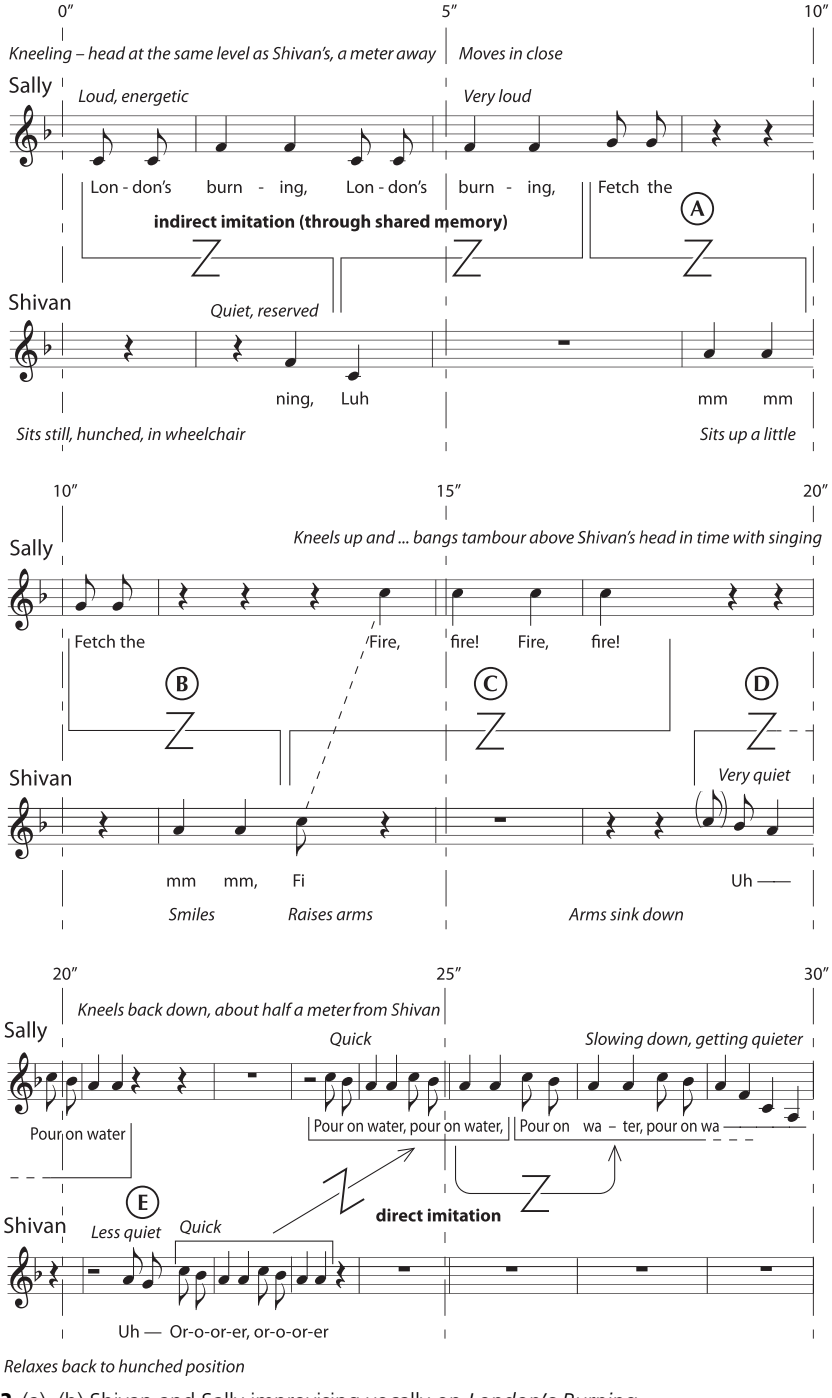



Fig. 4.23 (a), (b) Shivan and Sally improvising vocally on *London's Burning*.

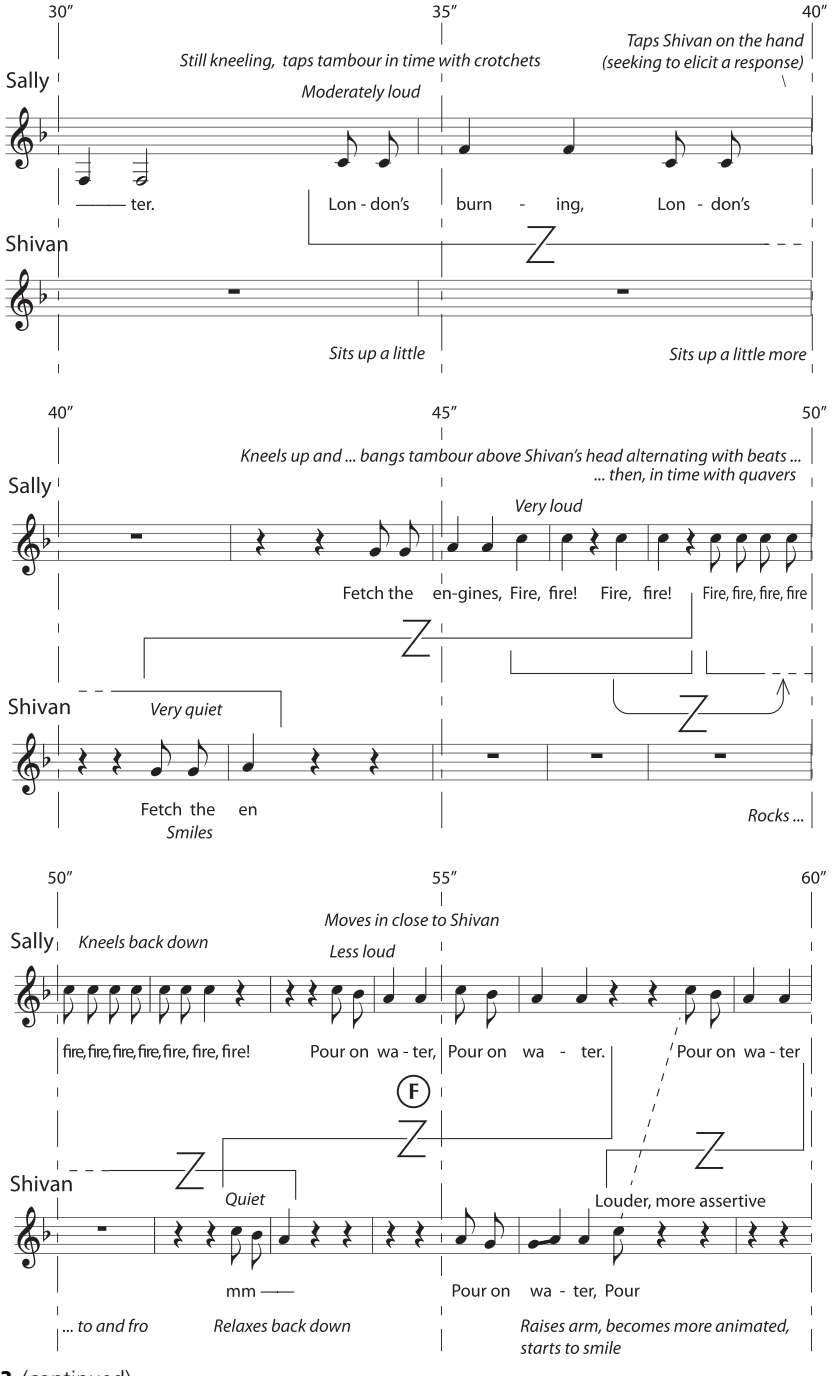


Fig. 4.23 (continued).

participants' shared knowledge of *London's Burning*, and much of the influence between them is *indirect*, although their modi operandi are subtly different. When Sally offers the beginnings of motifs, Shivan tends to complete them—continuing from where Sally left off (see, for example, A and B in Fig. 4.23). Sally, on the other hand, when presented with the openings of phrases by Shivan, mentally winds back and reiterates the beginning of the melodic snippet each time before carrying on (e.g. C and D in Fig. 4.23). It is as though Sally intuitively acts in the way that a parent conversing with a child in the early stages of language development would: feeling the need to reinforce what Shivan "says" in musical terms by repeating his statement, and thereby acknowledging receipt of the message, before moving on (cf. Aspeli-Castro, 2002). Shivan, in contrast, merely responds to the partial stimuli that Sally presents by unthinkingly plugging in to long-term memory and completing the traces that are activated.

Intriguingly, on two occasions (E and F in Fig. 4.23), such indirect influence is overwhelmed by another early musical instinct—to imitate the pitch that has just been heard (Kessen *et al.*, 1979). Here, Shivan's point of departure is the last note that Sally sings (A4) rather than the C5 indicated by *London's Burning* (see Fig. 4.24). It is moments like this that give one an insight into the workings of Shivan's musical mind as he seeks to reconcile the different forces of musical influence that are at work: the more immediate, direct zygonic relationship, stemming from the sound just heard, or the more oblique, indirect relationship, generated from an abstract mental representation. Elsewhere (Ockelford and Matawa, 2009, pp. 118, 119), this is presented as evidence of Shivan functioning at Level 4 rather than Level 5 of the *Sounds of Intent* music-developmental framework (see Chapter 5). Ockelford and Matawa (2009) also argue that it shows "weak central coherence" in Shivan's cognitive style—thought to be a key characteristic of autism (Frith, 2003).

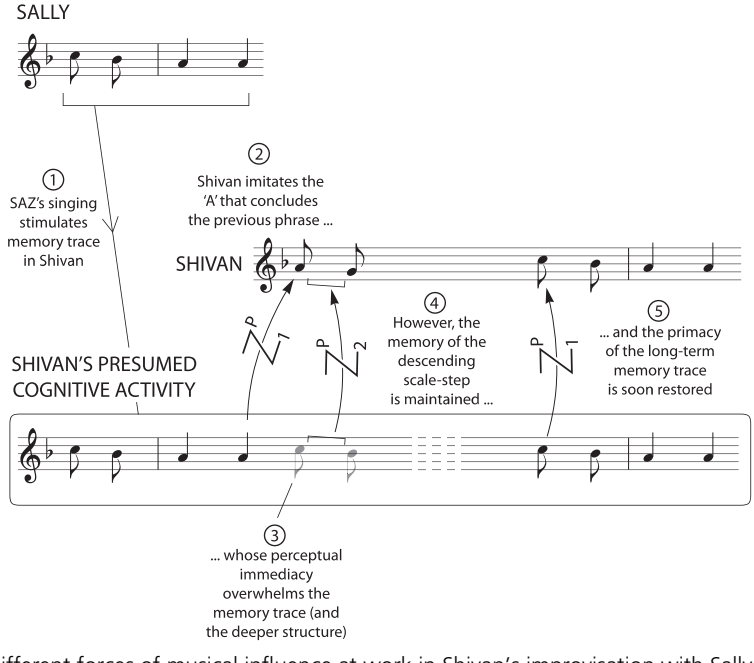


Fig. 4.24 Different forces of musical influence at work in Shivan's improvisation with Sally.

Finally, it is of interest to note that although Sally contributes more music to the dialog (her efforts account for 71% of the notes that are sung, as against Shivan's 29%), their influence on one another is equal (with eight instances each in the passage shown). That is, Shivan controls the course of events just as effectively as Sally, though rather more efficiently, using only half as much material!

Conclusion

In this chapter we have seen how zygonic theory can be used to gauge *influence* in improvised musical interactions by quantifying the variables "control" and "autonomy", and using the ratio

$$\text{control} : \text{control} + \text{autonomy}$$

(i.e. Formula 4.3). This can be used to measure the influence between participants continuously over time, or as an average of their musical impact on one another over predetermined periods (the example of K's song utilizes both approaches). It can function with two performers or more (as in Shibazaki's research). Its potential value in gauging the locus of control in music-therapeutic contexts, as well as capturing the direction of the creative flow in group improvisation (as art) awaits further research.

Chapter 5

Modeling musical development in children with complex needs: the *Sounds of Intent* project

Introduction

If the mind does indeed comprehend musical structure in the manner suggested by zygonic theory (see Chapter 2), then it follows that this capacity must *develop* as a feature of human maturation. Here we explore the evidence for such development that has been amassed in the context of studies of children and young people with "complex needs," referring in particular to those who have severe or profound learning difficulties, with the possibility of autism. That is not to say that the music-developmental findings pertaining to this special group could reasonably be taken to be representative of the wider population without substantial further research. However, as we shall see, the conclusions that are drawn are at least consistent with the findings of the "mainstream" music-developmental literature that has appeared to date, and preliminary work with other (non-disabled) cohorts of children indicates that the framework of musical development that is proposed may well have wider applicability. There are advantages too in studying children whose musical evolution is more protracted than that of the majority: tiny developmental increments may become discernible, and auditory milestones that typically occur *in utero* may occur later, in childhood, making them easier to observe and analyze.

Music education for children with learning difficulties—a neglected area

At the turn of the 21st century, I produced a position paper concerning the music education of children and young people with severe, or profound and multiple learning difficulties—in particular, looking at issues in UK provision that were current at the time, setting out a new conceptual framework for teachers working in this area, and presenting proposals for research (Ockelford, 2000). A number of initiatives followed, including a survey of the music offered in special schools in England (subsequently known as the PROMISE report; see Welch *et al*., 2001; Ockelford *et al*., 2002); a doctoral study by Kyproulla Markou at Roehampton University that examines the relationship between music education and music therapy for pupils with learning difficulties (see Ockelford, 2008b, pp. 37–45; Markou, 2010); and the establishment of the *Sounds of Intent* project, whose aim was to map the musical development of young people with complex needs (see, for example, Ockelford *et al*., 2005; Cheng *et al*., 2009; Ockelford and Matawa, 2009; Welch *et al*., 2009). Once this mapping was complete, the intention was to produce an interactive web-based version of the resulting developmental framework, which would enable practitioners and parents to gauge their children's levels of musical attainment, to chart the changes that may occur over

time and in response to particular interventions, and to record qualitative observations in the form of verbal, video, or audio data to build up a profile of a child's experiences and achievements over time (see <http://www.soundsofintent.org>).

Sounds of Intent—initial evidence

From the outset, the *Sounds of Intent* research team adopted a "bottom up" approach, which involved working with a group of practitioners who were active in the field—music therapists, teachers, and others—with a view to developing accurate descriptions and shared interpretations of the different forms and levels of musical engagement that they observed among pupils with severe or profound learning difficulties or autism. Members of the group held half-day meetings once or twice a term over a 2-year period to analyze in detail video recordings of musical behaviors that were deemed to be "typical," "exceptional," or otherwise of particular interest. The responses, actions, and interactions of children with a very wide range of abilities and needs were carefully noted and encapsulated in short descriptions such as those shown in Table 5.1.

It quickly became evident to the *Sounds of Intent* researchers, in the light of examples such those given in Table 5.1, that it would be difficult (if not impossible) to conceptualize musical development unidimensionally since, for instance, a child's capacity for attending to sounds may well have outstripped his or her ability to produce them. Hence, at least two dimensions would be required: "listening and responding," for which the single term "reactive" was adopted, and "causing, creating, and controlling," for which the label "proactive" was used. In relation to the examples given in Table 5.1 scenarios 1, 2, 4, 7, 8, 10, 15, 18, 22–24, 26, 27, 29, 31, 35, 38–41, 44, 45, 51, 53, 54, 59, 63, 64, 70, 71, and 78 could be considered to be entirely or predominantly "reactive" and scenarios 2, 5, 6, 13, 16, 17, 23, 30, 33, 37, 39, 42, 45–50, 52, 55, 56, 60–63, 65, 67, 68, 70, 75, and 76 "proactive."[1] However, that left a further group of observations (as in scenarios 3, 9, 11, 12, 14, 19–21, 25, 28, 32, 34, 36, 42, 43, 54, 57, 58, 66, 69, 70, 72–74, and 77) in which listening to sounds and making them occurred in the context of participation with others, and it was decided that this concept too merited the status of a separate dimension, which was labelled "interactive."

It was also apparent that the behaviors that were observed covered a huge developmental range, from what appeared to be the very beginnings of musicality (or even, in some cases, stages of development in which musicality was yet to evolve) to highly sophisticated levels of musical engagement. Now, it was evident to the *Sounds of Intent* team that, if the zygonic hypothesis were correct—that musical structure is ultimately created and cognized through imitation—then it should be possible, within the wide diversity of descriptors set out in Table 5.1, to detect when this capacity first emerges, or at least identify examples where it is unequivocally present (and instances where it is not).

What are likely to be the signs? In the *proactive* domain, we should expect to observe repetition in the context of potential sonic variety. This may involve a particular quality of sound, such as pitch or timbre (for example "Damario has been able to make a wide range of vocal sounds ever since he started school, but recently he has begun to make more melodious vowel sounds, which he repeats in short sequences", Scenario 16), or it may entail the reiteration of differences between notes, such as inter-onset intervals. For instance, "Liz can tap out a regular beat at different speeds on a range of handheld percussion instruments" (Scenario 48).

[1] Some observations, such as Scenario 23, pertained more or less equally to two dimensions.

Table 5.1 A selection of the forms of musical engagement observed by members of the *Sounds of Intent* team

1	Anna sits in her wheelchair making no voluntary movement. Her teacher approaches and plays a cymbal with a soft beater, gently at first, and then more loudly, in front of her and then near to each ear. Anna makes no reaction that the teacher can observe.
2	Rosina is lying in the "Little Room,"[1] vocalizing in an almost constant drone. Occasionally a sudden movement of her right arm knocks her hand against a bell, which is wrapped in tinsel, and glints in the light. Each time, she smiles and her vocalizing briefly turns into a laugh.
3	Mark's music therapy session begins—as ever—with the "hello" song, during which he is given a rainstick adorned with reflective paper, a multisensory soundmaker which he is encouraged to use as a personal symbol. And as ever, he makes no discernible response.
4	Ben startles and then smiles when someone drops a tray of cutlery in the dining room.
5	Taybah brushes her left hand against the strings of guitar that someone is holding near to her. There is a pause and then she raises her hand and brushes the strings again, and then for a third time.
6	Yakov usually makes a rasping sound as he breathes. He seems to be unaware of what he is doing, and the rasping persists, irrespective of external stimulation. His class teacher has tried to see whether Yakov can be made aware of his sounds by increasing their intensity (using a microphone, amplifier, and speakers), but so far this approach has met with no response.
7	Grant's teacher notices that he often turns his head towards her when she sings to him, but she has never noticed him turn towards other sounds.
8	Wendy giggles when people repeat patterns of syllables to her such as "ma ma ma ma ma," "da da da da da," or "ba ba ba ba ba."
9	Jamie's short, sharp vocalizations, which vary in quality according to his mood, are interpreted by his teachers and carers to mean that he wants someone to vocalize back to him.
10	Khira gets very excited when she hears the regular beat on the school's drum machine.
11	Ubanwa enjoys "call and response" games and joins in by making his own, distinctive sounds.
12	Carol copies simple patterns of vocalization—imitating the ups and downs of her speech and language therapist's voice.
13	Samantha waves her hand more and more vigorously through an ultrasonic beam, creating an ever wider range of swirling sounds.
14	Nathan often vocalizes in response to vocal sounds that are made close to him, although he doesn't seem to copy what he hears.
15	Zabrina loves the sight and sound of the bell tree being shaken, and when it stops she rocks in her chair which staff interpret as a gesture for "more."
16	Damario has been able to make a wide range of vocal sounds ever since he started school, but recently he has begun to make more melodious vowel sounds, which he repeats in short sequences.
17	Lottie hums distinct patterns of notes and repeats them. Her favorite sounds rather like a playground chant, and she repeats it from one day to the next, though not always starting on the same note, her music teacher notices (see Fig. 5.1).

[1] A small, largely enclosed area, originally designed by the Danish psychologist Lilli Nielsen, which may be placed over a prone child's head and upper torso, and in which potentially sound-making objects and toys are suspended, so that movements the child makes (whether accidentally or deliberately) are likely to create a range of sounds with a good deal of acoustic feedback. At the same time, auditory clutter from the outside is minimized. For further information, see <http://www.lilliworks.com/products.htm>.

Table 5.1 (continued) A selection of the forms of musical engagement observed by members of the *Sounds of Intent* team

18	Freya cries whenever she hears the "goodbye" song. It only takes the first two or three notes to be played on the keyboard, and she experiences a strong emotional reaction.
19	Hirsch enjoys copying simple rhythms on a non-tuned percussion instrument. Now he's started making his own rhythms up too, and he flaps his hands with delight when someone else copies what he's doing.
20	Ellen just laughs and laughs when people imitate her vocalizations.
21	Vaughan vocalizes to get his therapist to make a sound—it doesn't matter what, he just seems to relish having a vocal response.
22	Imogen always gets excited in the middle of the "slowly/quickly" song—to which she has recently learnt to tap the beat—anticipating the sudden change of pace.
23	Oliver scratches the tambourine, making a range of sounds. Whenever he plays near the rim and the bells jingle, he smiles.
24	Qiang's eye movements intensify when he hears the big band play loudly; *what* they are playing seems unimportant.
25	Xavier distinctly tries to copy high notes and low notes in vocal interaction sessions.
26	Peter has learnt to associate his teacher's jangly bracelet, which she always wears, with *her*: for him, it is an important part of her identity.
27	William's rocking increases markedly as the Japanese taiko drumming gets faster and faster.
28	Milán is lead singer in a pop group at school, whose members all have learning difficulties. With the help of their music teacher, the group are getting better at following him as he slows down before the return of each chorus for expressive effect.
29	Ashley's parents have tried playing her just about every kind of music, and have taken her to all sorts of performances, from traditional church choirs to big band jazz, but as yet she has shown no reaction.
30	Hackett gets a buzz out of playing the drum, starting with a slow beat and getting faster and faster.
31	Yuma likes it when her teaching assistants play "catch" with short vocal phrases, each person picking up from where the other left off.
32	Dennis will respond to musical sounds that are made near to him by vocalizing next to his right ear, so he can feel the adult's breath on his skin, and he is now sustaining his concentration on this listening task for longer periods of time.
33	Vic can choose which activity he would like to do next by shaking the bells (for music) or squeezing a horn (for "ride the bike").
34	Faisal has severe learning difficulties and hemiplegia. He has AP and plays the keyboard with his left hand only, learning material by ear quite quickly. He has recently joined the school's band, and has found a role for himself playing the bass parts. Now he not only picks up on what the left hand of the other keyboard player is doing, but he has started to improvising around the harmonies too.
35	Penny has come to realize that the gong in her classroom means "lunchtime" when it is sounded.
36	Gabrielle does not appear to relate to other's sound-making and, in an effort to gain her attention, her co-workers react positively to sounds that she makes, apparently by chance, and they model interactions for her, one taking her part vocally in the "good morning" routine, for example.

Table 5.1 (continued) A selection of the forms of musical engagement observed by members of the *Sounds of Intent* team

37	Emily makes up songs with short phrases that sound connected—and when her teacher listened carefully to a recording that she had made of Emily's singing, she noticed that one phrase often started more or less where the other one left off.
38	Jamil has severe learning difficulties and is on the autism spectrum but he has sophisticated musical tastes. He likes the vocal music of the Baroque period—especially Bach and Handel—but much prefers a purity and lightness of vocal tone with little vibrato.
39	Tanya likes improvising responses on the keyboard to the melodic openings that her teacher makes up—and she's now learnt to "hear" the same structures in many themes by Haydn and Mozart.
40	Quincy knows that when his music teacher plays the last verse of *Molly Malone* in the minor key it signifies sadness.
41	Noriko loves the little runs on the panpipes in Papageno's *Birdcatcher's Song* from *The Magic Flute*.
42	Sabina plays her cello with a Suzuki group, and is much better now at performing in time and in tune with the other children.
43	Osman enjoys singing the bassline in his school choir, and has memorized around 50 pieces that they have sung over the last few years.
44	Brett went to an African performing arts workshop, and he was really engaged as the short bursts of music were echoed back and forth between groups.
45	Ruth is a good singer, used to performing in public, although she has severe learning difficulties and autism. She can learn new songs just by listening to her teacher (who is not a singer) run through them, and as she gets to know a piece, she intuitively adds expression as she feels appropriate, showing that she has an underlying sense of the structure and content of the music. Later, when she listens to other people singing the songs she knows, she clearly prefers some performances to others. Her teacher believes this shows that she has a mature engagement with pieces in mid-to-late 20th-century popular style.
46	Lacey uses a switch to operate a drum synthesizer, and she is showing an increasing ability to control the sounds that are made. Originally, she would only concentrate on the task in the relatively constrained auditory environment of her classroom, but now she enjoys making music in the school hall too.
47	Ursula, who is blind and has learning difficulties, improvises pentatonic tunes on the recorder using the notes (D5, E5, G5, A5, B5). Initially, it didn't seem to matter to Ursula which note they ended with, but more recently, they tend to conclude with G.
48	Liz can tap out a regular beat at different speeds on a range of handheld percussion instruments.
49	Zachary, who has moderate learning difficulties and is on the autism spectrum, loves to compose using the computer, which he can do with someone to help him control the software. He has been creating pieces to accompany the school play, and has now put together a dozen excerpts which convey a range of different moods.
50	Tabitha can't speak, but she can hum short phrases to communicate her preference for certain activities (see Fig. 5.2).
51	Ude, with profound and multiple learning difficulties, is fascinated with the ever-changing sonorities produced by the didgeridoo.
52	Ciara, who is a good vocalist despite having severe learning difficulties, is learning how to convey a range of different emotions in her singing through using techniques such as rubato, consciously employing a wider range of dynamics, and producing darker and lighter sounds.

Table 5.1 (continued) A selection of the forms of musical engagement observed by members of the *Sounds of Intent* team

53	Aletia, who is severely autistic, experiences a strong emotional reaction when she hears *This Little Light of Mine* ever since it was played at her classmate's funeral.
54	Xiang, who has profound pervasive developmental delay, has at last started to respond to her teacher singing as well as to her mum, and this occurs in an increasing range of contexts, including her classroom and the multisensory room.
55	Valerie has a good deal of involuntary movement in her arms, and her music therapist has tried to give her a sense of cause and effect by using an ultrasonic beam, which she links to a variety of electronic sounds. To date, Valerie has shown no signs of awareness that she is controlling the sounds, however.
56	Diane makes short melodic patterns—usually going up three or four notes—using single syllables such as "dah" or "me."
57	Heidi's speech and language therapist tries to interpret her vocalizations and facial expressions in the context of early communication, producing similar sounds in return.
58	Chas really enjoys playing the bongos in his college band—maintaining a regular beat even when the music gets quite syncopated, and not afraid to add his own ideas too.
59	Eamon, with moderate learning difficulties and autism, is always listening to pop music, but he has his clear favorites to which he returns time and again.
60	Iona appears to have no voluntary movement, and her therapist lifts her arm up and down in the ultrasonic beam to generate flute-like sounds from the computer.
61	Faith, who has severe learning difficulties, used to be able to play only a few nursery rhymes on the keyboard, mostly with the right hand, but now she can manage whole pop songs, with a simple bass line all the way through.
62	Oscar has learnt to sing much more in time and in tune over the last year, his music teacher notices, and he improvises simple melodies, typically comprising several short phrases, that are always in the major key, the first phrase beginning, and the last ending, on the tonic.
63	Xena waits for the "tick, tocks" in *My Grandfather's Clock* and grins with excitement when the moment comes. Very occasionally she joins in.
64	George loves it when his one-to-one support worker claps short rhythmic patterns to him.
65	Imran's piano technique has improved dramatically over the past year since his new teacher taught him scales and arpeggios in every key, and he can now perform his repertoire of early jazz much more fluently.
66	Janet, with severe learning difficulties, has developed the confidence to introduce new material on her saxophone in the school's jazz quartet, and is thrilled when the other players pick up on what she is doing.
67	Yolanda can sing most of *Twinkle, Twinkle Little Star* when prompted at the beginning of each phrase, though her sense of key tends to drift.
68	Keith can improvise over a number of pop songs in a simple style over the keyboard.
69	Stephen plays the clarinet in the local wind band, and intuitively picks up on the changes in dynamics and tempi that they make.
70	Mehul performs expressively on his guitar, whether he's playing folk music, blues, or country and western. He's happy playing on his own or with others, and he enjoys going to concerts to hear music in these different styles played live too. If he had to choose, his preference would always be for folk music, though.

Table 5.1 (continued) A selection of the forms of musical engagement observed by members of the *Sounds of Intent* team

71	Zeeshan laughs and rocks when he hears his teacher imitating Tom's vocal sounds.
72	Neha copies elements of the short phrases her music therapist sings, particularly picking up vocally on the highest or lowest notes, or the first or last in a group.
73	Patrick's music therapist tries interacting with him in a number of different environments—the music room, the multisensory room and the hall—to see if the different acoustics will encourage him to engage with her and respond.
74	Rachel enjoys "give and take" sessions with her piano teacher using two keyboards. She can copy the short rhythms that her teacher makes up and gets most of the pitches right too.
75	Wallace is getting better at holding a steady tonal centre when he sings, and has recently started making up pieces that have a distinct beginning, middle, and end.
76	Brian always plays the bell-tree in music sessions (he becomes distressed if attempts are made to encourage him to play other instruments)—for him, at this stage, it is an integral part of the experience.
77	Karen thinks it's great fun when her music therapist copies the number of beats that she makes on the tambourine.
78	Qabil's day at school is organized so that key activities have sounds that precede them as auditory cues—shaking the bell-tree means "it's time for music," for example, banging the gong means "lunchtime," and a horn means "ride the bike." Similarly, his key worker always wears the same jangly bracelet, and his classroom is identifiable by the windchimes at the door. At the moment, Qabil does not react to any of the sounds, and there's no evidence that he understands any of the connections that are being presented to him—but staff persist in the hope that offering Qabil a structured learning environment will eventually pay off.

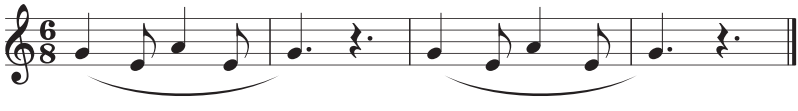



Fig. 5.1 Lottie's song.

Reactively, we should anticipate that imitation of one form or another would engender a particularly marked response and, again, examples are to be found. For instance: "Wendy giggles when people repeat patterns of syllables to her such as 'ma ma ma ma ma', 'da da da da da,' or 'ba ba ba ba ba' " (Scenario 8).

In terms of *interaction*, we would predict that children and young people would imitate the sounds made by others, and react when other people imitated them, and, once more, examples do occur. For instance: "Xavier distinctly tries to copy high notes and low notes in vocal interaction sessions" (Scenario 25) and "Ellen just laughs and laughs when people imitate her vocalizations" (Scenario 20).

However, there are many other examples of repetition being created or cognized that appear to suggest more advanced levels of musical functioning. For instance: "Brett went to an African performing arts workshop, and he was really engaged as the short bursts of music were echoed back and forth between groups" (Scenario 44); "Tanya likes improvising responses on the keyboard to the melodic openings that her teacher makes up—and she's now learnt to 'hear' the

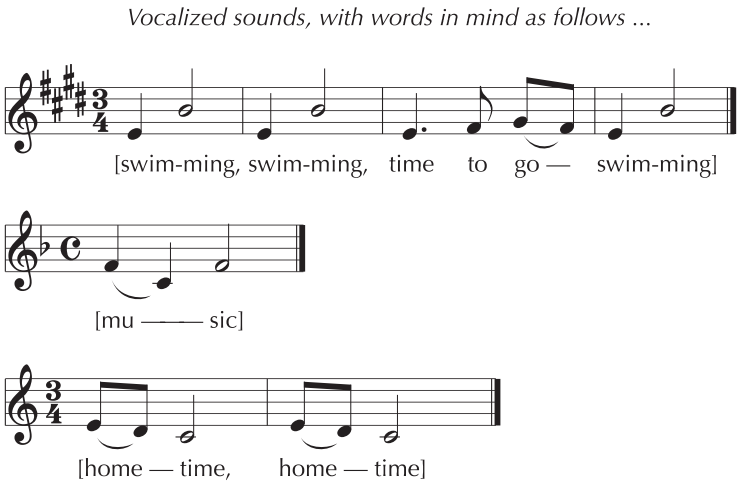


Fig. 5.2 Tabitha hums short melodic contours to communicate.

same structures in many themes by Haydn and Mozart" (Scenario 39); and "Janet, with severe learning difficulties, has developed the confidence to introduce new material on her saxophone in the school's jazz quartet, and is thrilled when the other players pick up on what she is doing" (Scenario 66). How do we conceptualize behaviors such as these in developmental terms? It seemed, to the *Sounds of Intent* research team, that the evolution of music-structural cognition, as defined by zygonic theory, was almost certainly an incremental process. The key question, from the point of view of seeking to formulate a music-developmental framework, was whether distinct, common stages on the maturational journey could be identified.

Events, groups, and frameworks

My work with Derek Paravicini, a musical savant (Ockelford, 2007a, 2011; reported in Chapters 6, 7, and 9), lent weight to the earlier suggestion (Ockelford, 2008b) that musical structure is processed on three different levels—events, groups, and frameworks—which, it was postulated, could underpin a developmental cognitive hierarchy. Before examining evidence to support this assertion, let us consider what we mean by "events, groups, and frameworks" and investigate how they function in music-structural terms.

Events

I define a musical event as the shortest perceived unit of activity present in a given musical context (which will typically comprise a series of comparable events) (cf. Ockelford, 1999, pp. 115–49). Events are usually conceptualized by musicians working in the Western tradition as "notes" (in the UK) or "tones" (in the US): something that is reflected in the system of stave notation that typically uses one sign per note or tone. In terms of the examples given above and in Chapter 3, we can conceive of each syllable (ba, da, or ma) in the repeated series that make Wendy laugh as constituting a single event; and the same is true of Liz's discrete percussive taps, and Abby's individual strums on the digital guitar using Soundbeam®.

When one event is deemed to imitate another, musical structure in its simplest form is created, and in Chapter 3 we considered at some length the criteria that observers might use to gauge

intentionality in a child's repetition of sounds in the context of engaging musically with others (that is, *interactively*). This is because the intent to repeat is an essential ingredient in imitation: recall from Chapter 2 that sounds may be repeated for many reasons, but, according to zygonic theory, they only become music in the mind of the creator (or listener) when one is deemed to imitate another.

The criteria identified in Chapter 3 for assessing the presence of imitation in interactive contexts can be used in *proactive* scenarios too. A key issue is whether the child is capable of producing a range of different sounds (or do "person-based" constraints prevent this?), and whether he or she has the opportunity to do so (or are "environmental" constraints a hindrance?). For example, in the case of a pupil who has the capacity to produce only one type of vocal sound, it would be impossible to say whether repeated vocalizations were intended to be imitative or not. Similarly, for the student who has access only to a single chime bar, playing two notes or more in succession would mean that repetition of pitch was inevitable: hence the desire to imitate could not be inferred. Conversely, given his ability to make a wide range of vocal sounds, Damario's vocal repetition (Scenario 16), is likely to represent the creation of simple structures that are truly musical in nature.

Turning to the *reactive* domain, the extent to which children with complex needs perceive the repetition of sounds as imitative, and therefore indicative of musical structure, is more difficult to determine (being an internal, mental process), unless they respond by producing related sounds themselves—in which case, their engagement would be classed as *interactivity*. However, there may be other physical and emotional reactions that suggest that certain patterns are perceived in a music-structural way (while others are not). For example, it may be that the human element is important in Wendy's positive reaction to repeated patterns of sounds (Scenario 8), since comparable stimuli that occur repetitively in the environment do not elicit the same effect. However, while this would offer an indication that Wendy was processing the repeated syllables of her carer in music-structural terms, it would be no guarantee, since human (or sometimes other animal) agency is only a *necessary* and not a *sufficient* factor for imitation to exist (see Chapter 2, pp. 30–1).

It is also important to remember that while repetition which was intended to form a musical structure need not be cognized in that way, it is equally conceivable that repeated sounds which were not created as music can nonetheless be perceived—or at least treated—as such (see p. 30). This is shown powerfully, though idiosyncratically, among some of those on the autism spectrum. For example, Romy (whom we encountered in Chapter 4) has the habit of incorporating certain everyday sounds that may occur in the course of her music lessons into her improvising. If her father's mobile phone goes off during her lessons, for instance, she will incorporate the sound repeatedly into what she does on the piano. But is this because Romy hears the ring tone as music (and reinforces this perception by repeating it), or because by imitating its sound she can in some sense "control" a feature of the auditory landscape that she is aware has a significance that she does not fully understand and which causes her anxiety?[2] Or perhaps both interpretations are correct

[2] The notion that through imitating the sound that something makes one can in some way control it, own it, or even in some sense *become it* is a very ancient one. "If a man is capable of reproducing exactly the croaking of the frog or the hissing of the snake, it is because his mystic ancestor was the totem-god of the frog or the snake. When he imitates the voice of his totem with the greatest realism, he imagines he is obliterating the boundary between subject and object and identifying himself with the totem. Whoever croaks like a frog, is a frog. . . . He becomes in fact a sound-symbol. . . . Vocal imitation is the strongest form of mystic participation in the surrounding world" (Schneider, 1957, pp. 9, 10).

(Ockelford, 2012b): for teachers and therapists working with children such as Wendy and Romy, the important thing is less about having a definitive sense of how they perceive (and perhaps conceptualize) certain everyday sounds than being alive to the musical opportunities they present.

Groups

While individual events may constitute the ultimate building blocks of music, they rarely convey enough information to have distinct and memorable identities, and so usually lack the capacity to function as discrete units of musical meaning in the esthetic sense. The exceptions that exist are sounds that are characteristic enough to stand alone and be recognizable as musical entities in their own right: the opening low fortissimo string Cs in Beethoven's *Coriolanus Overture*, Op. 62, for example, and the canonic Gs to which Bach set the word "Et" in the third movement of the *Symbolum Nicenum* from the Mass in B minor (see Fig. 2.13). The powerful reaction of some people on the autism spectrum with AP to certain notes suggests that, in their minds, particular pitches may have distinct personalities—"familiar friends in a confusing world" (Ockelford, 2007a, pp. 34, 35)—that would pass most neurotypical listeners by. Hence for them, *individual* sounds may have as powerful an identity as *groups* do for most people.

Notwithstanding these exceptions, most music is designed and is heard to comprise distinct "chunks" of activity: groups of notes defined according to the principles of *Gestalt* perception such as "proximity," "similarity," and "good continuation" (Bregman, 1990; Deutsch, 1999). The most straightforward definition of a group is that members have something in common that is not shared by non-members (Deliège, 1987, 2001b; Ockelford, 2004).

As music is a temporal art, grouping in the temporal domain is a prerequisite of grouping in all others, since unless perceived sounds are juxtaposed in time, they cannot be heard as forming part of a larger whole, no matter how similar or proximate they may be in terms of pitch, timbre, or loudness. As Bregman says, it is the "relative lengths of silence between moments of sound [that] will be an important determinant" (Bregman, 1990, p. 472). In terms of zygonic theory, this means that, within a group, the onsets of notes following the first will closely imitate the endpoints of preceding notes, and that a group boundary will be determined by a relatively long break (and therefore a lack of imitation) between the endpoint of a note and onset of the one that follows. It is possible to see this principle in action in K's improvised song about her dog (Fig. 4.5): consider, for example, how phrases 2 and 3 are articulated, whereby two uninterrupted streams of sound are separated by a period of silence of just over a second (in bar 8).

Given this underlying requirement of proximity in the domain of perceived time, there are a number of other ways in which sounds can be grouped which can work in any combination, reinforcing, complementing, or even competing with one another (Lerdahl and Jackendoff, 1983, pp. 36ff.). In the domain of pitch, for example, grouping may occur through proximity, operating through chains of perfect or imperfect zygonic relationships (connecting successive pitches that are the same or nearly so). In the domains of timbre and loudness, grouping may occur in a similar way through similarity (see Fig. 5.3). Grouping by "good continuation" entails regular change in one dimension or more (Deutsch, 1999, p. 320) and Fig. 5.3 shows an example in my accompaniment to K's improvised vocal line (that occurs at the same time as her grouping by proximity).

In terms of musical development, it seems inevitable that the processing of musical events and the relationships between them should precede an understanding of how groups of sounds are formed. This is because the mental formulation of groups is predicated on a *series* of relationships between events being constructed in the mind, which need to be held in working memory to

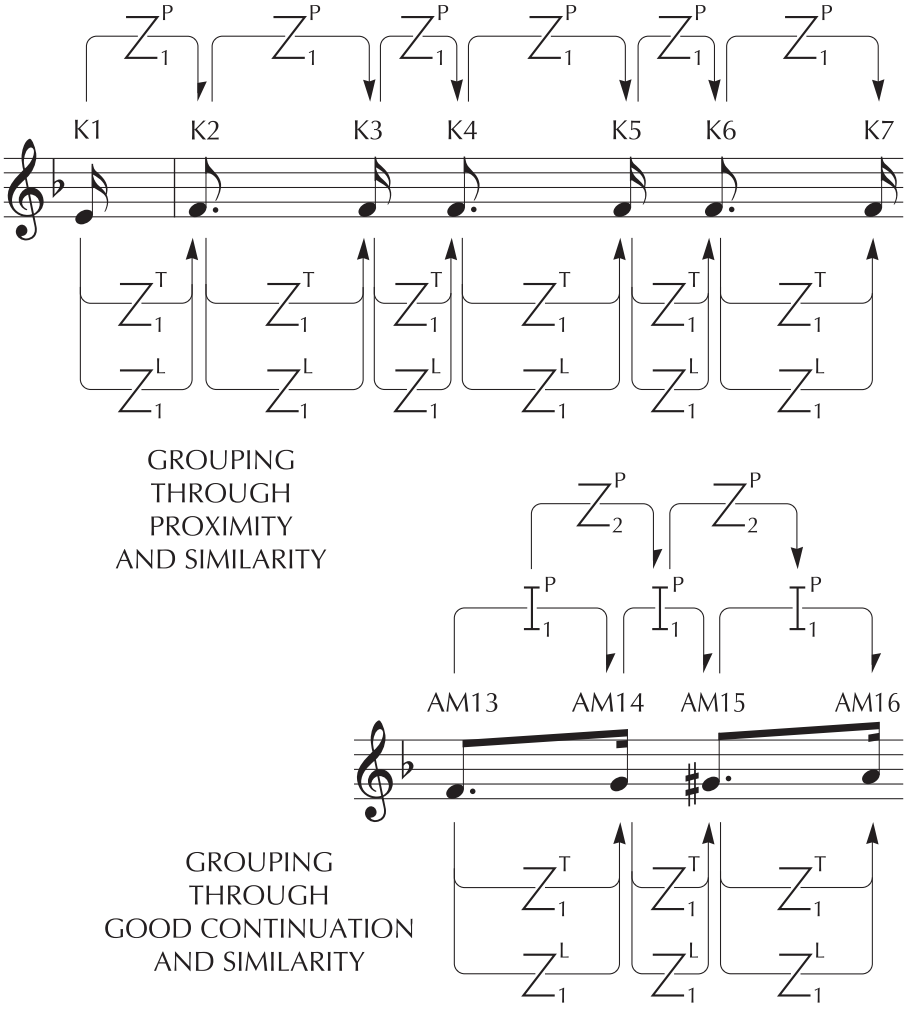


Fig. 5.3 Grouping through proximity and good continuation in the domain of pitch, reinforced through similarity in the domains of timbre and loudness.

enable them to be compared with one another and so allow the listener to establish what the group constituents are and where the boundaries with other groups lie.

The recognition of relationships *between* groups is even more cognitively demanding, since all the information required to define one group must be stored and then compared with the perceptual data needed to specify another. Moreover, relationships between groups can take many different forms—an inevitable consequence of the multifarious nature of music itself (Ockelford, 2009b). Hence a certain mental agility rooted in substantial experience of listening to a variety of music is likely to be required for the brain intuitively to grasp the range of connections between groups of notes that are used by composers. Zygonic theory suggests that these take two principal forms (Ockelford, 2009b):

(1) where one group is perceived to derive *as a whole* from another; and

(2) where one *aspect* of a group is perceived as deriving from another.

In terms of relationships of type (1), there are eight ways in which groups can be related to one another in the domain of pitch: through repetition, transposition, inversion, intervallic augmentation or diminution, sequential change (for example, retrogression), and the omission, addition, or alteration of material (cf. Schoenberg, 1967, p. 10; Large, 1993; Palmer and van de Sande, 1993; Repp 1996; Crawford *et al.*, 1998). With regard to rhythmic relationships between groups, the position is even more complicated, since there are three potential variables: duration, inter-onset interval, and "relative metrical location" (the position of each note within the prevailing meter; see Ockelford, 1993, p. 589). Together, these variables yield 21 categories of group transformation.

Hence, relationships between groups of notes as a whole can vary enormously in terms of complexity and, we can assume, cognitive processing load. Let us take two further examples from K's song and accompaniment (Fig. 4.5). The simplest of relationships between groups, involving the repetition of pitch and rhythm, is to be found in bar 19 in the right hand of the piano part (Fig. 5.4).

A far more elaborate network of connections exists between K's three vocal phrases in bars 17–22, where a pattern of three descending pitches is successively transposed and varied, mirroring and enhancing the rhetorical form of the verbal narrative at this point: "*one* for her biscuits, *one* for her water, and *one* for her meat." Exact transposition of the intervallic descent, which would have demanded a B♭ at the beginning of bar 19, appears to have been overwhelmed by K's desire for a convincing consonance at this juncture (with the emphasis on the repeated word "one"). Accordingly, she modifies the opening two notes of the phrase to conform to the F major and D minor harmonies, whereby they are lowered a semitone to become fourth-octave As. Thus K demonstrates the intuitive ability to weigh up and manage conflicting musical demands, and, in the midst of her improvisation, the capacity to select the form of intergroup relationship best suited to her expressive intentions (see Fig. 5.5).

Despite these intricacies, the musical structure that K creates is relatively easy to perceive, thanks to the rhythmic similarity and metrical equivalence of the three phrases. However, this is not the case with all relationships between groups that composers have chosen to use. As Temperley (1995, pp. 141, 167) observes:

> There is an important distinction to be drawn in the way different kinds of motivic relationships are perceived ... metrically parallel transpositions ... are perceived in a fast automatic way ... [they] are also phenomenologically direct: there is a strong sense of hearing that they are there ... Other relationships—non-parallel transpositions, retrogrades, and other set-theoretic relationships—may be detected, but only in a slow, deliberate phenomenologically indirect way.

That is, the cognitive standing of relationships between groups varies from ready perceptibility, through conceptually enhanced perception (as, for example, when a listener's attention is drawn

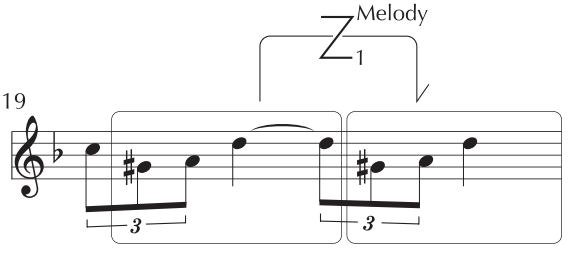


Fig. 5.4 Relationship between groups involving repetition in the domains of pitch and perceived time.

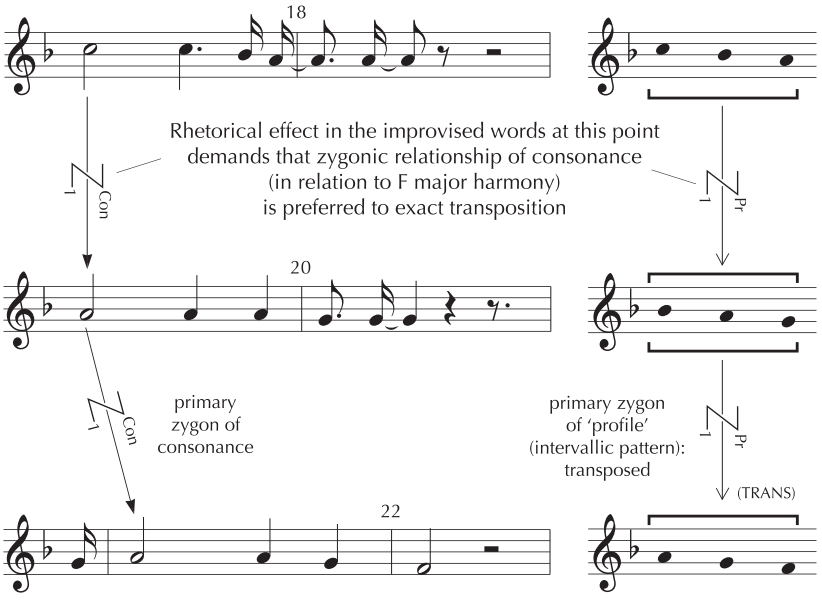


Fig. 5.5 Groups linked through modified transposition.

to the inversion of a theme in the program notes that accompany a performance), to their apprehension only as concepts (in the case of the connections between 12-tone rows, for instance). With regard to children and young people with severe or profound learning difficulties, who are very unlikely to be at the stage of making conceptual judgments about music, it is highly probable that their perception of relationships between groups as a whole will be of the direct, intuitive kind.

The other type of logical connection between groups of notes—where one *aspect* is perceived as deriving from another—also manifests itself in many different ways. Turning again to K's song, we can see two of these in action. Her favored approach is to use primary zygonic relationships: taking a pitch at or near the end of a phrase and using it to start the next (see, for example, the connections between phrases in bars 8 and 20). On a number of occasions, K uses secondary zygons to link different ideas (for instance, between bars 16 and 17) (see Fig. 5.6). Shivan uses such links idiosyncratically in his session with Sally (Fig. 4.23), completing groups that she has initiated, and providing her with the starting points for the groups that follow.

As was the case with intragroup relationships, it is clear that the ability to recognize or create such connections *between* groups—whatever form they take—is contingent on the capacity to process relationships between individual events, since without these one-to-one bonds, more substantial associative networks could not be built up. Hence, developmentally, one would expect to see the latter capacity preceding the former.

Frameworks

A "framework" is a mental representation of an abstract series of intervals within a given domain (notably pitch or perceived time) which may (theoretically) be reified at any absolute point and in any combination or permutation. A particular framework may be implied from an incomplete representation.

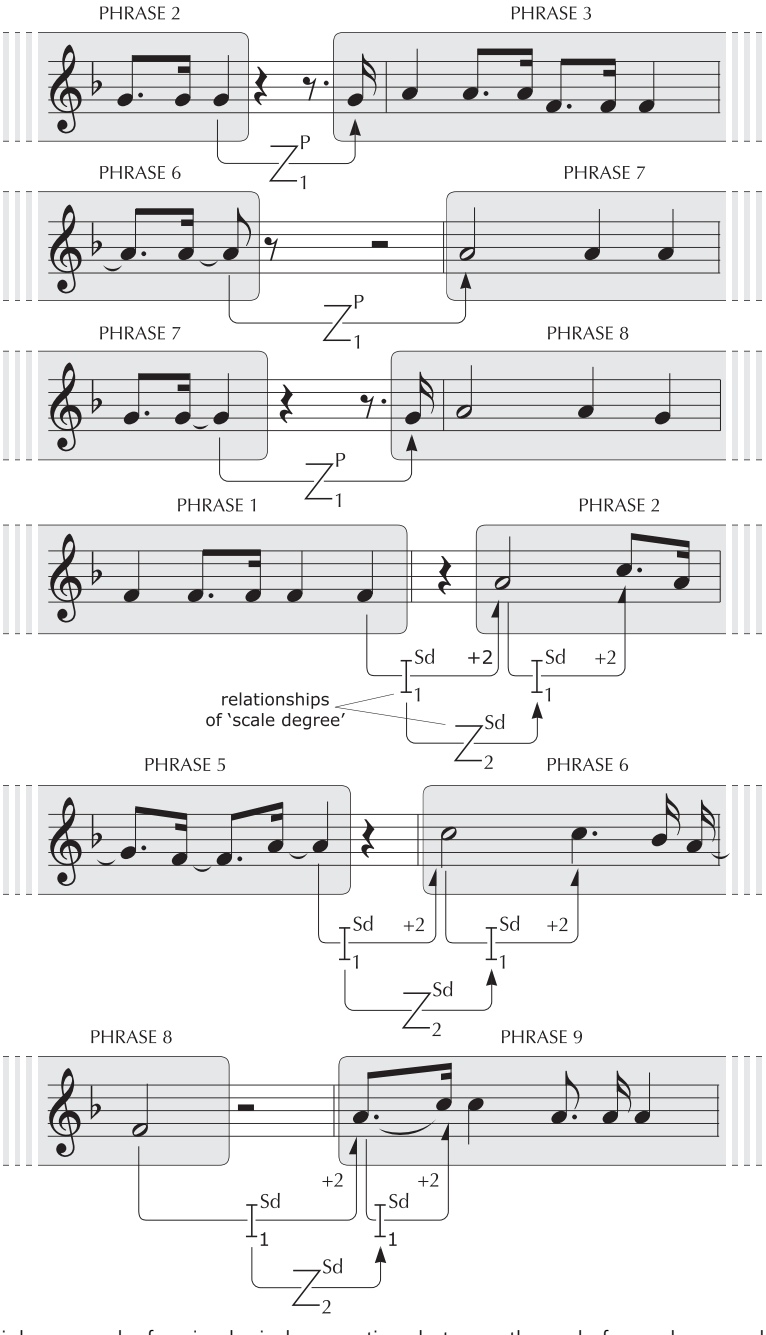


Fig. 5.6 K links groups by forming logical connections between the end of one phrase and the beginning of the next.

To observe frameworks in action, consider the research with Derek Paravicini mentioned earlier (Ockelford, 2011). Derek participated in an experiment in which he attempted to learn a short tonal piece of piano music (in the style of Mozart), excerpts adapted from Bartók's *Whole-Tone Scale* from *Mikrokosmos*, Book 5, and the opening bars of Schoenberg's *Klavierstück*, Op. 11, No. 1, that eschews tonality. The latter part of the experiment is reported in Chapter 9.

As the title of the composition by Bartók suggests, it uses the "whole-tone" scale—that is, a pitch framework in which all intervals are equal, comprising two semitones. Figure 5.7 shows the opening segment, and Derek's attempts to play it over four trials. None of Derek's renditions is entirely accurate with regard to events (he had an average error rate of around 30%) or groups, but all conform to the pitch framework of the original. This suggests that the whole-tone scale that Bartók used exists as an abstract entity in Derek's mind, distinct from the surface events that define it. Similarly, to those hearing Derek's responses, intuitively they have an affinity with the original despite surface details being different.

The important issue in the current context is to determine (or at least hypothesize) how such frameworks become established in cognition, and where they stand developmentally in relation to creation and recognition of musical structures pertaining to events and groups. We will consider what direct, ontogenetic psychological evidence there is in due course, but as a first step, we will adopt an indirect, phylogenetic tack, and consider how pitch frameworks evolved historically.

It seems likely that, from the earliest times, the creation of new works entailed utilizing melodic fragments taken from other (extant) pieces. Since, generally speaking, people's long-term memory

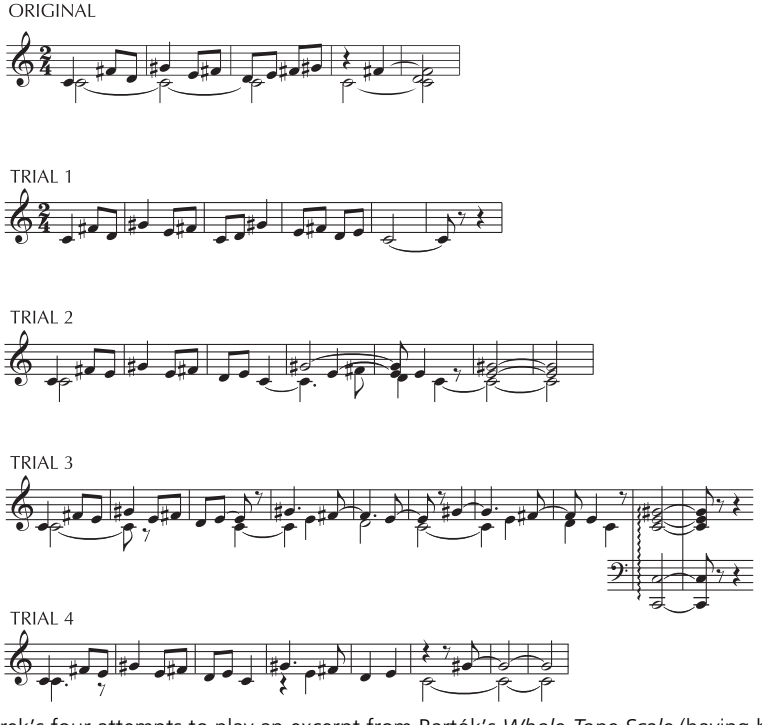



Fig. 5.7 Derek's four attempts to play an excerpt from Bartók's *Whole-Tone Scale* (having heard the original before each attempt).

for absolute values of pitch tends to be comparatively poor (cf. p. 63), this translocation of material would normally have occurred, we may surmise, on an intervallic level. Had links of this nature not been forged, then the pitch structure of each piece would necessarily have been unique, which appears to be cognitively inconceivable, from the standpoints of both production and reception. It seems reasonable to assume that some snatches of melody found wider service than others, while a few became well-established members of a general fund of ideas to which musicians were inclined to turn time and again. Today, theorists refer to the members of such a stylistic repertory as "melodic formulae" (see, for example, Apel, 1969, p. 519).

In some cultures, it appears that melodic formulae were not just transferred from piece to piece individually but in groups; evidently certain combinations were judged to be more fitting than others. Aggregations of this sort are known as "melody types" (Apel, 1969, p. 519). One of the reasons for the alliance of a particular body of melodic formulae seems to have been that they shared the same underlying framework of pitches. A number of different cultures have used, and some continue to use, melody types as the basis for the creation of new pieces. Examples range from the eight "echoi" of ancient Byzantine chant (Wellesz, 1961, p. 44), a classification that continues to apply in the Armenian, Russian, and Serbian churches (Apel, 1969, p. 251), to the ragas of Indian music, each of which may be defined as a fusion of scalar and melodic elements (Jairazbhoy, 1971/1995, p. 28). In some cultures, however, their influence has become less pervasive. As Reese (1940, p. 164) puts it, musicians found it possible "to preserve modal character without adhering slavishly to formulas only." Hence, within the constraints imposed by a given pitch framework, original tunes have been composed and new melodic formulae have arisen. In the words of Balzano (1982, p. 348): "Just as the desired movement of a melody over time shaped the character of these pitch set materials, so it was found that the character of the pitch set in turn shaped the perceptible quality of its melodies."

As this account suggests, pitch frameworks are much more than abstract ladders of intervals upon which notes can be hung more or less indiscriminately. In almost all musical styles (excluding those that use "artificial" grammars such as the "serial" techniques devised by Arnold Schoenberg; see Lerdahl, 1988; Ockelford and Sergeant, in press; see also Chapter 9), the pitches pertaining to frameworks are used in ways that differ systematically from one another (Huron, 2006, pp. 147ff.; Thorpe *et al.*, 2012; see also pp. 349–56). Since the more often something has happened in the past, the stronger, ceteris paribus, will be a listener's sense that it will occur again, members of pitch frameworks, and the relationships between them, develop distinct probabilistic identities. We *expect* "mid-range" pitches to occur more frequently than those at the extremes. We *expect* smaller intervals to be used more than larger ones. We *expect* pieces to end in the tonic key, following a dominant harmony (through a "perfect cadence"). These expectations lie at the heart of the sense of "tonality": the notion that relative pitches, as abstract entities, can fulfill different roles in relation to each other. Examples from the *Sounds of Intent* data include Scenario 47, Ursula, who improvises pentatonic tunes on the recorder (using the pitches D, E, G, A, and B) comprising short clusters of notes, the last of which invariably ends on G—suggesting that she has come to construe this as a tonic; and Scenario 62, Oscar, who improvises simple melodies, typically comprising several short phrases, that are always in the major key, the first phrase beginning, and the second ending, on the tonic.

In terms of a cognitive hierarchy, these examples suggest that the perception and creation of groups underpin the processing of frameworks, and therefore must occur earlier in development—something that is supported by the historical record, which, as we have seen, indicates that groups of notes ("melodic formulae") preceded the use of "abstract" pitch sets.

Evidence for a cognitive hierarchy pertaining to events, groups, and frameworks from the "mainstream" music-developmental literature

Further corroborative evidence for these three stages in music-structural processing capacity (events alone; groups and events; frameworks, groups, and events) is to be found in the literature pertaining to neurotypical musical development in the early years. For example, it seems that young humans have a built-in propensity to imitate others (see, for instance, Meltzoff and Prinz, 2002) that soon comes to play a part in early sound-making at the level of musical *events*:

> Careful auditory and acoustic analyses of preverbal communication at 2, 3, 5, and 7 months demonstrate that 34–53 per cent of infant vocal sounds are part of reciprocal matching sequences, framed by mothers' modelling and/or matching utterances (Papoušek, 1996, p. 97).

Moreover, it appears that infants below 5 months of age are capable of imitating individual pitches (Kessen *et al.*, 1979), pitch contours (Kuhl and Meltzoff, 1982), and vowel-like harmonic resonances (Legerstee, 1990).

In music, similarity and difference in sound work together to foster in listeners a sense of movement and repose, of initiation and closure, and to enable them to perceive trends and hierarchies. As we have seen, at a fundamental level, repetition binds variety together through the principles of *Gestalt* perception (Ockelford, 2002). This capacity features early in musical development. For example, Fassbender (1996) observed that infants as young as 2 to $5\frac{1}{2}$ months of age organize rapid tone sequences perceptually on the basis of proximity and similarity. The integrated recognition of sameness and difference is also important in the discrimination of melodic patterns. For instance, Trehub (1990) notes that infants can distinguish between different tunes on the basis of relational information at the age of 5 to 6 months—sensitively detecting violations of contours but *not* transpositions or contour-preserving transformations. Babies integrate repetition and variety in their vocal production too. For instance, between 4 and 6 months

> The impression of playful creative exploration arises from observations of infants' persistent motivation to reproduce sounds discovered by chance, and to repeat and modify their vocal products with overt signs of effort, eagerness, and joy (Papoušek, 1996, pp. 104, 105).

Later, from 7 to 11 months, the notion of repeating and varying *groups* of sounds as the basic units of proto-musical structure appears . . .

> canonical babbling involves production of short musical patterns or phrases that soon become the core units for a new level of vocal practising and play . . . (Papoušek, 1996, p. 106).

Gradually, groups of sounds may be linked through repetition or transposition to form chains, and the first self-sufficient improvised pieces emerge:

> Between the ages of one to two years . . . a typically spontaneous infant song consists of repetitions of one brief melodic phrase at different pitch centres (Welch, 2006, p. 318).
>
> They are unlike adult songs, however, because they lack a framework of stable pitches (a scale) and use a very limited set on contours in one song . . . (Dowling, 1982, pp. 416, 417).

From the age of $2\frac{1}{2}$, "pot pourri" songs may appear (Moog, 1976, p. 115), which borrow (and may transform) features and fragments from others—standard songs that are assimilated into the child's own spontaneous song schemes (Hargreaves, 1986, p. 73).[3]

[3] See also Mang (2005), who notes that self-generated songs may be seen as "referent-guided improvisation" using source materials derived from learned songs.

Table 5.2 The *Sounds of Intent* data and the literature on neurotypical musical development pertaining to events, groups, and frameworks

	***Sounds of Intent* data**[1]	**Evidence from the literature on neurotypical musical development**
Events	8, 10, 12, 16, 20, 25, 27, 30, 33, 41, 48, 51, 56, 71, 77	Kessen *et al*. (1979), Kuhl and Meltzoff (1982), Legerstee (1990), Trehub (1990), Fassbender (1996), Papoušek (1996)
Events and groups	17–19, 31, 37, 39, 44, 47, 50, 63, 64, 67, 72, 74	Moog (1976), Dowling (1982), Hargreaves (1986), Papoušek (1996), Welch (2006)
Events, groups, and frameworks	22, 34, 40, 42, 53, 58, 59, 62, 63, 66, 75	Hargreaves (1986)

[1] Numbers refer to scenarios in Table 5.1.

Finally, around the age of 5, two major advances typically occur, which pertain to *frameworks*. First, children develop the capacity to abstract an underlying pulse from the surface rhythm of songs (meaning that he or she performs "in time" to a regular beat). Second, they acquire "tonal stability," with the clear projection of a key center across all the phrases of a piece (Hargreaves, 1986, pp. 76, 77). These abilities imply a cognizance of repetition at a deeper structural level in the "background" organization of music.

The data from *Sounds of Intent* and the literature pertaining to the cognition and creation of musical events, groups and frameworks are summarized in Table 5.2.

The nature of auditory perception and cognition prior to the capacity to process musical structure

This model of how music-structural cognition may evolve begs an important question: what are its developmental precursors? As we saw in Chapters 2 and 3, at the heart of zygonic theory lies the notion of imitation, which has significance solely in the context of potential *variety*, since it is only through the sense of one sound deriving from another, which requires a potential range of options, that the notion of human agency in repetition comes to exist.

To take a step further back: for a child deliberately to create variety in sound (indeed, consciously to create a sound at all) implies that he or she has a sense of *agency*—the motivation and capacity for intentional action. And recognition of sound demands a basic level of auditory awareness, implying, in Sean Gallagher's terms (2000, p. 15) a "minimal sense of self . . . a consciousness of oneself as an immediate subject of experience, unextended in time" (Ockelford and Welch, 2012).

What evidence do we have from the *Sounds of Intent* data for the awareness, ability, and initiative to produce or recognize sounds in the absence of structure? A number of the scenarios set out in Table 5.1 attest to this level of development. Scenario 2, for example, shows the impact on Rosina of hearing the bell in the Little Room ring, as her vocalizing turns briefly into a laugh. We do not get the sense that the situation has predictability or pattern: it appears merely that Rosina reacts to the occurrence of a sound in her immediate environment. Similarly, in Scenario 24, Qiang's eye movements intensify when he hears the big band play loudly, though *what* they are playing (defined by the structure and content of the music) does not seem to be important; and Nathan (in Scenario 14) often vocalizes in response to vocal sounds that are made close to him, without, apparently, ever imitating what he hears. Here we have an interaction that is not yet structured in

the musical sense. Other scenarios pertaining to this level of functioning are Scenarios 4, 5, 7, 9, 11, 13, 15, 21, 23, 32, 35, 46, 54, and 76.

Engagement with sound of this nature is found early in neurotypical development too, both in terms of listening

> Infants in the first postpartum months are able to detect and discriminate small differences in frequency, amplitude, and the harmonic spectrum . . .. They are able to process time-related information and to differentiate sounds in terms of duration, pause length, tempo and relative timing in rhythmic sequences (Papoušek, 1996, p. 89).

and vocal production

> accounts of prelinguistic stages of vocal development . . . converge on a differentiation of six stages of vocal production: phonation (0–1 months); melodic modulation and primitive articulation in cooing (2–3 months); exploratory vocal play (4–6 months) . . .. Infants alternately produce squealing and growling sounds, screams and whispers, brief staccato-like noises, and drawn-out vowel-like sounds with extensive frequency modulation, which occasionally expand across one or two octaves (Papoušek, 1996, pp. 103, 104).

It is interesting to reflect, in the context of zygonic theory, what these observations tell us about the point at which specifically *musical* development emerges from the evolutionary path of more

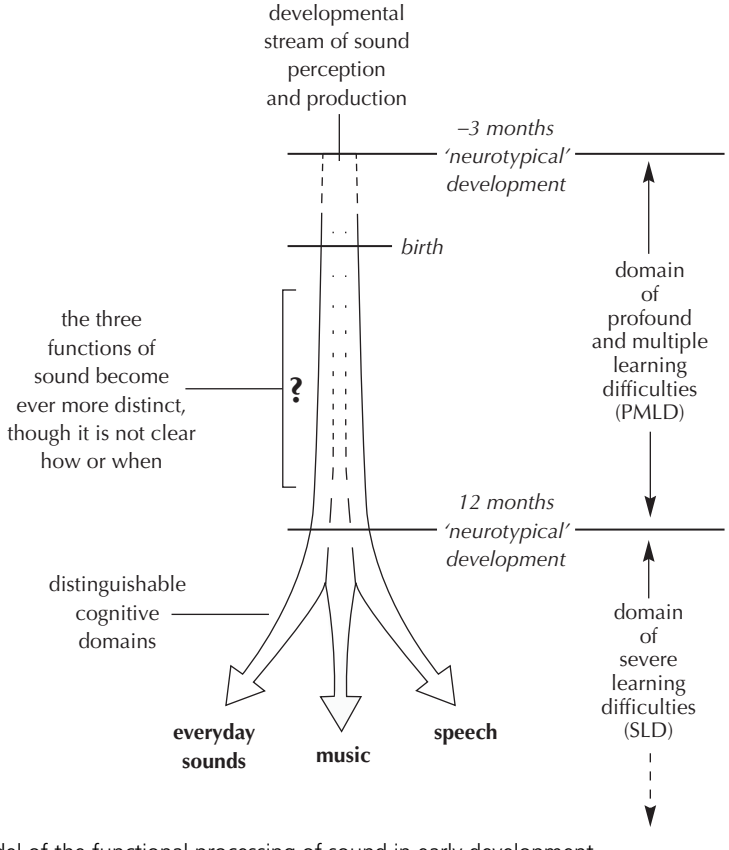


Fig. 5.8 Model of the functional processing of sound in early development.

general auditory skills—a question that has exercised some musicians having contact with the fields of education and therapy pertaining to those with profound and multiple learning difficulties (PMLD), and one that I have raised before in the context of an ecological model of acoustic perception (cf. Gaver, 1993; Clarke, 2005) (see Fig. 5.8).

While it is evident that, in a neurotypical context, children in the early years intuitively come to distinguish between the three main functions of sound (as music, as language, and as "everyday" auditory input, ranging from car engines to the wind whistling in the trees, from crashing waves to slamming doors), the neuropsychological literature is divided as to how much music processing shares neural circuitry with other areas, particularly language (see, for example, Maess *et al*., 2001; Koelsch *et al*., 2002; Levitin and Menon, 2003) or is modular (for instance, Peretz and Coltheart, 2003; Fedorenko *et al*., 2011). And there is also ambiguity pertaining to functional observations in the classroom. For example, on seeing a lesson in which I was encouraging pupils with PMLD to attend to different sounds, a piano teacher (used to working with children without intellectual impairment) questioned whether the activity in which the class was engaged was really *musical*. And on another occasion I was asked whether, by setting up a drum so that a young boy's repeated (and unthinking) arm movement created a regular pulse, which I then used as a basis for an improvised piece, one could reasonably say that he was functioning *musically* (since his contribution seemed to be unaffected by anything that I did).

One could argue that a certain confusion is inevitable without an agreed definition of "music." However, as we saw in Chapter 2, zygonic theory offers a way forward, in defining music unambiguously as a stream of sounds that are heard as deriving from one another through imitation. This offers psychologists and neuroscientists a point of reference to use when deciding which category auditory stimuli should fall into. And it answers the questions posed by my colleagues as to what constitutes "music" in working with children with PMLD. In the case of the children being

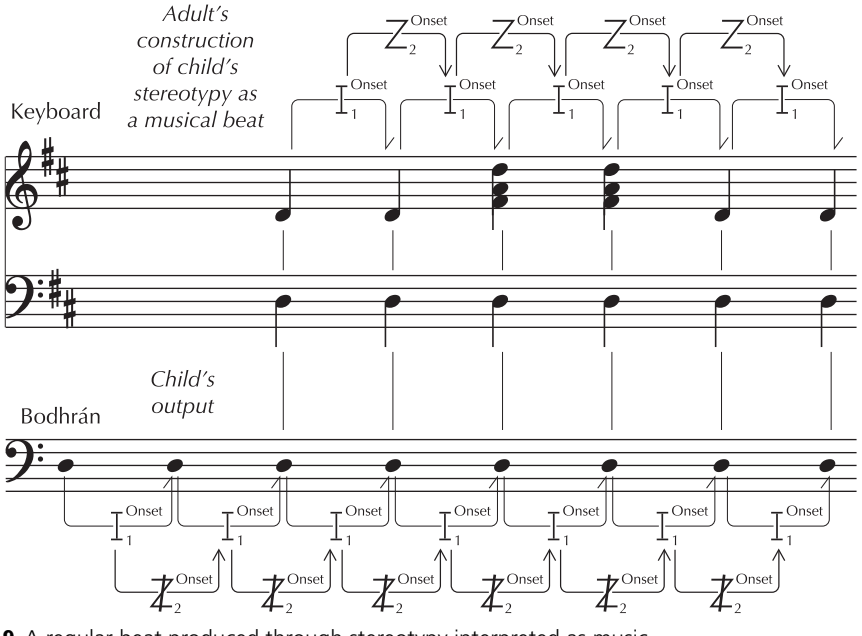


Fig. 5.9 A regular beat produced through stereotypy interpreted as music.

encouraged to attend to different sounds (between which no imitation is present), zygonic theory suggests that this should not be construed as an act of music cognition (though, as we have seen, the capacity to recognize perceived sonic variation is a necessary precursor). In the scenario in which a child repeatedly hit a drum as a result of dyskinesia (rather than consciously conforming to an externally determined pulse; see Fig. 3.15) and I improvised a musical framework around it, the position is more complex: philosophically akin to a listener hearing cuckoo calls as music (see Fig. 2.16). Here the results of the child's stereotypy were mentally *constructed* as music by staff: a specialist realization of a familiar teaching strategy to those working in the field of profound cognitive impairment, in which a child's actions are imbued with interactive or communicative intent in the belief that such scaffolding may foster development (cf. Wood *et al*., 1976; Vygotsky, 1987; Stone, 1998) (see Fig. 5.9).

A stage before auditory perception

As Fig. 5.8 shows, while the auditory perceptual system typically starts to function in the last trimester of pregnancy (Lecanuet *et al*., 1995), because children and young people with PMLD may be operating cognitively at a pre-natal level, their hearing may not (yet) have evolved, or may have been damaged to such an extent that the processing of sound appears not to occur at all. There are a number of examples in Table 5.1 that seem to indicate functioning at this level. For instance, Anna (Scenario 1), does not appear to react to the sound of the cymbal, even when her teacher plays it loudly near to each of her ears; Mark (Scenario 3) makes no discernible response to the "hello" song in music therapy sessions; and Yakov (Scenario 6) is apparently unaware of the rasping sounds he makes as he breathes. Other *Sounds of Intent* observations relating to this level of functioning are scenarios 36, 55, 57, and 60.

It is important to acknowledge that just because someone makes no discernible response or effort to engage with music this does not necessarily mean that they have no musical awareness or, indeed, intentionality: recent neuroscientific research has shown that patients in hospital who are unable to make voluntary "bedside" responses may nonetheless be able to communicate through willful modulation of brain activity (Monti *et al*., 2010). In the case of many profoundly disabled children, whose brains developed abnormally *in utero* or who suffered perinatal trauma, it seems unlikely that the necessary bank of memories would have been acquired for them to use the protocol of Monti *et al*., which demands consciously thinking about a particular experience. However, in the absence of evidence to the contrary, and as the case of Abby cited in Chapter 3 shows, it would seem ethically and philosophically unsafe to assume that children have no awareness of music, or desire to participate in musical activity, unless and until it is demonstrated incontrovertibly otherwise. Recent work in "bio-guided" music therapy (Miller, 2011) offers a promising way forward in this area.

Towards musical "maturity" in a given social and cultural context

The five categories of musical engagement identified above capture many of the *Sounds of Intent* scenarios described by practitioners (Fig. 5.1), but not all. Consider, for example, Scenario 38, in which we learn that Jamil, who has severe learning difficulties (SLD) and is on the autism spectrum, has "sophisticated musical tastes", enjoying music of the Baroque period and preferring a vocal tone with little vibrato. And take Scenario 52, which describes how Ciara, who is a good vocalist despite having SLD, is learning to convey a range of different emotions in her singing through using subtle variations in tempo and dynamics. Jamil and Ciara seem to have moved

beyond the abstract frameworks of pitch and time that children typically acquire around the age of 4 (Hargreaves, 1986) to a stage where they can consciously manipulate the characteristics of musical sounds in largely culturally determined ways to achieve expressive ends (see Swanwick and Tillman, 1986; Swanwick, 1991).

The six levels of music cognition suggested by the *Sounds of Intent* research

The foregoing discussion suggests that there are six levels of music-cognitive development that can be identified in children and young people with learning difficulties. These are set out in Table 5.3 (see Ockelford *et al*., 2010, p. 36). There now follows detailed discussion of these stages in relation to the scenarios set out in Table 5.1.

Level 1

There is no evidence of awareness of any sound, musical or otherwise; hence the issue of recognizing imitation does not arise (Fig. 5.10).

Level 2

Here sound emerges as a distinct perceptual entity, but relationships between sounds are not yet processed with sufficient consistency or coherence for the notion of imitation to exist (Fig. 5.11).

Level 3

At this level, children and young people are developing an awareness of the possibility and significance of *relationships* between single events or the basic features of sounds. The notion of "same" and "different" evolves, and, in due course, according to zygonic theory, underpins the

Table 5.3 The six levels underpinning the *Sounds of Intent* framework (acronym "CIRCLE")

Level	Description	Core cognitive abilities
1	Confusion and **C**haos	No awareness of sound as a distinct perceptual entity
2	Awareness and **I**ntentionality	An emerging awareness of sound as a distinct perceptual entity and of the variety that is possible within the domain of sound
3	Relationships, repetition, **R**egularity	A growing awareness of the possibility and significance of *relationships* between sonic *events* and the basic aspects of sounds
4	Sounds forming **C**lusters	An evolving perception of *groups* of sounds, and the relationships that may exist between them
5	Deeper structural **L**inks	A growing recognition of whole pieces, and of the *frameworks* of pitch and perceived time that lie behind them
6	Mature artistic **E**xpression	A developing awareness of the culturally determined "emotional syntax" of performance that articulates the "narrative metaphor" of pieces

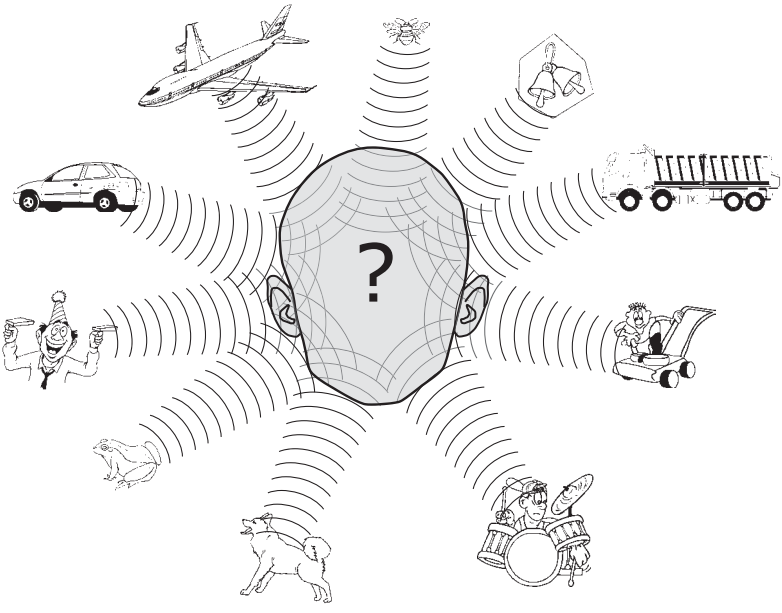


Fig. 5.10 *Sounds of Intent* Level 1: no awareness of sound as a distinct perceptual entity.

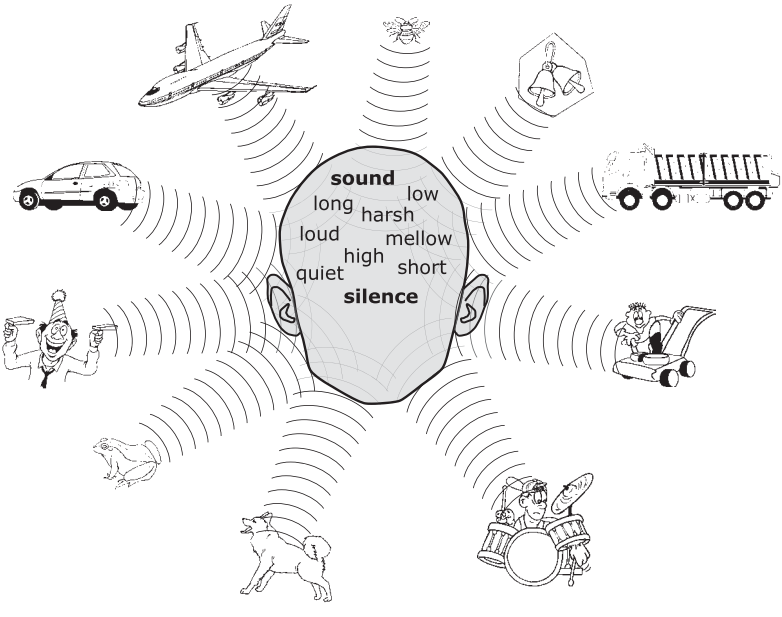


Fig. 5.11 *Sounds of Intent* Level 2: an emerging awareness of sound as a distinct perceptual entity and of the variety that is possible within the domain of sound.

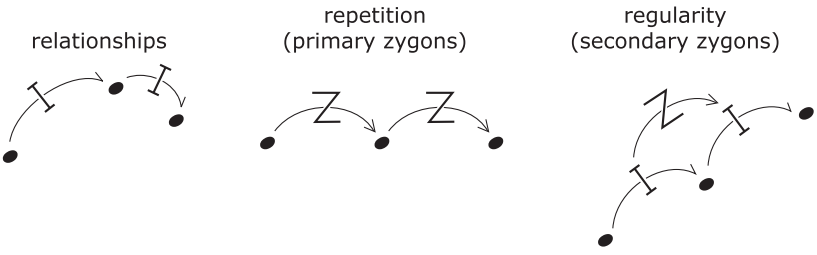


Fig. 5.12 *Sounds of Intent* Level 3: a growing awareness of relationships, repetition, and regularity in the domain of sound.

sense that, through imitation, one sound may be perceived as deriving from or generating another. As noted above, this is the point at which cognitive activity specifically pertaining to *music* can be identified (see Chapter 2). In abstract terms, auditory processing of this kind implies the recognition of primary interperspective relationships, primary zygonic relationships, and, potentially, the secondary zygonic relationships that may connect these (Fig. 5.12).

A key question here, discussed at some length in Chapter 3 and on p. 146–7 in relation to proactive engagement with music, is just when *repetition*—the notion of "the same sound again"—becomes *imitation*—the idea that one sound is heard as copying another in the context of potential variety on account of human agency. Consider, once more, Scenario 8, in which Wendy giggles when she hears people repeating patterns of syllables such as "ma ma ma ma" and "ba ba ba ba." To establish that this represents auditory processing at Level 3, one would have to be persuaded that it was the relationships between a chain of separate sounds that were the same rather than the quality of the sounds themselves (either individually or a group) that elicited Wendy's response. Hence, if a similar reaction were to be evoked by a *single* syllable or a stream of *different* vocal sounds, this would suggest that repetition was not an essential factor. Conversely, if the repetition of other sounds (but not changes in them) were to cause a comparable response, then this would support the view that Wendy could recognize relationships of identity in the auditory domain.

But this would not necessarily mean that Wendy could discern *imitation*, and therefore process sounds *musically*. This "pre-musical" level of functioning would be indicated if the repetition of any sounds, irrespective of their source (such as the sequences of beeps on microwave ovens or even the ticking of clocks and timers), induced the same emotional reaction as vocalizations. The sense of human agency demanded by music is easiest to observe in *inter*action: see, for instance, Scenario 71, where Zeeshan laughs and rocks when he hears his teacher imitating Tom; Scenario 20, where Ellen laughs when people repeat her vocalizations (but not, we may assume, when they make different sounds); and, most compelling of all, Scenario 25, where Xavier tries to copy the high and low vocal sounds of another.

Similar issues pertain to the way in which the relationships between sounds are themselves perceived as being related. For example, in Scenario 51 we learn that Ude is fascinated by the ever-changing sonorities of the didgeridoo, and Scenario 13 describes how Samantha waves her hand more and more vigorously through an ultrasonic beam, creating an ever wider range of swirling sounds. Here it seems to be the fact that change itself is changing that is the important thing; there is no evidence that the imitation of change is in play.

The fact that Noriko (Scenario 41) loves the little runs on the panpipes in Papageno's *Birdcatcher's Song* (Fig. 5.13) may appear to indicate that she can process secondary zygonic

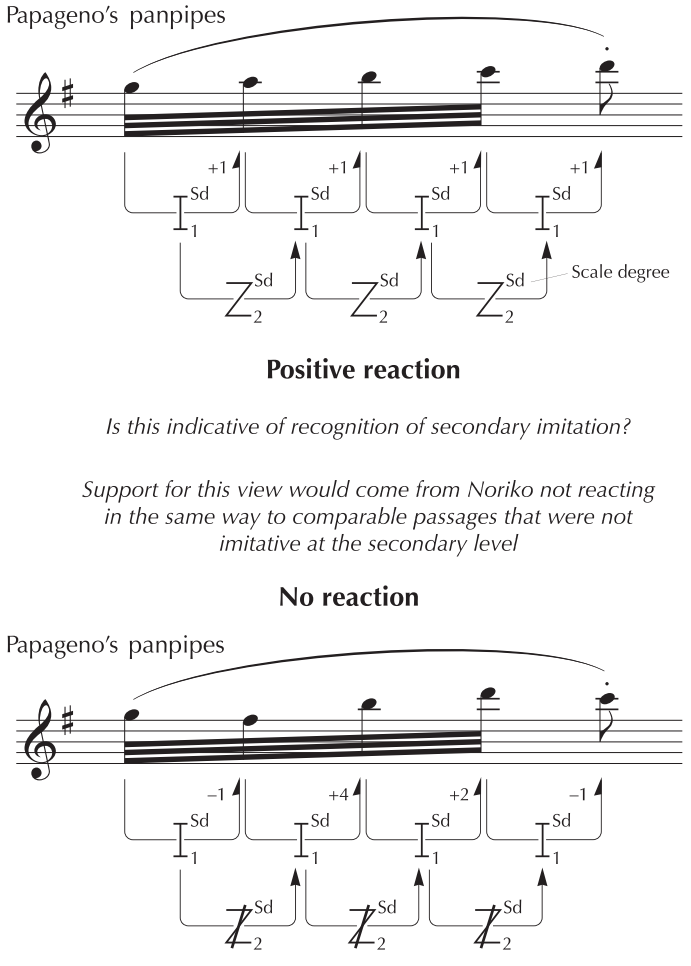


Fig. 5.13 Is Noriko's enjoyment of the runs on the panpipes in Papageno's *Birdcatcher's Song* an indication that she recognizes imitation at the secondary level?

relationships of pitch, through which successive ascending scale steps are heard as imitating those that precede. However, in the absence of further information, we could not be sure if her positive reaction to the melodic fragments merely resulted from a rapid increase in pitch in a high register. Hence we would need to expose Noriko to different configurations of ascending (and perhaps descending) notes to ascertain whether it was the structural properties (rather than other, surface features) to which she was responding. Or, maybe, like Diane (Scenario 56), Noriko occasionally produces short melodic vocal runs that ascend or descend in scale steps; or, like Carol (Scenario 12), she sometimes copies the ups and downs of her speech and language therapist's voice. This would be powerful evidence of the presence of secondary zygonic imitation.

Similarly, Scenario 10, where Khira gets excited when she hears the beat on the school's drum machine, would, on the face of it, seem to imply the recognition of secondary zygonic relationships

of onset. However, one would need to rule out whether it were just a series of electronically synthesized sounds that caused the reaction (perhaps by playing Khira series of notes that were irregularly temporally spaced) or even the sound of the drum machine itself (by testing whether she reacted to a regular beat that utilized other sounds). This, though, would merely confirm that it was the repetition of inter-onset intervals that was important. To be sure Khira's was a *musical* reaction, in which imitation played a part, one may need to observe her engaging proactively in rhythmic work (as in Scenario 48, for example, where Liz taps out a regular beat at different speeds on a range of handheld percussion instruments) or interactively (copying a range of different pulses).

It may be that tertiary zygonic processing is also possible at Level 3. For example, William's rocking (Scenario 27) increases markedly as the Japanese taiko drumming gets faster and faster. But we would need to be persuaded that it was the *regularity of increase* that caused William's change of behavior. The position is clearer with Hackett (Scenario 30), who makes the change of pace himself (Fig. 5.14).

Level 4

Here, children and young people have an evolving perception of sounds functioning as *groups*, and of the relationships that may exist between these (Fig. 5.15). We saw earlier (pp. 136–9) how groups of sounds are formed by members having a quality or qualities in common that are not shared by non-members—invariably in the domain of perceived time, and often in relation to pitch, loudness, or timbre too. According to zygonic theory, such similarity is deemed to occur through imitation—through primary, secondary, or (occasionally) tertiary zygonic relationships (see Ockelford, 2004). As we observed, relationships *between* groups can take one of two forms: where one is perceived to derive from another *as a whole*, and where one *aspect* of a group is perceived as deriving from one *aspect* of another.

Examples of this theory were presented earlier in relation to vocal interactions involving K and Shivan. We now take this discussion further, drawing first on the description of Lottie's musical engagement set out in Table 5.1 (Scenario 17), which tells us that she likes to hum a distinct pattern of notes and repeat it (see Fig. 5.1). Here, the primary grouping mechanism is temporal, in that the onsets of notes following the first are contiguous with the endpoints, in each case, of those that precede, and the boundary between groups is determined by the relatively long break between the end of one note and the beginning of the next. The sense that there are two distinct clusters of notes is reinforced through the repetition of the first group as a whole.

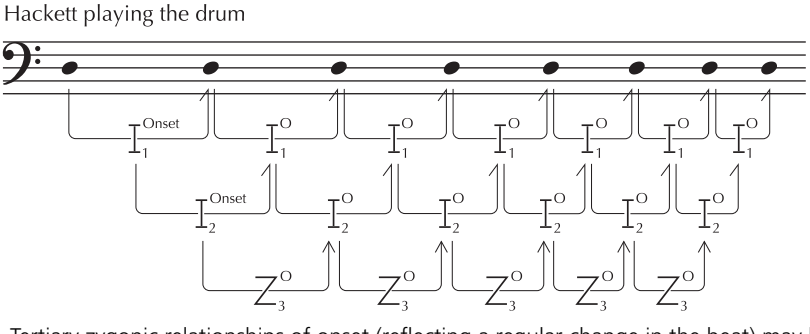


Fig. 5.14 Tertiary zygonic relationships of onset (reflecting a regular change in the beat) may be part of music-cognition at *Sounds of Intent* Level 3.

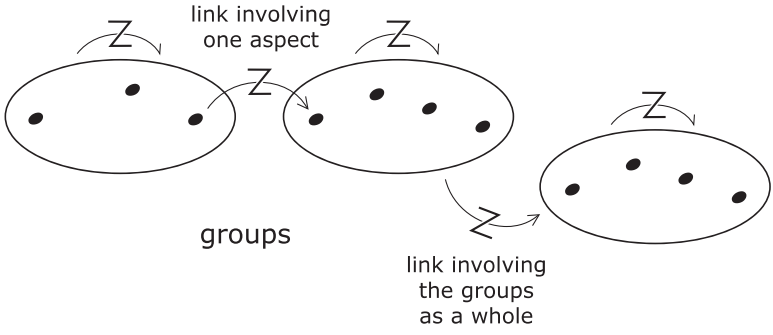


Fig. 5.15 *Sounds of Intent* Level 4: an evolving perception of groups of sounds, and the relationships that may exist between them.

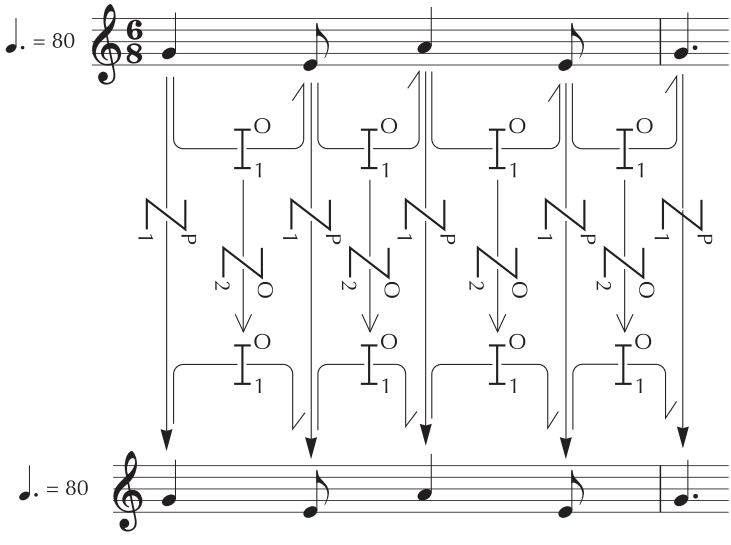


Fig. 5.16 Lottie's short-term recall of the motif is assumed to function using primary zygons of pitch and secondary zygons of onset.

Since both motifs use the same series of pitches and inter-onset intervals, the imitation between groups could be thought to occur through primary zygonic relationships of pitch, and secondary zygons of onset (Fig. 5.16).

However, as Lottie sings the same motif on different occasions at various pitches and tempi, it is evident that the sequence of notes is also encoded in relative terms, through primary inter-perspective relationships of pitch and secondary relationships of onset. In these circumstances, the imitative relationship between one motif and another needs to be understood in terms of secondary zygons of pitch and tertiary zygons of onset (see Fig. 5.17).

We can surmise, though, that absolute links are not entirely absent for Lottie, since the motifs she reproduces on separate occasions are broadly similar in pitch and tempo. However, for children such as Faisal (Scenario 34) and Romy (p. 135), who have AP, the position is rather different, since they have the capacity to encode the pitch data from motifs directly, rather than as intervals. Hence, in seeking to remember and repeat groups of notes over significant periods of time, they

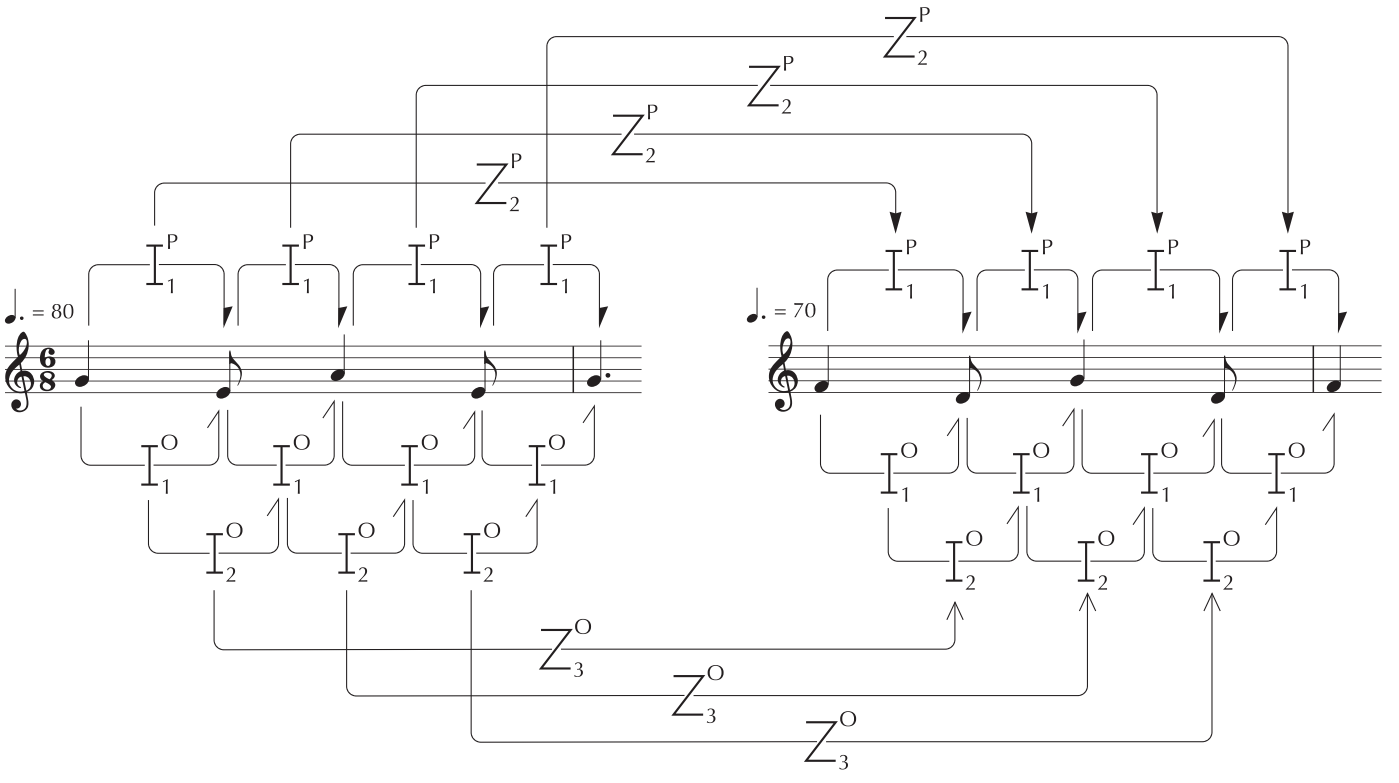


Fig. 5.17 Lottie's long-term recall of the melodic motif is assumed to use secondary zygons of pitch and tertiary zygons of onset.

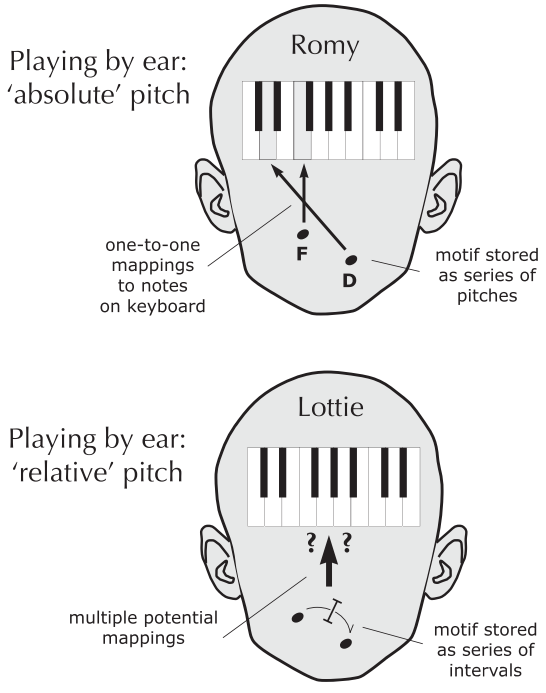
have a processing advantage over Lottie, since she has to extract and store information at a higher level of abstraction.

This may help to explain why children on the autism spectrum with AP tend to show musical precocity, often developing instrumental skills at an early age (particularly on the piano or keyboard) with no formal tuition (Ockelford, 2010a, b, 2012c). For them, reproducing groups of notes that they have heard is merely a question of remembering a series of one-to-one mappings between given pitches as they sound and the keys on a keyboard that produce them. These relationships are invariant: once learnt, they service a lifetime of music-making, through which they are constantly reinforced. When children such as Lottie seek to play by ear, however, they have to master the far more complicated process of calculating how the intervals that they hear in their heads map onto the distances between keys, which, due to the asymmetries of the keyboard, are likely to differ according to one's starting point. For example, producing a minor third (the interval that opens Lottie's vocal motif shown in Fig. 5.1) can be achieved through 12 distinct key combinations, comprising one of four underlying patterns. Moreover, the same physical leap between keys may sound different according to its position on the keyboard (see Fig. 5.18).

For sure, many children with AP who learn to play by ear rapidly develop transpositional skills too, and some, including a proportion of those with SLD, are able to play fluently in every key (a capacity that, as a teacher, I strongly encourage). This may appear contradictory, in the light of the processing advantage conferred by being able to encode pitches as perceptual identities in their own right, each of which, as we have seen, maps uniquely onto a particular piano or organ key. But the reality of almost all pieces is that motifs variously appear at different pitches, and so to make sense of music, young children with AP need to learn to process pitch relatively as well as absolutely. This begs the question of how the two forms of processing evolve and interact in a child's musical development—an issue that provides an example of where the more protracted cognitive maturation of children with learning difficulties may hold an advantage for the observer, since changes that usually occur quickly and early on (around the age of 2 in the case of AP; Ockelford 2012c) may still be in evidence later, and subject to very gradual transformation.

Let us take the case of Romy once more, who was 8 when we met her in Chapter 4. At the time of writing she is 11, and has a repertoire of around 60 song excerpts and fragments of other pieces from a wide range of styles that she enjoys using as material for improvised interactions on the piano. In re-creating these motifs, she largely plays the melody alone with the right hand, although she sometimes supplies a bassline in the left, occasionally adding chords and, in the case of the opening of the theme from the second movement of Beethoven's *Pathétique* sonata, a moving inner part. Apart from being an utterly joyous musician with whom to work, Romy is fascinating from a music-psychological point of view because she does not always get things right, and it is in her pattern of errors that one can obtain a rare glimpse into the workings of an exceptional musical mind (cf. Ockelford, 2011): in particular the relationship between absolute and relative pitch processing, which, in her case, is still evolving.

For example, one of her passions of the moment is the theme from *Vltava* by Smetana. I first played Romy the tune in E minor (the key in which it initially appears in the symphonic poem), and she quickly picked it up using her AP ability, invariably reproducing the outline of the melody correctly, sometimes adding new details of her own (see Fig. 5.19). This seems straightforward enough. But Romy is what can only be described as an obsessive transposer. She will very often play the same motif over and over again, frequently changing key between each rendition, and sometimes even modulating *within* a particular appearance of the musical fragment concerned. As she likes me to provide an accompaniment, the latter tendency is particularly challenging. It may be, though, that it is this very challenge that offers one possible explanation for Romy's



first key press produces sound
mental calculation of interval from this sound
(initial) trial and error to find second key (to match the interval)
there are 12 possibilities: four different patterns
confounding factor: the same pattern and similar ones produce different *intervals*

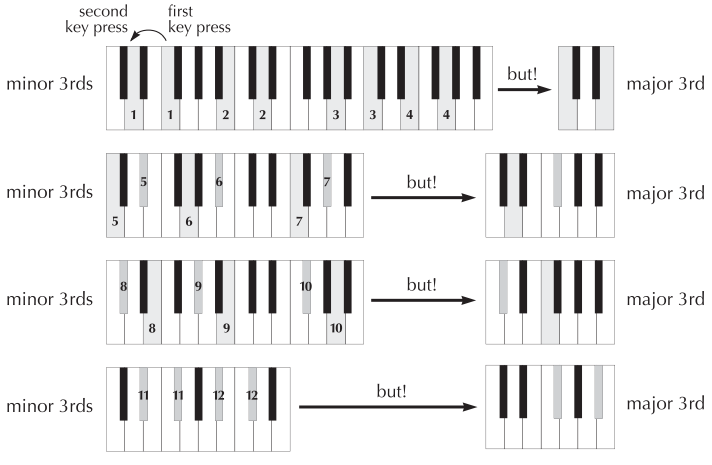


Fig. 5.18 Different mechanisms involved in playing by ear using 'absolute' and 'relative' pitch abilities.

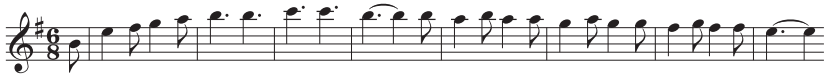



Fig. 5.19 A typical rendition of the *Vltava* theme in E minor by Romy.

maverick modulations, since they keep her firmly in control of the shared musical narrative. This is a subtle development of the influence she previously exerted through playing material in different keys to *prevent* me from joining in (see pp. 89–93). Three years later, she is now content for me to participate in her creative flow provided that she feels in charge of what is happening.

Another reason, I believe, for Romy's constant key changes is the buzz she gets from hearing things that are at once well-known and novel: "so familiar and yet so strange" (Kayzer, 1995). Only someone with her powerful sense of AP could experience shifts of key in this way: she will often leap up and shriek with excitement as she hears the impact of a motif that she knows well appearing as a fresh set of pitches—seeing old friends in a new light. And yet she sometimes makes mistakes that remain uncorrected at the time, and which are repeated on future occasions. For example, in her version of the introduction of the *Vltava* melody in F minor, she plays a B♮ instead of a C (see Fig. 5.20). This is a blatant error (observers in Romy's lessons notice it straight away) that is not—unlike most of her other (infrequent) mistakes—rule-preserving within the prevailing tonal schema (see Level 5).

It seems inconceivable that, at a certain level, Romy, does not recognize that something is wrong, given her advanced music-processing abilities. Yet at the same time, we can assume that she *wants* to play things correctly (she very rarely makes mistakes, and is somewhat intolerant of any changes that I may try to introduce—rule-preserving or not—within the accompaniments with which she is familiar). So what is going on? Zygonic theory provides an effective way of analyzing this "*Sounds of Intent* Level 4" issue.

To this end, let us take a step back and reconsider Lottie and her musical motif (see pp. 153–4). Since Lottie reproduces her pattern of intervals at different absolute pitches, we previously made the assumption that this information is encoded largely as primary interperspective relationships of pitch (cf. Fig. 5.17). Now, imagine that Lottie is at the stage of beginning to sing the first note. Without thinking, she chooses a pitch (which will approximate to the ones she has used in earlier renditions of the same motif). We can surmise that this will be stored in working memory and become a reference point for those that follow (functioning as a temporary "absolute" in the domain of pitch). Similarly, the second note will be retained, as a potential benchmark for others. Hence the third note will have two possible points of reference, the fourth three, and so on: the unfolding network of relationships creating an embryonic pitch "framework" (see comments on pp. 139–42, and later in relation to Level 5) through which the notes are mentally locked together (Fig. 5.21). There are no conflicts, and the structure is self-sustaining.[4]

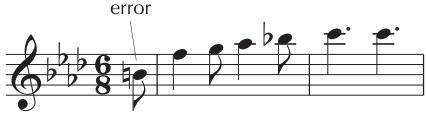



Fig. 5.20 Romy's rendition of the opening of the *Vltava* theme in F minor.

[4] Although, as amateur choirs know to their cost, temporary "absolute pitch" markers can drift over time without the singers' cognizance.

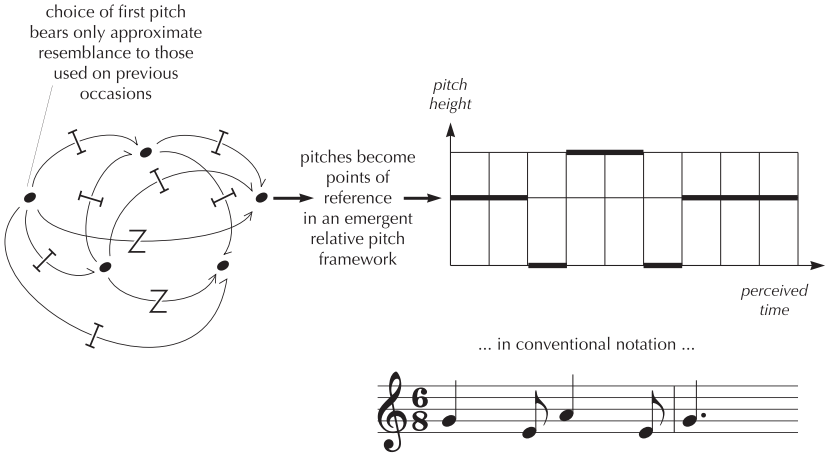


Fig. 5.21 A 'relative pitch framework' is thought to emerge and subsequently underpin Lottie's production of a motif, beginning at an unspecified pitch level.

How does this differ from Romy's position? We know that she initially encoded the *Vltava* theme as a series of pitches pertaining to E minor (and therefore starting on an B). When retrieving the melody at this pitch level, the task appears (for her) to be straightforward, and she re-creates it without error (Fig. 5.19): we can assume that she plugs into her absolute pitch memories (which are, of course, not unique to this melody) and reifies them on the piano.

It is not clear whether she *also* encoded the melody in relative terms, distinct from the "absolute" memories; although, as we shall see, the error she makes throws this into doubt. Let us assume for the moment that the pitches were only encoded as absolute values. Given a series of data in this form, zygonic theory suggests that there are two strategies that Romy could adopt when she tries to transpose. The first would be to draw into working memory her long-term recall of absolute pitches, and calculate a transposed version of each. Inevitably, this would produce interference in working memory, since the values being calculated anew would conflict with those being remembered, yielding the potential for confusion, and therefore error (see Fig. 5.22). Similar incompatibilities would arise if an attempt were made to extract intervallic information from the series of absolute pitches as they were recalled, either in the form of successive intervals, or as a succession of values relative to a given tonic. However, if relative data, in either of these two forms, were *dissociable* from the absolute, then conflicts would not arise, and, we can surmise, errors would be less likely. Hence, one explanation for Romy's mistakes in transposition may be a lack, or partial lack, of isolable relative encoding of pitch in her long-term memory. Further research, which examined her *pattern* of errors in different keys, may or may not lend support to this hypothesis.

What is clear, however, is that most children with AP *do* find ways of resolving the potential conflict between the "absolute" and "relative" encoding of pitch. Freddie, for example, aged 12, with autism and AP, learnt to play major and minor scales in every key on the piano by ear—but he only required C major and C minor as models. These provided him with the all the information he required. When asked to play the scales on other notes, one could hear him singing the next note that was required, and then finding the relevant key on the piano, which he did very rapidly

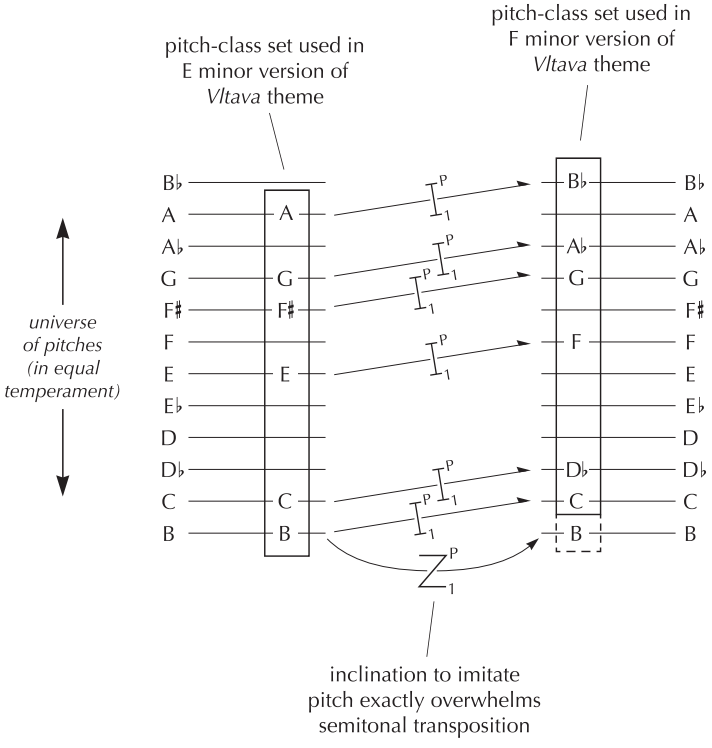


Fig. 5.22 Conflict between absolute memories recalled and (potentially) transposed is thought to result in confusion and induce error.

as, through his AP, he has a good awareness of what each note sounds like.[5] Any mistakes he made (largely due to difficulties with fingering, which he continues to learn much more painstakingly through physical demonstration and support) were immediately corrected. Hence we can assume that Freddie encoded the initial scalar patterns (C major and C minor) absolutely, abstracted intervallic information from those traces, and subsequently drew on the relative pattern when transposing, plugging the nodes of the intervals back into his AP framework (at a different level from the original) (Fig. 5.23).

Whether Freddie's pitch relativity exists between successive notes or between each note and an imagined tonic is a moot point, although the evidence of the negative impact of atonality on one musical savant's capacity to process intervals (and even pitches)—see Chapter 9—suggests that the latter (the perception of "scale degree") is likely to be an important ingredient in the encoding mix.

[5] Indeed, Freddie frequently plays "silent" scales, just touching the notes with his fingers, sometimes singing the pitches that would have sounded, and sometimes (presumably) hearing them only in his aural imagination. It appears that, for him, pressing the keys to make them sound is a redundant activity, since he has such a vivid impression of the pitch of each.

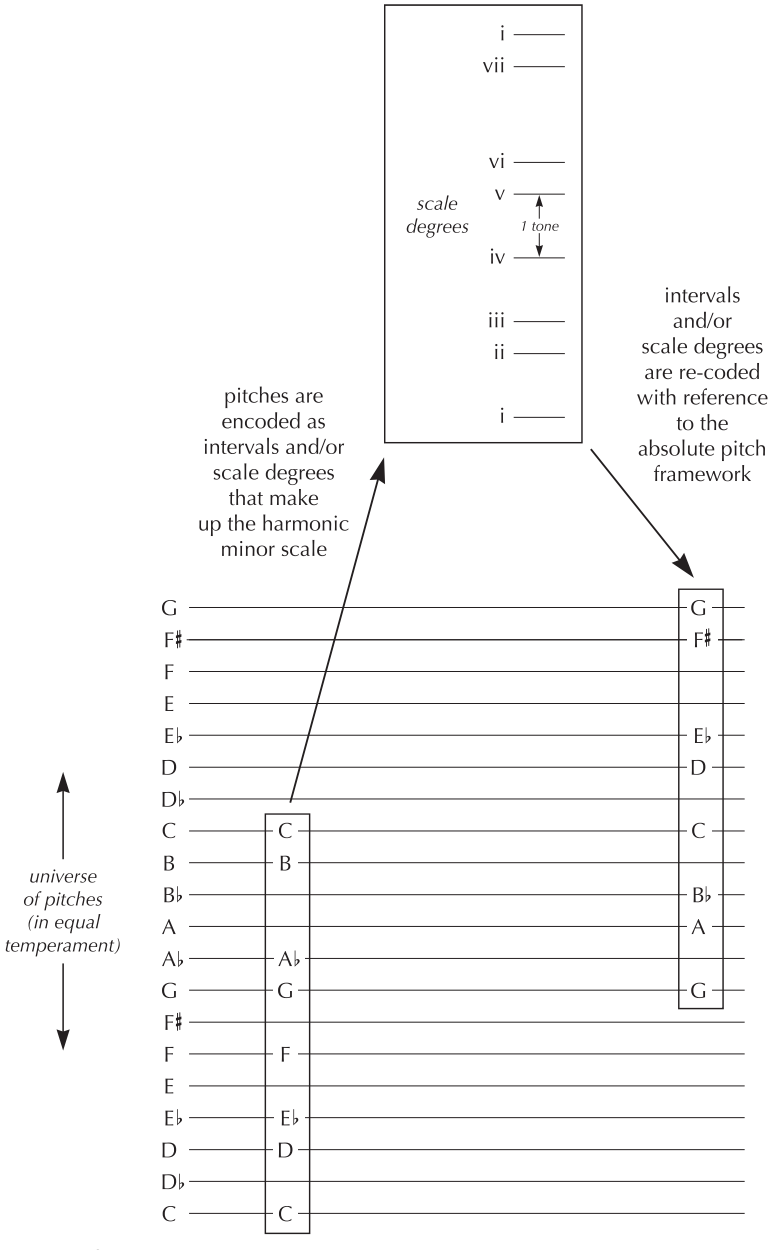


Fig. 5.23 Example of Freddie's hypothesized mental processing in transposing a scale.

In summary, then, despite the conflicts that may arise from retrieving pitches encoded relatively and absolutely, there seems to be little doubt that the possession of AP offers a huge advantage to the musical development of children with learning difficulties in particular, for whom many of the more conventional ways of learning (through emulating peers working in social groups or through being taught using notation, for example) may not be available. In short, AP may well

enable children who would otherwise be unable to do so to function at *Sounds of Intent* Level 4 and above, and beyond this it is AP that catalyses the exceptional achievement found in musical savants (see Chapters 6 and 7).

Level 5

The musical products of Lottie, Romy, and Freddie point towards the development or existence in cognition of abstract *frameworks* of pitch—imaginary intervallic ladders upon which notes can be hung. Similarly, in the domain of perceived time, the apprehension of a hierarchy of pulses (theorized as "meter") underpins rhythmic creation and cognition. It is believed that such frameworks are internalized through repeated exposure and, in one form or another, are common to virtually all music. Internally, they are highly structured, repeatedly using the same (or very similar) primary interperspective values of pitch and onset. In zygonic terms, this implies derivation occurring *between* appearances of pitch-time frameworks and *within* them (see Fig. 5.24).

Pitch frameworks are typically asymmetrical, which means that values can be used idiosyncratically with respect to the unique position that each occupies within a set (Ockelford, 2006a, p. 117). As we noted earlier, the perception of pitches as fulfilling distinct and recognizable functions in relation to one another is a characteristic of many styles and has given rise to the notion of "tonality." There are a number of ways in which tonal schemata (whose precise nature varies from pitch set to pitch set and style to style) are engendered. One is through the relative frequency of occurrence of values, a factor that a number of studies have shown is important in learning, perception, and expectation (for direct evidence, and comparisons with earlier work, see Krumhansl *et al.*, 1999, pp. 157ff.). Subsequently, Aarden (2003) showed that the *context* of occurrence of pitch-degrees is important too. The fact that exposure to music in which the frequency distribution of perspective and interperspective values is reasonably consistent can translate into future expectation as to their future probabilities of occurrence can be modeled zygonically (see Fig. 8.41). In tonal music, *transitions* between values have distinctive frequencies of occurrence too (see p. 354).

This complex cognitive activity is held to be characteristic of musical development at Level 5 of the *Sounds of Intent* framework. It is not entirely clear, however, how the different elements evolve. For example, there are tentative signs that, in Ursula's case at least (Scenario 47), an awareness of pitch frameworks appears before a full appreciation of their idiosyncratic patterns of utilization, as her improvised pentatonic tunes on the recorder have, over time, become increasingly likely to conclude with G.

General evidence for the cognitive development of pitch and perceived temporal frameworks is to be found in children singing or playing increasingly in time and in tune over sustained periods (for the duration of whole songs): consider, for instance, Sabina's progress in her Suzuki cello group (Scenario 42), and Oscar's advances in singing (Scenario 62). Finally, note that a developing awareness of frameworks seems to go hand in hand with the recognition of pieces as holistic entities, and of the prominent structural features within them (Fig. 5.24). Consider, for example, Scenario 22, in which Imogen gets excited in the middle of the "slowly/quickly" song, to which she has recently learnt to tap to the beat, anticipating the sudden change of pace; and Scenario 75, in which Wallace, who is getting better at holding a steady tonal center throughout songs, has recently started improvising short pieces that have a distinct beginning, middle, and end.

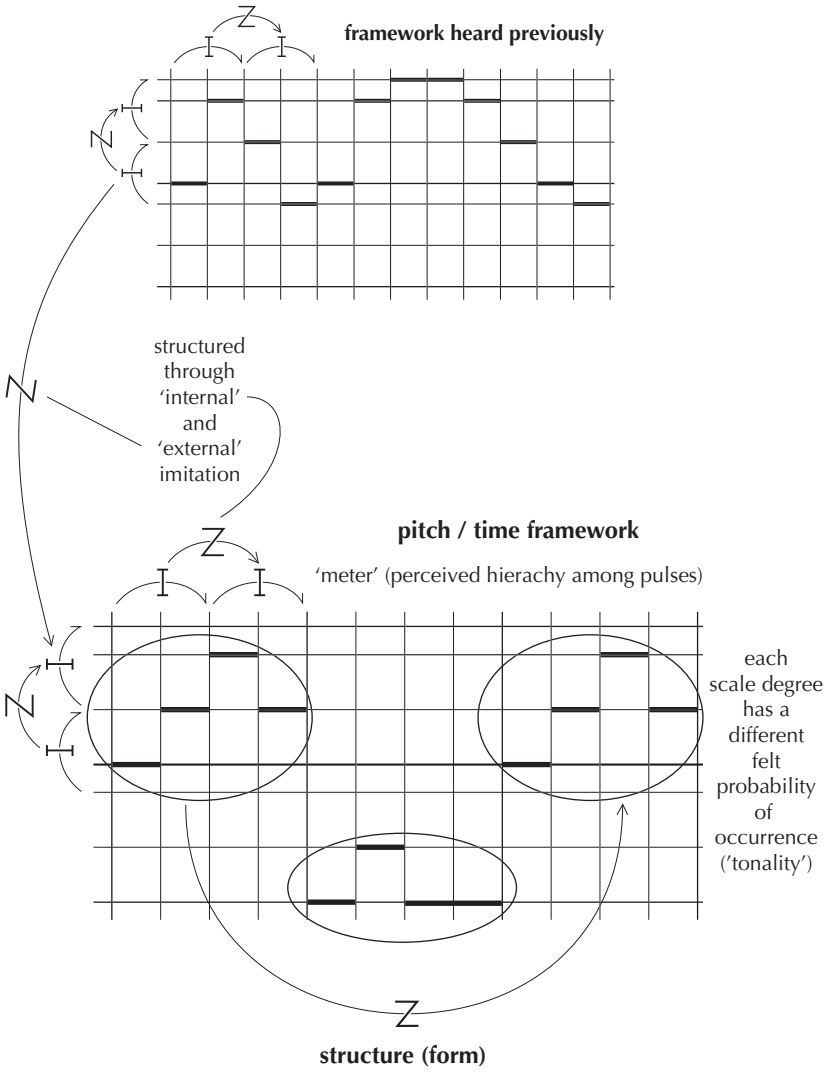


Fig. 5.24 *Sounds of Intent* Level 5: a growing recognition of whole pieces, and of the frameworks of pitch and perceived time that lie behind them.

Level 6

This level, which is concerned with what may be described as "mature musicianship"—when children and young people are aware of the conventions of performing and creating music within their culture, and intuitively understand the expressive and communicative intent of pieces to which they are exposed—is the least researched of all, in either the music-psychological or educational domains (though see Swanwick and Tillman, 1986; Swanwick, 1991). In Western performance, functioning at Level 6 entails an awareness of how underlying musical content and structure may be enhanced perceptually through devices such as rubato, vibrato, and dynamics. Such perturbations to the stable, invariant, imaginary "core" of a piece (which experienced listeners are

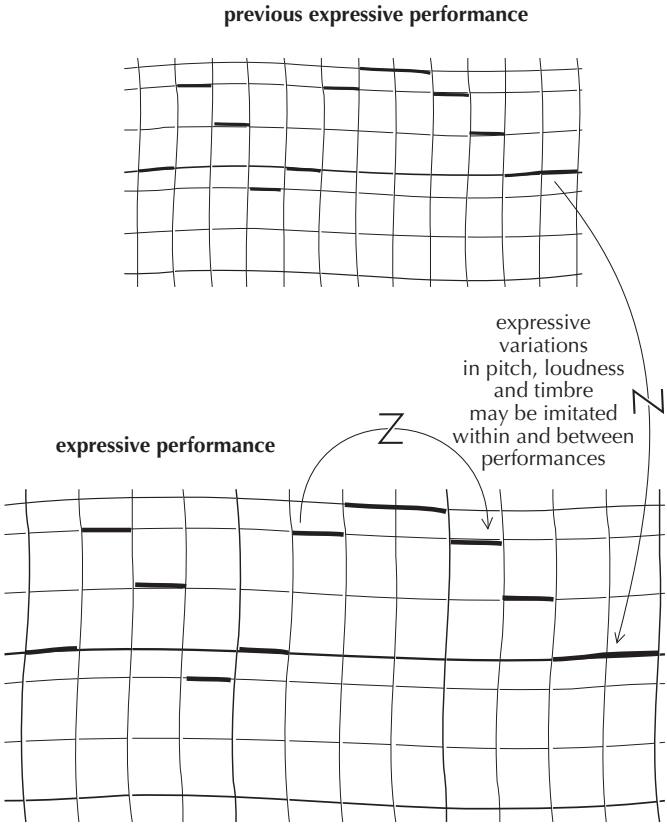


Fig. 5.25 *Sounds of Intent* Level 6: a developing awareness of the culturally determined 'emotional syntax' of performance that articulates the 'narrative metaphor' of pieces.

intuitively able to extract) are determined largely through convention—in zygonic terms, through the imitation of previous performances—although some expressivity may be specific to a particular rendition, and may be passed between performers in ensembles (see Fig. 5.25). In this way musicians articulate the "narrative metaphor" of pieces (the abstract stories in sound that they tell).

There are a number of examples of children and young people who appear to be functioning at Level 6 in the *Sounds of Intent* data cited in Table 5.1. Consider, for instance, Scenario 5.28, in which Milán—lead singer in his pop group at school—slows down before the return of each chorus of *Thank You for the Music* for expressive effect. Milán is severely developmentally delayed and on the autism spectrum, and, as he normally displays little or no emotion in everyday life, his teacher questions whether he actually *feels* the music and, if so, whether it is emotional engagement that drives the rubato or (his teacher wonders) is it merely a device that Milán has copied unthinkingly from Agnetha Fältskog's performance with ABBA that he has accessed on YouTube? Evidence for the latter view comes from the fact that, although Milán uses similar conventions of Western musical expression in other songs, they always appear to match recordings that he has heard rather closely. And, as far as his teacher is able to ascertain, Milán does not transfer the interpretative gestures he reproduces in one context to novel scenarios.

Other performers, such as the blind, autistic, learning-disabled pianist Derek Paravicini (see Chapters 6 and 7), in whom it is similarly possible to discern only a limited range of emotions in day-to-day life, seem to have taken the next step. Derek has learnt the "emotional syntax" of expressive performance in a range of styles with which he is familiar: that is, he has acquired a repertoire of expressive devices that he can apply to new music in a rule-based way at appropriate points to communicate different feelings. For example in the documentary about him, *The Musical Genius* (originally screened in 2005 on Channel 5 in the UK and Discovery Health in the US), I created a short sequence of chords on the computer that, in terms of performance, were devoid of any expressivity at all. However, in conversation with the music psychologist John Sloboda, Derek showed that he was able to convey different emotions (joy, sorrow, and—least convincingly—anger) through improvising on the series of chords in different ways, which included the introduction of expressive devices (such as changes in dynamics and rubato) as well as structural alterations (including the introduction of the minor key).

On viewing the program, a number of people have asked the same question that Milán's teacher was keen to answer, to the effect of: "Derek may be able to convey emotion in his playing (he has evidently learnt the 'code' of expressive performance), but does he *feel* it himself?" Ultimately, since Derek has very limited powers of metacognition (his capacity to reflect on his own thinking), this issue may remain unresolved. However, there are two points that I think are worth making in this regard. The first is, does it matter? Derek loves playing *for other people* (he rarely, if ever, plays at his own instigation for his own amusement), and since his performances bring him and his audience pleasure, is it critical to have a precisely shared message? Or is the fact that positive communication takes place (even if the message as transmitted and received is somewhat different) the important thing? This highlights an issue that is problematic for all performers: since, as we saw in Chapter 2, music exists only in the ear of the beholder so, by definition, does musical *meaning*, and it is inevitable that in any live musical engagement, performers and members of the audience will experience subtly (even, on some occasions, radically) different things. The second point is that Derek, and others like him, may come to learn about their own feelings *through music*, which they may then recognize in everyday life (rather than via the more common route of experiencing reactions to people and events, which are subsequently felt to be conveyed by music). Such responses may occur directly, as when Derek *feels* emotion as he listens to music (just as neurotypical listeners do), or indirectly: for example, when he performs with others, and detects a communicative intent in the way they play or sing—intentions that may be confirmed verbally.

It is issues such as this, that lie at the heart of what it means to be "musical," which are central to the thinking that underpins *Sounds of Intent* Level 6.

Representing the *Sounds of Intent* framework visually

Extending the six *Sounds of Intent* levels across the three domains of musical engagement that had been identified (reactive, proactive, and interactive) gave rise, after much discussion among the *Sounds of Intent* research team and practitioner colleagues, to the following "headlines" or "level descriptors" of musical engagement (see Fig. 5.26). These were arranged as 18 segments in circular form, which was regarded as being the most appropriate metaphor for children's development, ranging from the center, with its focus on self, outwards, to increasingly wider communities of others. For ease of reference, levels were ranked from 1–6, each of which could be preceded with an R, a P, or an I to indicate, respectively, reactive, proactive, or interactive segments.

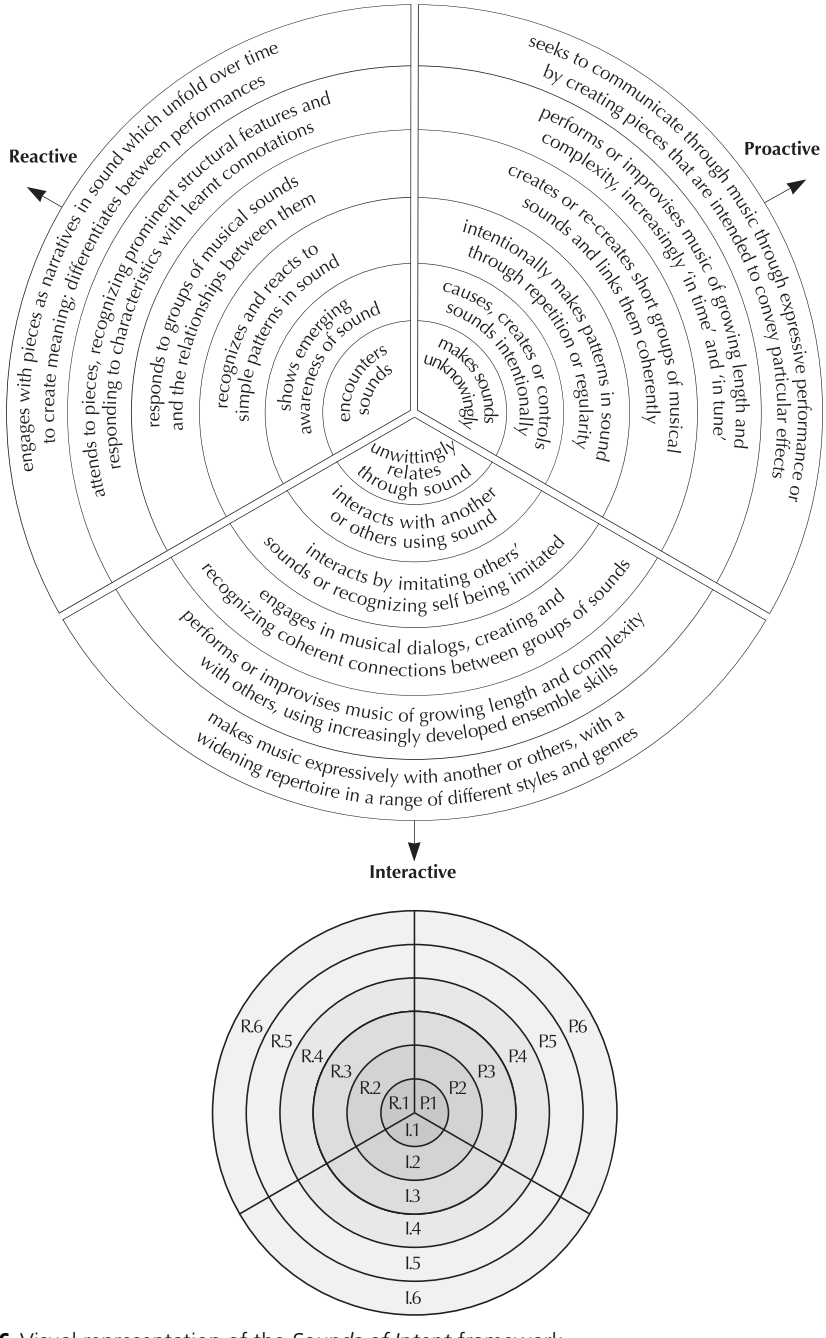


Fig. 5.26 Visual representation of the *Sounds of Intent* framework.

Using data such as those shown in Table 5.1, each of these 18 descriptors was broken down into four more detailed elements (see Fig. 5.27), which, through extended piloting, discussion, and modification, the *Sounds of Intent* research team believed offered a fair reflection of each segment. Some related purely to engagement with sound and music, others to sound and music in relation to other sensory input, and the remainder to technical matters pertaining to performance, which it was felt became important at Levels 5 and 6.

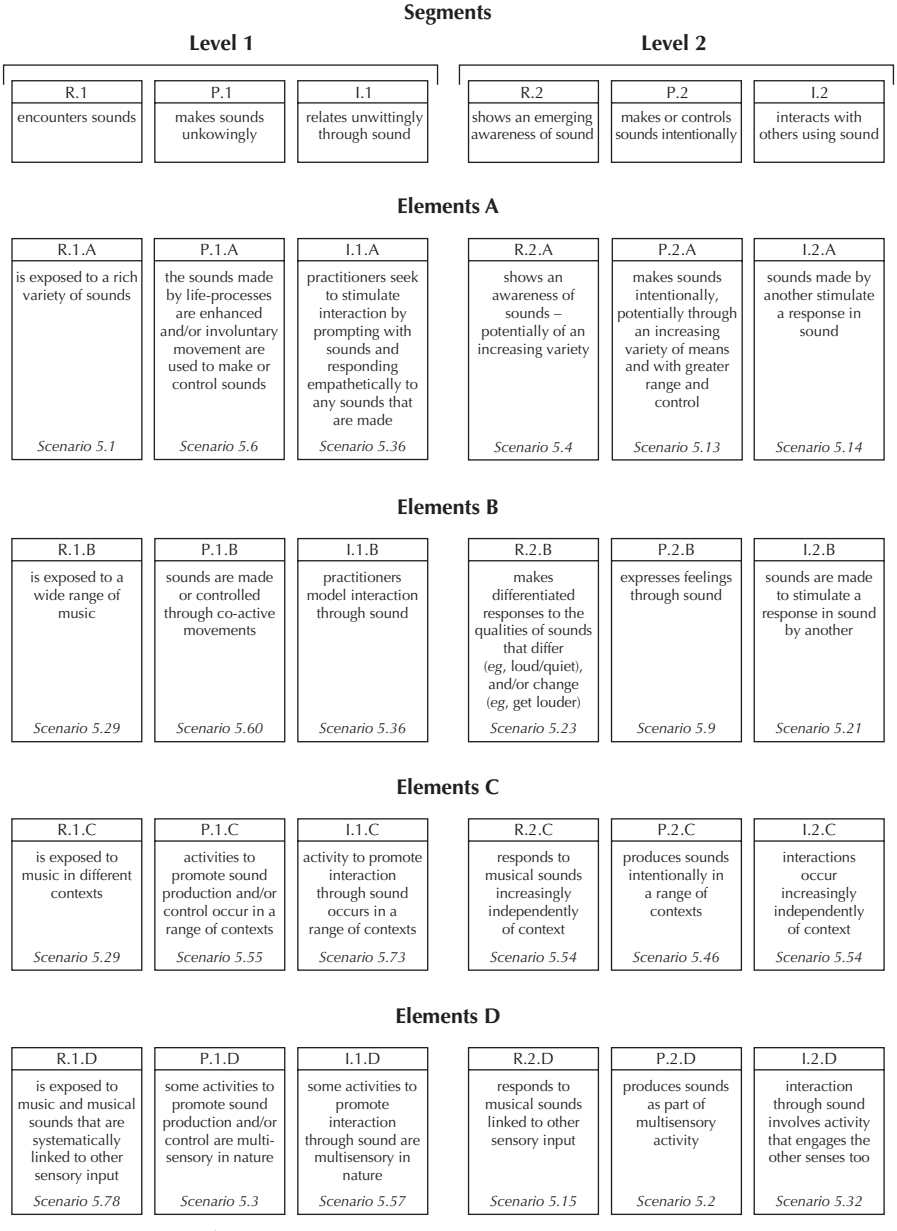


Fig. 5.27 (a)–(c) *Sounds of Intent* elements.

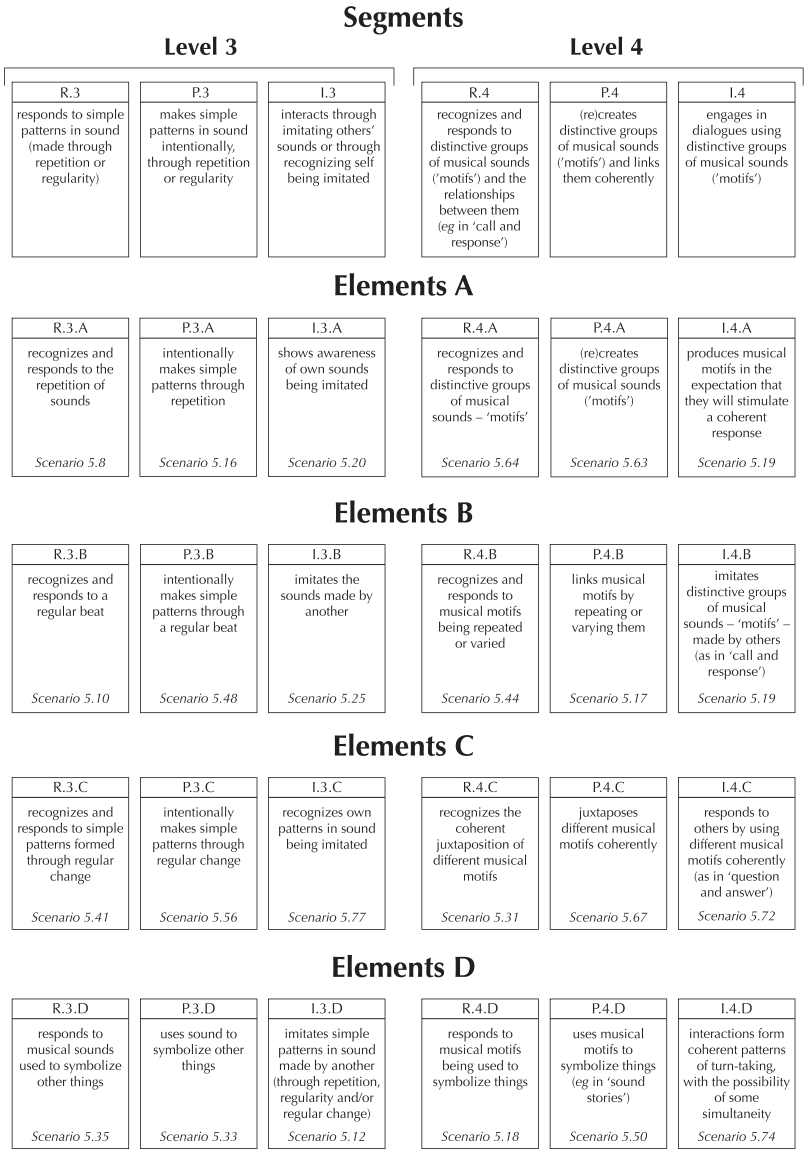


Fig. 5.27 (continued).

Although Fig. 5.27 is regular in appearance, the way that the level descriptors and elements relate to each other within and between the reactive, proactive, and interactive domains is complex. Level descriptors form a hierarchy whereby, within each domain, achievement at higher levels is dependent on the accomplishment of all those that precede. So, for example, in the interactive domain, I.4, "Engages in musical dialogs, creating and recognizing coherent connections between groups of sounds," could only occur following I.3, "Interacts by imitating other's sounds or recognizing self being imitated" and (therefore) after accomplishing I.2 and I.1. *Between* domains,

Segments

Level 5

R.5	P.5	I.5
attends to whole pieces; recognizes prominent structural features (*eg* choruses); responds to general characteristics (*eg* tempo); develops preferences	(re)creates short and simple pieces of music, potentially of growing length and complexity; increasingly 'in time' and (where relevant) 'in tune'	performs and/or improvises music of growing length and complexity with others, using increasingly developed ensemble skills

Level 6

R.6	P.6	I.6
emgages with pieces as abstract 'narratives in sound' in which patterns of notes are repeated or varied over time to create meaning; differentiates between styles and performances	seeks to communicate through expressive performances, with increasing technical competence; creates pieces that are intended to convey particular effects	makes music experessively with others, with a widening repertoire, in a range of different styles and genres

Elements A

R.5.A	P.5.A	I.5.A	R.6.A	P.6.A	I.6.A
attends to whole pieces of music, becoming familiar with an increasing number and developing preferences	performs short and simple pieces of music, potentially of growing length and complexity; increasingly 'in time' and (where relevant) 'in tune'	performs simple pieces simultaneously with others, sharing a common part	develops a mature response to music, engaging with pieces as abstract 'narratives in sound'	plays or sings expressively using familiar conventions of performance, at the highest level producing original compositions	is aware of, and emulates the expressivity of others' playing or singing in ensemble performance
Scenario 5.59	*Scenario 5.61*	*Scenario 5.43*	*Scenario 5.45*	*Scenario 5.52*	*Scenario 5.69*

Elements B

R.5.B	P.5.B	I.5.B	R.6.B	P.6.B	I.6.B
recognizes prominent structural features (such as the choruses of songs)	improvises on familiar pieces of music, varying the original material in simple ways	performs with others, using increasingly developed ensemble skills and maintaining an independent part	becomes familiar with an increasing number of styles and genres and develops preferences	improvises on familiar music to convey desired effects, potentially producing original versions of existing pieces (as in 'jazz standards')	contributes own expressivity in ensemble playing to infuence co-performers
Scenario 5.22	*Scenario 5.68*	*Scenario 5.58*	*Scenario 5.70*	*Scenario 5.45*	*Scenario 5.28*

Elements C

R.5.C	P.5.C	I.5.C	R.6.C	P.6.C	I.6.C
responds to general characteristics of pieces (such as mode, tempo and texture)	creates simple pieces, potentially of increasing length and complexity, whose general characteristics may convey particular moods or feelings, and which may be linked to external associations	improvises with others, repeating, varying and/or building on the material that is offered in simple ways	becomes familiar with different performances of pieces and styles of performance and develops preference	composes pieces in a familiar style or styles to convey desired effects, at the highest level producing original material judged to be of intrinsic musical value	improvises with others with stylistic coherence, sharing and developing material in increasingly sophisticated ways
Scenario 5.40	*Scenario 5.75*	*Scenario 5.39*	*Scenario 5.45*	*Scenario 5.49*	*Scenario 5.34*

Elements D

R.5.D	P.5.D	I.5.D	R.6.D	P.6.D	I.6.D
responds to pieces through connotations brought about by their association with objects, people ore events in the external world	has the physical capacity to produce short and simple pieces of music, potentially evolving to meet the needs of material of growing length and complexity	improvises with others, consciously offering material for them to use	becomes aware of how music as an abstract narrative in sound relates to other media (words, movement, *etc*) to create multimodal meaning	technical proficiency develops to meet the demands of a widening repertoire	develops increasingly advanced ensemble skills, managing material of growing technical and musical complexity as part of a group
Scenario 5.53	*Scenario 5.42*	*Scenario 5.66*	*Scenario 5.38*	*Scenario 5.65*	*Scenario 5.70*

Fig. 5.27 (continued).

there is a broad flow of contingency that runs from reactive to proactive and then to interactive. For instance, in the proactive domain, intentionally making patterns in sound through repetition (P.3) depends on the capacity to recognize simple patterns in sound (R.3); while interacting with another or others using sound (I.2) relies on the ability to cause, create, or control sounds intentionally (P.2), which in turn requires an awareness of sound (R.2).

The pattern of contingencies that links the 72 elements is more intricate, however. Although in some cases there is a necessary connection between elements at different levels *within* domains (for example, a pupil could not engage in intentional repetition, P.3.A, before having the wherewithal to make a variety of sounds, P.2.B) and *between* them (for instance, imitating the sounds made by another, I.3.A, similarly requires functioning at the level of P.2.B), this is not always the case. It is perfectly conceivable that a child could intentionally make simple patterns through a regular beat (P.3.B), for example, before using sounds to symbolize particular people, places, or activities (P.2.D).

However, the research team felt that intricacies of this type were an inevitable consequence of the complicated nature of musical development: multilayered and multistranded. At any given time, it was unlikely that the framework would indicate a pupil as being at a particular *point* on a developmental scale, but, rather, having a music-developmental *profile*, incorporating attainment at different levels in relation to a number of different elements. But, given these complexities, how could the framework work in practice as a tool for assessment, enabling practitioners to record pupils' levels of achievement and change, to draw comparisons between the attainment and progress of individuals and groups, and to gauge the potential impact of different music-educational and therapeutic interventions?

Testing the framework (i)

Evangeline Cheng, a doctoral student at the Institute of Education, University of London, tested the *Sounds of Intent* framework using a series of longitudinal case studies (Cheng *et al.*, 2009; Cheng, 2010). She observed six young people with complex needs engaging in weekly music sessions over a period of two terms (around 6 months), and assessed them in relation to the elements set out in Fig. 5.27. She recorded the frequency with which given levels of engagement were observed, session by session. The example of an 11-year-old boy, J, follows.

> The documentation held by J's school indicated that he had severe learning difficulties, cerebral palsy, visual impairment, a speech, language, and communication difficulty, and epilepsy. J was able to say a few single words including "hi, bye, no, me, more, book" and the names of a few members of staff who had been working with him for some years. He would nod for "yes" and sometimes used a switch to play pre-recorded messages conveyed between home and school. J used a wheelchair, and needed help with life skills including eating, dressing, and personal hygiene.

Cheng observed J for 21 weeks, a period that she divided for the purposes of analysis into two phases. Phase 1, which ran from weeks 1 to 14, entailed sessions with the school's music teacher, involving songs and musical games to promote socialization and language acquisition, and rhythmic activities with non-tuned percussion instruments. In Phase 2 (from weeks 15 to 21), J's class participated in a special music community link project called *Music Makers Sing!*, with two members of a professional London orchestra and a music technician. Their presence meant that each child had the opportunity to interact more intensively with adults through music on a one-to-one basis, and switches were introduced to facilitate proactive participation.

In total, Cheng observed 513 instances of musical engagement on J's part: 184 "reactive," 181 "proactive," and 148 "interactive"—an average, respectively, of 9, 9, and 7 occurrences per session. These are summarized, phase by phase, in Table 5.4.

Combining the reactive, proactive, and interactive scores for levels 2, 3, 4, and 5 shows a distinct shift in J's global *Sounds of Intent* profile between Phases 1 and 2 of the observation period—the first time that the framework had been used to show change in a pupil's musical engagement over time (see Fig. 5.28).

However, in the process of Cheng's analysis, it became evident that each element potentially embraced a *range* of behaviors. For example, P.2.B, "creates an increasing diversity of sounds intentionally through an increasing variety of means" could refer equally to a child vocalizing within a limited pitch range and tapping a drum with the fingers of one hand, and a young person making a wide range of vocal sounds and playing a number of non-tuned percussion instruments. Similarly, I.3.A, "imitates the sounds made by another" could denote a pupil echoing a single vocal sound made by his music teacher, or a client copying a variety of vocalizations and instrumental sounds made by her music therapist. Hence it became apparent to the research team

Table 5.4 Cheng's observations of J using the *Sounds of Intent* framework

Domain	**Level**	**Weeks 1–14**		**Weeks 15–21**	
		Frequency	**%**	**Frequency**	**%**
Reactive	R.2	6	6	0	0
	R.3	23	22	10	12.5
	R.4	48	45.5	24	30.5
	R.5	28	26.5	45	57
	R.6	0	0	0	0
	Total	**105**	**100**	**79**	**100**
Proactive	P.2	12	11	1	1
	P.3	40	36	9	11
	P.4	35	31	20	25
	P.5	25	22	39	48
	P.6	0	0	0	0
	Total	**112**	**100**	**69**	**100**
Interactive	I.2	18	22	9	13.5
	I.3	8	10	1	1.5
	I.4	44	53.5	42	63.5
	I.5	12	14.5	14	21.5
	I.6	0	0	0	0
	Total	**82**	**100**	**66**	**100**

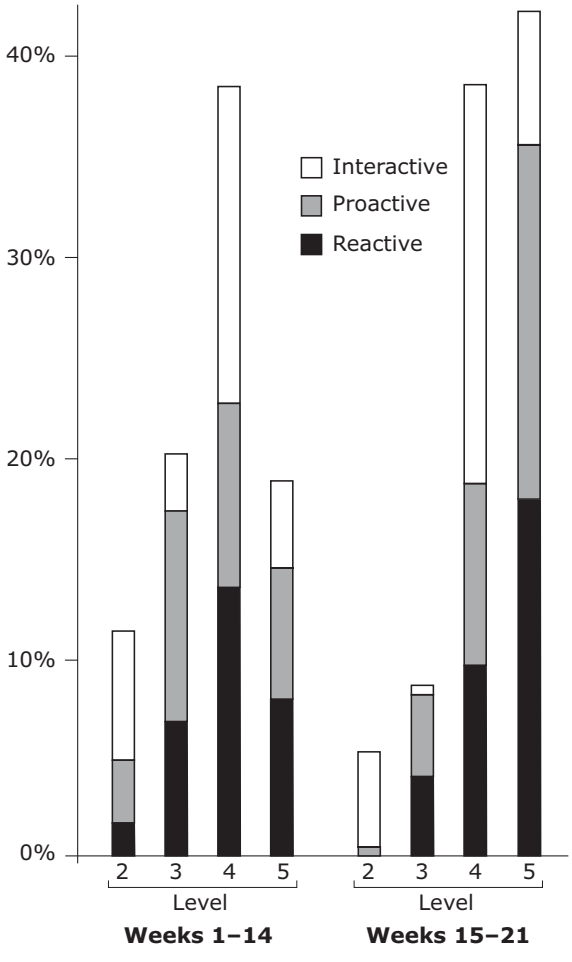


Fig. 5.28 The change in J's profile of musical engagement over time.

that more subtle intrapersonal changes—particularly important for practitioners working in the domain of PMLD—could be recorded if elements were themselves broken down into different degrees of engagement. To test this principle out, a further episode of exploratory empirical work was undertaken.

Testing the framework (ii)

A cohort of 20 young people with PMLD was identified at Linden Lodge School, London, ranging in age from 11 years 11 months, to 17 years 7 months [mean (M) = 15 years 3 months, standard deviation (SD) = 2.03]. They came from a wide variety of ethnic and cultural backgrounds from across London and the south-east of England. All had profound levels of global developmental delay: none was verbal and the great majority were wheelchair users. Many had some degree of visual impairment.

The materials used for this *Sounds of Intent* study were taken exclusively from *All Join In!* (Ockelford, 1996), a set of 24 songs that were originally designed to offer a framework for making

music with young people who were visually impaired and had learning difficulties (although they subsequently proved effective in a range of contexts, including for those working with children in the early years, and with pupils who have autism spectrum disorders). The topics of the songs are "self and other," "time and place," "things around," and "music and sound." Throughout, the language used is simple and concrete, with the conscious avoidance of abstract concepts or metaphor (that characterize so many children's songs). Key words and phrases are consistently allocated the same rhythm and, where possible, melodic shape (see Fig. 5.29), opening up the possibility of musical fragments acquiring symbolic meaning in their own right. Musically, the songs conform

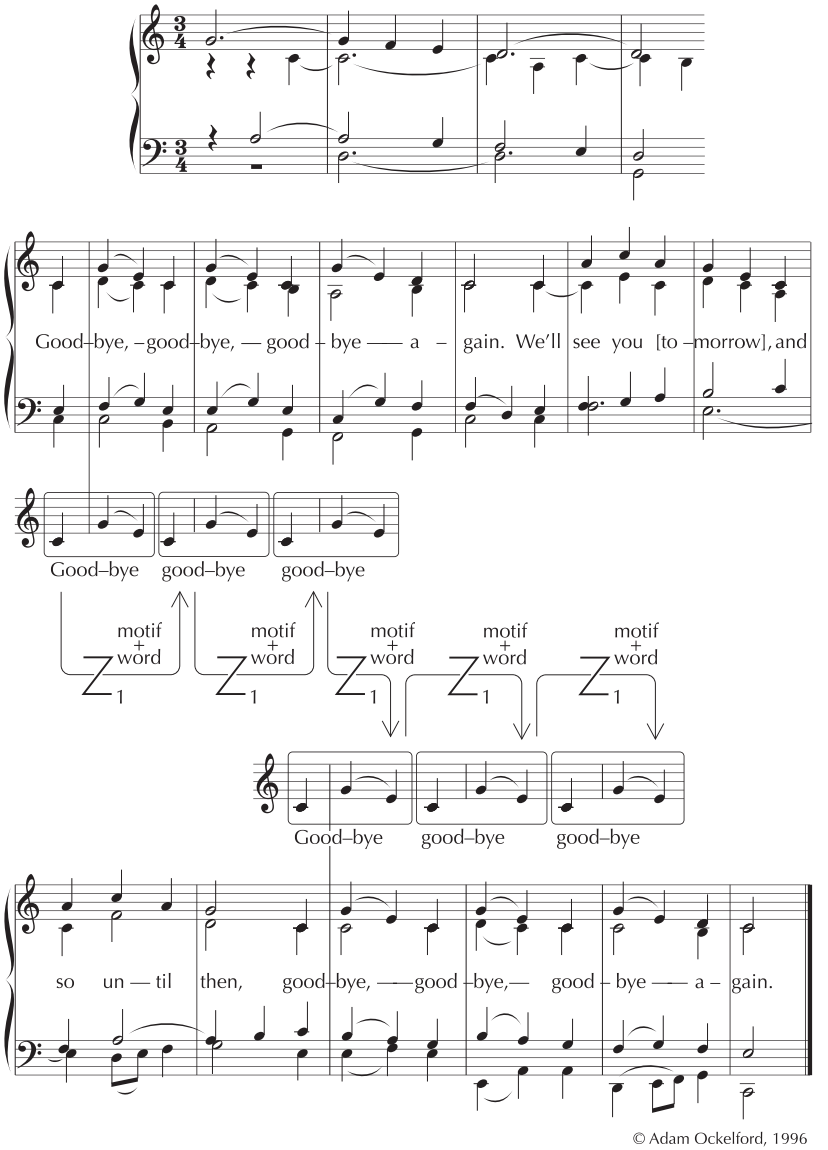



Fig. 5.29 The 'goodbye' song from *All Join In!*, in which the repetition of words and motifs is systematically linked.

to what could reasonably be described as the western popular "musical vernacular" of the late 20th century, with simple rhythms, regular metrical structures, and diatonic tonal frameworks. Melodies are constrained in pitch range and are repetitive. In summary, the songs are intended to be as easy to learn and engage with as possible.

I arranged to take the young people's weekly music lessons in the spring and summer terms (from January to July, with breaks for the half-term and Easter holidays), a total of 24 sessions of 45 minutes each (amounting to 18 hours of musical exposure). The format of each session was the same. Work took place in the pupils' classrooms (the environments with which they were most familiar). Each had a one-to-one teaching assistant. Everyone sat in a circle (including me). I had access to a touch-sensitive electric keyboard, which was set to sound like a piano. Lamorna Jewell-Gore, the music teacher at Linden Lodge, who knew the young people very well, participated in all the sessions, largely through supporting the staff, when she was not formally observing the pupils. A wide range of non-tuned percussion instruments was available. Each session used the *All Join In!* framework, which comprises introductory songs (A and B) and concluding songs (D and E) that are fixed, with a menu of possibilities (C_1 to C_5) in between (see Fig. 5.30).

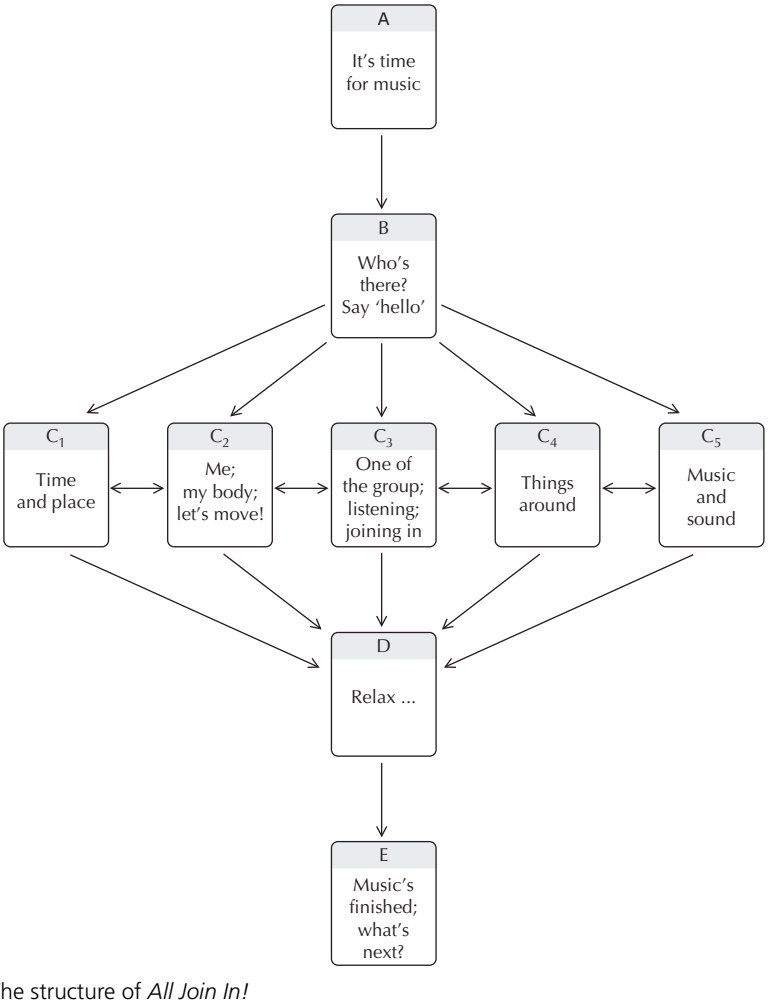


Fig. 5.30 The structure of *All Join In!*

Once a month (on six occasions), Jewell-Gore stepped back from proceedings and observed each of the young people in action, noting examples of musical reactivity, proactivity, or interactivity that appeared to be typical of their engagement in the session concerned. Written comments were supplemented with some video recordings for later reference. Subsequently, Jewell-Gore mapped the behaviors that she had observed and recorded onto the *Sounds of Intent* framework, gauging which element offered the best fit for each description, and grading them as "low" (that is, *just* achieving the level of engagement that was described), "high" (fulfilling the terms of the descriptor *comprehensively*), or "medium" (for levels of attainment *between* the two extremes). For example:

- J "showed slight reaction to loud noises but no reaction to localized instruments playing. Did not . . . change reaction to change in tempo/dynamics"—assessed as R.1.A(low).
- G "laughed each time the tambourine was hit, and responded to sudden chord changes"—assessed as R.2.A(medium).
- A "vocalized throughout songs and changed notes with key change"—assessed as I.3.A(low).
- B "laughed at a particular motif played on the piano"—assessed as R.4.A(low).
- L "reacted to people playing matching sounds, eyes looking from one to the other"—assessed as R.3.A(low).
- D "listened to sounds made by the other children, sometimes just looking, sometimes smiling, sometimes laughing"—assessed as R.2.B(high).
- Q "laughed a lot when his own made-up musical sounds were imitated (the 'wah wah' song)"—assessed as I.3.B(high).

To facilitate analysis of the data, each was assigned a rank on an ordinal scale, according to its position within the *Sounds of Intent* framework, such that activity at Level 1 (low) was categorized as 1, Level 1 (medium) was classed as 2, Level 1 (high) was allocated 3, and so forth, as shown in Table 5.5. The results are shown in Table 5.6.

Over the course of the sessions, there is movement away from observed musical engagement at Level 1 and an attendant increase in classifications at Level 3—a high degree of variability in the data notwithstanding (see Fig. 5.31).

The underlying trend in this changing pattern of observations can be gauged by comparing means of the reported ranks, session by session, which offers a proxy indication of the children's changing perceived level of musical engagement (Fig. 5.32). This implies a marked rate of musical development (equivalent to one *Sounds of Intent* level in 18 months), which experience of working with children with PMLD suggests would not be sustainable. Hence it is reasonable to assume that there were exceptional factors at work in the study, which potentially include:

- the young people's growing familiarity with the materials, the routine of the sessions, and with me, which may have enabled them to engage musically more fully as time went on;
- my deepening knowledge of the young people, which may have enabled me to scaffold the young people's interactions more effectively as the sessions progressed;
- Jewell-Gore's practice in using the *Sounds of Intent* framework, which may have meant her observations became more pertinent and perceptive over the 6 months; and
- Jewell-Gore's wish for progress, which may have exerted a subconscious influence on her categorization of musical behaviors, particularly towards the end of the intervention period.

Table 5.5 The *All Join In!* elements ranked on an 18-point ordinal scale

***Sounds of Intent* elements**													**Rank**
R.1.A(L)	P.1.A(L)	I.1.A(L)	R.1.B(L)	P.1.B(L)	I.1.B(L)	R.1.C(L)	P.1.C(L)	I.1.C(L)	R.1.D(L)	P.1.D(L)	I.1.D(L)		1
R.1.A(M)	P.1.A(M)	I.1.A(H)	R.1.B(M)	P.1.B(M)	I.1.B(M)	R.1.C(M)	P.1.C(M)	I.1.C(M)	R.1.D(M)	P.1.D(M)	I.1.D(M)		2
R.1.A(H)	P.1.A(H)	I.1.A(M)	R.1.B(H)	P.1.B(H)	I.1.B(H)	R.1.C(H)	P.1.C(H)	I.1.C(H)	R.1.D(H)	P.1.D(H)	I.1.D(H)		3
R.2.A(L)	P.2.A(L)	I.2.A(L)	R.2.B(L)	P.2.B(L)	I.2.B(L)	R.2.C(L)	P.2.C(L)	I.2.C(L)	R.2.D(L)	P.2.D(L)	I.2.D(L)		4
R.2.A(M)	P.2.A(M)	I.2.A(M)	R.2.B(M)	P.2.B(M)	I.2.B(M)	R.2.C(M)	P.2.C(M)	I.2.C(M)	R.2.D(M)	P.2.D(M)	I.2.D(M)		5
R.2.A(H)	P.2.A(H)	I.2.A(H)	R.2.B(H)	P.2.B(H)	I.2.B(H)	R.2.C(H)	P.2.C(H)	I.2.C(H)	R.2.D(H)	P.2.D(H)	I.2.D(H)		6
R.3.A(L)	P.3.A(L)	I.3.A(L)	R.3.B(L)	P.3.B(L)	I.3.B(L)	R.3.C(L)	P.3.C(L)	I.3.C(L)	R.3.D(L)	P.3.D(L)	I.3.D(L)		7
R.3.A(M)	P.3.A(M)	I.3.A(M)	R.3.B(M)	P.3.B(M)	I.3.B(M)	R.3.C(M)	P.3.C(M)	I.3.C(M)	R.3.D(M)	P.3.D(M)	I.3.D(M)		8
R.3.A(H)	P.3.A(H)	I.3.A(H)	R.3.B(H)	P.3.B(H)	I.3.B(H)	R.3.C(H)	P.3.C(H)	I.3.C(H)	R.3.D(H)	P.3.D(H)	I.3.D(H)		9
R.4.A(L)	P.4.A(L)	I.4.A(L)	R.4.B(L)	P.4.B(L)	I.4.B(L)	R.4.C(L)	P.4.C(L)	I.4.C(L)	R.4.D(L)	P.4.D(L)	I.4.D(L)		10
R.4.A(M)	P.4.A(M)	I.4.A(M)	R.4.B(M)	P.4.B(M)	I.4.B(M)	R.4.C(M)	P.4.C(M)	I.4.C(M)	R.4.D(M)	P.4.D(M)	I.4.D(M)		11
R.4.A(H)	P.4.A(H)	I.4.A(H)	R.4.B(H)	P.4.B(H)	I.4.B(H)	R.4.C(H)	P.4.C(H)	I.4.C(H)	R.4.D(H)	P.4.D(H)	I.4.D(H)		12
R.5.A(L)	P.5.A(L)	I.5.A(L)	R.5.B(L)	P.5.B(L)	I.5.B(L)	R.5.C(L)	P.5.C(L)	I.5.C(L)	R.5.D(L)	P.5.D(L)	I.5.D(L)		13
R.5.A(M)	P.5.A(M)	I.5.A(M)	R.5.B(M)	P.5.B(M)	I.5.B(M)	R.5.C(M)	P.5.C(M)	I.5.C(M)	R.5.D(M)	P.5.D(M)	I.5.D(M)		14
R.5.A(H)	P.5.A(H)	I.5.A(H)	R.5.B(H)	P.5.B(H)	I.5.B(H)	R.5.C(H)	P.5.C(H)	I.5.C(H)	R.5.D(H)	P.5.D(H)	I.5.D(H)		15
R.6.A(L)	P.6.A(L)	I.6.A(L)	R.6.B(L)	P.6.B(L)	I.6.B(L)	R.6.C(L)	P.6.C(L)	I.6.C(L)	R.6.D(L)	P.6.D(L)	I.6.D(L)		16
R.6.A(M)	P.6.A(M)	I.6.A(M)	R.6.B(M)	P.6.B(M)	I.6.B(M)	R.6.C(M)	P.6.C(M)	I.6.C(M)	R.6.D(M)	P.6.D(M)	I.6.D(M)		17
R.6.A(H)	P.6.A(H)	I.6.A(H)	R.6.B(H)	P.6.B(H)	I.6.B(H)	R.6.C(H)	P.6.C(H)	I.6.C(H)	R.6.D(H)	P.6.D(H)	I.6.D(H)		18

Table 5.6 Observations of 20 young people with PMLD over a 6-month period using the *Sounds of Intent* framework ranked over 18 different levels

Child	Age (yy.mm) as at 07.09	13.02.09		6.03.09		24.04.09		15.05.09		19.06.09		3.07.09	
A	14.03	R.2.A(M)	5	R.2.A(M)	5	R.3.D(L)	7	I.2.A(L)	4	P.4.A(M)	11	I.2.A(H)	6
		P.1.B(H)	3	R.2.B(M)	5	P.2.A(L)	4						
		P.2.A(L)	4										
B	11.11	R.1.A(L)	1	R.2.A(L)	4	ABSENT		R.2.A(L)	4	R.2.A(M)	5	R.2.A(H)	6
								P.1.B(L)	1				
C	12.11	I.2.A(H)	6	R.2.A(H)	6	I.2.A(H)	3	P.2.A(H)	6	R.2.A(H)	6	R.2.A(H)	6
		P.2.A(M)	5	R.2.B(M)	5					I.2.A(H)	6	I.3.A(L)	7
		R.2.A(M)	5										
D	12.02	R.1.A(L)	1	ABSENT		R.1.A(L)	1	ABSENT		P.1.B(H)	3	R.2.A(H)	6
						R.2.B(L)	4					I.2.A(M)	5
												R.2.B(L)	4
E	12.04	R.1.A(L)	1	R.2.A(L)	4	ABSENT		R.2.A(L)	4	R.2.A(M)	5	R.2.B(M)	5
				P.1.B(L)	1			R.2.A(M)	5	I.2.A(M)	5	I.3.B(L)	7
								R.2.B(M)	5	R.2.B(M)	5		
F	13.02	R.2.A(M)	5	ABSENT		ABSENT		R.2.A(H)	6	ABSENT		I.2.A(H)	6
								I.2.A(L)	4			R.3.A(M)	8
												I.3.B(L)	7
G	13.04	P.2.A(M)	5	SICK		R.2.A(M)	5	ABSENT		I.3.A(L)	7	R.2.A(H)	6
						P.2.A(M)	5			R.2.B(M)	5	I.3.B(M)	8
						I.2.A(M)	5			R.4.A(L)	10		

Table 5.6 (continued) Observations of 20 young people with PMLD over a 6-month period using the *Sounds of Intent* framework ranked over 18 different levels

Child	Age (yy.mm) as at 07.09	13.02.09		6.03.09		24.04.09		15.05.09		19.06.09		3.07.09	
H	15.01	R.2.B(L)	4	I.3.A(L)	7	R.2.A(L)	4	ABSENT		R.2.A(M)	5	I.3.A(L)	7
		P.2.A(L)	4	R.2.A(L)	4	P.2.A(L)	4			P.2.A(M)	5		
						I.3.A(L)	7						
I	15.08	P.2.A(M)	5	P.2.A(M)	5	P.3.B(M)	8	R.2.A(M)	5	R.3.A(L)	7	R.2.A(M)	5
		R.3.D(L)	7	P.2.B(M)	5	P.3.C(M)	8	R.3.A(L)	7	P.2.A(M)	5	R.3.A(M)	8
						I.3.C(M)	8					I.3.A(M)	8
						P.2.B(M)	5						
J	16.03	P.2.A(M)	5	I.2.B(M)	5	ABSENT		P.2.A(M)	5	R.2.A(M)	5	R.2.A(M)	5
		R.3.D(L)	7	P.2.A(M)	5			R.2.A(M)	5	P.2.A(H)	6	P.2.A(M)	5
		P.2.A(L)	4					R.3.A(M)	8	I.3.A(L)	7	I.3.A(L)	7
		I.3.A(L)	7										
K	14.04	P.2.A(M)	5	R.2.A(M)	5	R.2.A(H)	6	R.2.A(M)	5	R.2.B(L)	4	R.2.A(M)	5
		P.1.B(L)	1			R.3.A(L)	7			P.2.A(M)	5	P.2.A(L)	4
L	15.06	P.1.B(L)	1	P.2.A(M)	5	ABSENT		P.2.A(M)	5	I.3.A(L)	7	P.2.A(M)	5
		R.2.A(L)	4	R.2.A(M)	5			R.2.B(M)	5	P.2.A(M)	5	R.2.B(L)	4
		R.3.D(L)	7	I.2.A(M)	5								
M	16.00	ABSENT		R.2.A(M)	5	P.2.A(M)	5	ABSENT		ABSENT		I.3.A(M)	8
						R.2.A(M)	5					R.2.A(M)	5
						I.2.A(M)	5					R.3.A(M)	8

Table 5.6 (continued) Observations of 20 young people with PMLD over a 6-month period using the *Sounds of Intent* framework ranked over 18 different levels

Child	Age (yy.mm) as at 07.09	13.02.09		6.03.09		24.04.09		15.05.09		19.06.09		3.07.09	
N	17.03	P.2.A(M)	5	R.3.B(L)	7	I.2.A(M)	5	R.2.A(M)	5	ABSENT		P.2.A(H)	6
		R.2.A(M)	5	R.2.A(M)	5	P.2.A(L)	4	P.2.A(M)	5				
O	17.07	R.1.A(L)	1	ABSENT		P.2.A(L)	4	P.2.B(L)	3	R.2.B(M)	4	I.3.A(L)	7
						P.2.A(M)	5					R.3.A(L)	7
												R.2.B(M)	5
												I.3.A(L)	7
P	17.06	R.2.A(L)	4	R.2.A(M)	5	P.2.A(M)	5	P.2.A(M)	5	R.2.A(M)	5	R.2.A(M)	5
				R.3.D(L)	7					P.2.A(M)	5	I.2.A(M)	5
												P.2.A(M)	5
Q	17.06	R.3.D(M)	8	R.2.A(M)	5	ABSENT		P.2.A(H)	6	I.2.B(M)	5	I.3.B(M)	8
		R.2.B(M)	5					R.3.B(M)	8				
R	17.00	R.3.D(M)	8	ASLEEP		I.2.A(M)	5	R.2.A(M)	5	ASLEEP		P.2.B(M)	5
		P.2.A(M)	5			P.2.A(M)	5						
S	17.03	R.2.A(L)	4	R.2.A(M)	5	ABSENT		P.2.A(M)	5	P.2.A(M)	5	ABSENT	
T	17.07	R.2.A(M)	5	P.2.A(H)	7	ABSENT		ABSENT		ABSENT		ABSENT	
		R.3.D(M)	8	I.3.B(H)	9								
		R.3.C(M)	8	P.2.A(H)	6								

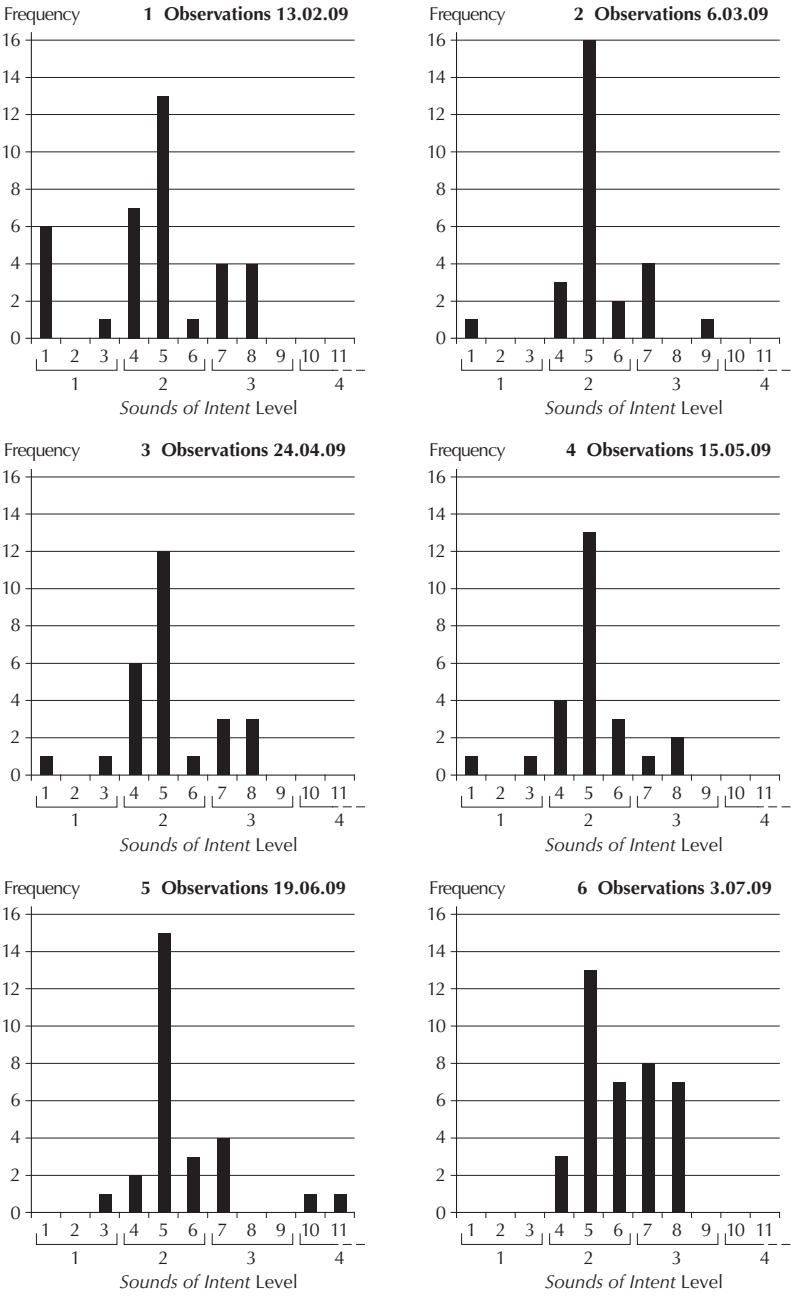


Fig. 5.31 Changing pattern of Jewell-Gore's observations over the 6 months of the intervention.

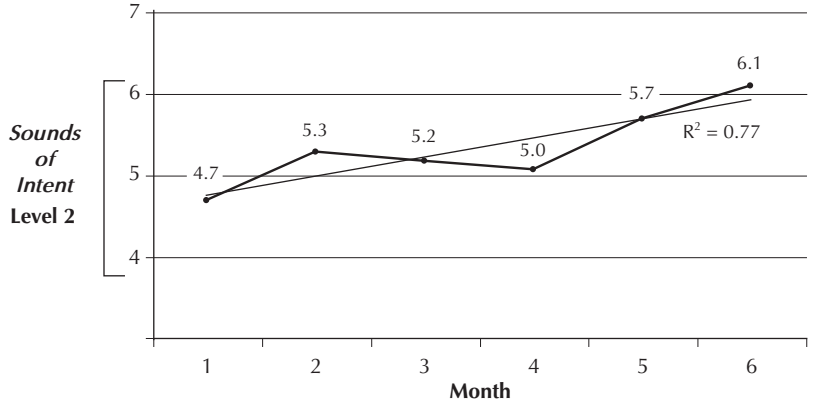


Fig. 5.32 The change in the means of ranked observations per session offers a proxy indication of the children's presumed advancing levels of musical engagement.

One way of cross-checking the results is to review the data from the perspective of individual students, taking the 6-month intervention as a relatively narrow window on a broader period of potential longitudinal change. Mapping mean ranks onto chronological ages suggests that, in general terms, progress may often occur at a much slower rate than Jewell-Gore's observations suggest (see Fig. 5.33).

Analyzing the data in this way shows a rise of just over one rank in 6 years. This equates to around one-tenth of the increase shown longitudinally. That is to say, any or all of the context-specific factors listed above may account for the great majority of the rise in the levels of musical engagement that were observed, or it could be that the intervention was particularly effective at engendering musical development, or both influences may have played a part. A great deal more

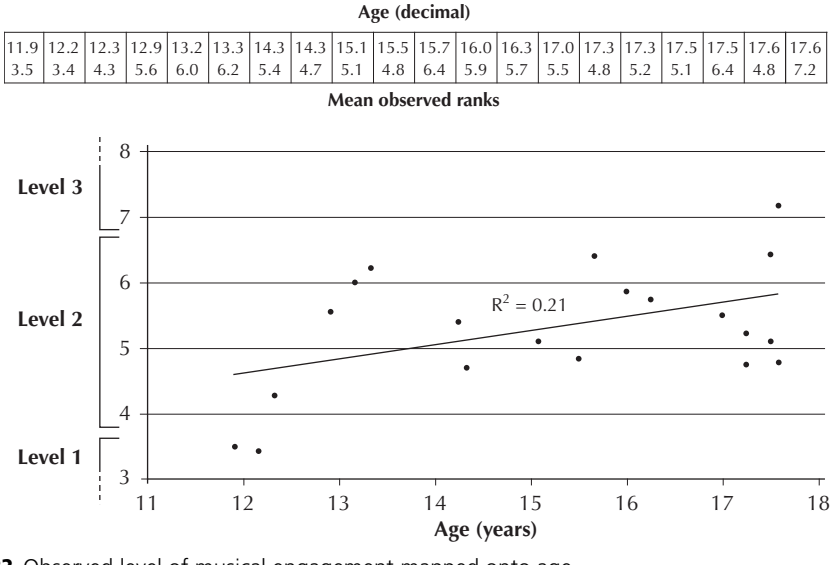


Fig. 5.33 Observed level of musical engagement mapped onto age.

data would be required to isolate and quantify the different ingredients in the mix, and to ascertain how they interrelate. The important thing is that this may be possible using the *Sounds of Intent* approach.

Change in musical behavior of this small order of magnitude suggests that, to be sufficiently sensitive for practitioners to chart progress meaningfully over time, observational schedules associated with the *Sounds of Intent* framework will need to be even more fine-grained than the system used by Jewell-Gore. Moreover, the work of Cheng suggests that, whatever protocol is devised, this should take into account not only children's levels of engagement, but also the relative frequency with which particular behaviors occur. Hence, a system along the following lines shown in Table 5.7 is currently being tested in the field (see <http://www.soundsofintent.org>), in which both these parameters figure equally.

This system can be accessed through a bespoke software package that uses any commercially available interface (including touch-screens). That is to say, practitioners can record their observations of a pupil's musical behaviors on a range of (commercially available) mobile devices as and when they occur, in the classroom or elsewhere, by selecting options from a series of drop-down menus structured around the *Sounds of Intent* framework and its elements. These are supplemented with audio and video recordings. Data are processed and stored automatically for later retrieval.

Table 5.7 Example of protocol that takes into account the level and consistency of musical behaviors within a single *Sounds of Intent* element

Gauging a participant's level of engagement	**Score**
No evidence	0
Reacts differentially to two contrasting qualities of sound or more, and/or to marked change	1
Reacts differentially to three or more differing qualities of or change in sound	2
Reacts differentially to four or more differing qualities of or change in sound	3
Reacts differentially to five or more differing qualities of or change in sound	4
Reacts differentially to six or more differing qualities of or change in sound	5
Gauging consistency	**Score**
Responses are never observed	0
Responses are observed *rarely* (on around one in eight occasions or fewer)	1
Responses are observed *occasionally* (on around one in four occasions)	2
Responses are observed *regularly* (on around one in two occasions)	3
Responses are observed *frequently* (on around three in four occasions)	4
Responses are observed *consistently* (on around seven in eight occasions or more)	5
Consolidating the two	
Multiply the 'level of engagement' score by the 'consistency' score. Change can be gauged by comparing scores over a period. The minimum score is 0 (where there is no available evidence or a behavior is never observed) and the maximum score is 25.	

Conclusion

In this chapter we presented evidence for how a sense of derivation through imitation in sound—and, therefore, an awareness and appreciation of music—may develop in children with learning difficulties. Six stages in this ontogenetic process were identified, which were set out in relation to three domains of engagement with music: reactivity, proactivity, and interactivity. The resulting *Sounds of Intent* developmental framework was supported by initial empirical data generated from two research projects, which both show musical progression on the part of the children and young people concerned. It may well be that further studies will suggest refinements to the model set out here, but the important thing is that, for the first time, practitioners have a basis for musical assessment and planning in their work with pupils and students with special needs that is both grounded in observation and theoretically coherent.

Part III

Applying zygonic theory to explore exceptional musical abilities

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Chapter 6

On absolute pitch, and the disaggregation of chords

Introduction

In my work over the last three decades with pupils who are blind or on the autism spectrum (or both), examples of which I have described in previous chapters, I have been struck time and again not only by the absolute pitch-processing abilities of many of the children—through which they can recognize and reproduce individual notes in isolation from others—but also by their capacity to "disaggregate" chords. It seems that, as well as hearing simultaneous clusters of notes as single *Gestalts* (which those with the necessary music-theoretical knowledge and expressive verbal language can label, for example, as "major" or "minor," with possible additional notes and chromatic inflections), young people with AP can apparently effortlessly disembed the individual tonal constituents of the perceived fusions of sounds characteristic of most Western music. While of interest from an academic, music-psychological point of view, this ability has practical implications too: for example, in greatly assisting pupils with no explicit music-theoretical knowledge to play multivoice instruments (such as keyboards) by ear.

The children's chord-disaggregation abilities are all the more striking since they appear to be so far removed from the norm. Most people, including musicians, struggle merely to say how many notes there are in a chord if the number rises above three (Huron, 1989; Parncutt, 1989), let alone identify them; indeed, the capacity to distinguish even two or three sounds heard simultaneously is generally acquired through extended periods of aural training. The resulting skills are thought, in traditional Western pedagogy at least, to be both an important element of musicality and a fair means of assessing it: they are a key component of examinations such as those administered by the Associated Board of the Royal Schools of Music, for example, and feature in some conservatoire entrance auditions.

As well as its significance to music educators, the matter of chordal disaggregation has intermittently engaged the interest of those working in the field of music-psychology too, ranging from the early work of Carl Stumpf (1883/2003) and Géza Révész (1924/1971) to the more recent contributions of David Huron and Richard Parncutt cited in the previous paragraph. However, little or no attention has been paid to the *strategies* that listeners may bring to bear in undertaking the task. Inevitably, for those without AP, who have to rely on identifying the differences *between* pitches within a chord (and the relationship of these to a predetermined reference), the task is a more complicated one than for those who can recognize each harmonic constituent in its own terms (cf. Miller, 1989, p. 59). In addition, both groups (those with AP and those without) are likely to use their experience of hearing common harmonic blends and knowing the patterns of notes from which these are made (for example, being aware that a major chord on the tonic comprises scale-degrees i, iii, and v). However, this strategy breaks down for unfamiliar combinations, leaving those reliant on relative pitch alone at a loss, particularly in the case of large or complex clusters of notes (as the example of the cellist David Popper in Stumpf, 1883/2003, shows).

Hence those with AP tend to be far more successful at chordal disaggregation as the usual limit of three notes does not seem to apply (see, for example, Révész, 1924/1971, pp. 74–83; Miller, 1989, p. 55). And since the possession of AP is a characteristic of musical savants (Miller, 1989, pp. 14, 15), we should not be surprised that disembedding notes from clusters heard simultaneously has long been regarded as a fair indicator of their exceptional musicality. Written descriptions go back to the 19th century and the American savant Blind Tom, who visited England in 1866. The *Manchester Courier* of 26 September 1866 gives the following account:

> To test his powers of analysing chords, Mr. Joule played him the following discordant combinations: the chord of B flat in the left hand, with the chord of A with the flat 5th and sharp 6th in right hand; the chord of E in the left hand, with the chord of D, two sharps, in the right; the chord of A, three flats, in the left hand, with that of A, three sharps, in the right. All these chords were at once correctly named by enumerating each note in succession from the lowest.

Not all savants, however, are able to label pitches correctly (even though they can recognize them as distinct sensations), and research, including, for example, that of Charness *et al.* (1988) into the abilities of an adult musical "mono-savant" (JL—who played with his left hand) and Miller's (1989) account of 5-year-old Eddie, use a "listen and play" protocol. In both these experiments, four-note chords were used as stimuli. In JL's case, 21 of the 59 scorable chord trials (36%) were completely correct (Charness *et al.*, 1988, p. 286). However, in 31 of the 42 harmonies in which the same pitch-class appeared twice (at the top and bottom of the chord), JL omitted the highest note. Since identical pitch-classes have a close auditory equivalence (and can be regarded in some senses as "the same thing" in musical terms, cf. p. 98), Charness *et al.* felt it was reasonable to ignore JL's omissions (particularly as he used only one hand to play), which raised his score to 55 out of 59 chords correct (93%). Chords were of two types: "conventional," which comprised major and minor chords, and dominant and supertonic sevenths; and "unconventional," which were created by transposing one of the non-duplicated notes of a conventional chord by a semitone. However, JL managed to reproduce both categories with the same degree of accuracy.

Using 24 four-note chords taken from those used by Charness *et al.* (1988), Miller tested Eddie and five others with AP, as well as four adults and three children without. Eddie correctly matched 98% of the notes comprising the "conventional" chords and 88% of those in the "unconventional" combinations (suggesting that he was supplementing his AP ability with experience of commonly occurring harmonic blends). The other possessors of AP scored an average of 95% on the "conventional" harmonies and 92% on the "unconventional" pitch aggregations. The responses of Eddie and others with AP were made rapidly and largely without subsequent correction.

In contrast, those without AP scored 42% on the "conventional" combinations and 38% on the "unconventional" ones, and their approach tended to be very different—typically attempting several different note combinations on a given trial before arriving at a their best attempt at a chord match. Hence, relative pitch perception clearly played a part, as notes were compared one with another in the process of arriving at a "solution." Moreover, as Miller points out, chance may well have figured in some of these responses—a topic to which we will return in some detail later.

Pam Heaton (2003) is among those to have suggested a connection between the chordal disaggregation abilities of musical savants and the "weak central coherence" that is characteristic of the cognitive style of those with autism (Frith, 2003, Happé, 1999), in which the perception and analysis of local features is favored at the expense of the development of global, context-dependent meaning. However, as Heaton points out, the fact that savants such as Eddie can hear familiar clusters of notes as single harmonies as well as comprising sets of individual pitches suggests that cognitive activity in the domain of music is not confined to local processing.

In summary, it was evident from the limited research that had been undertaken into the disembedding of pitch in chords that the informal observations of the blind and autistic children and young people with whom I was working merited further study, and it is to an account of this (ongoing) research that this chapter is devoted.

Derek Paravicini

Derek is someone with whom I have worked as a teacher, mentor, researcher, and friend—a relationship that has extended over some 27 years at the time of writing. He was born premature at just 25 weeks' gestation, with a birth weight of 0.65 kg. As a result of the oxygen therapy required to keep him alive, Derek developed retinopathy of prematurity (see, for example, Fielder and Reynolds, 2001), which irreversibly damaged his retinas and left him with only the perception of light in one eye (which he has since lost). It became apparent early on that his intellectual functioning was affected too, and during his school career Derek was classified as having "severe learning difficulties" (Ockelford, 1991, 2007a, 2008b), implying that his attainment in cognitive, emotional, and social terms was in the early stages (as in the first 12 to 30 months of neurotypical development; see Fig. 5.8 and Welch *et al*., 2001, p. 9). When he was 25, Derek's verbal IQ was 58 as measured on the WAIS-R (UK version), something that was subsequently confirmed when he was 30, although these results should be treated with caution, since inevitably the procedures employed were not entirely standard. In any case, it is evident that many of the building blocks of everyday understanding, such as "cause and effect," "same and different," and "left and right," are beyond Derek's conceptual grasp, and he needs one-to-one assistance in undertaking many routine activities such as preparing meals, washing, and getting dressed. In such situations, he seems to lack the central executive function needed to plan the required sequences of actions, and apparently has insufficient manual dexterity to realize the limited intentions that he may have.

As soon as Derek's fingers sense a piano keyboard beneath them, however, their infantile gaucherie evaporates, to be replaced with an extraordinary deftness and agility. Indeed, an unusual technical facility was already in evidence when I first encountered Derek when he was 5 (Ockelford, 2007a, pp. 70, 71). Then, his typically frenetic playing would generate a kaleidoscope of sounds, in which the main melodies of pieces were barely discernible amidst cascades of elaborate if somewhat chaotic passagework. Songs from the shows, TV theme tunes, nursery rhymes, folksongs etc. were all transformed through the addition of rapid figuration, largely produced with an "off-the-key" finger technique, resulting in a somewhat percussive style of playing that is still characteristic of Derek today.

With systematic weekly and then daily teaching over a period of 5 years, Derek flourished, and just before his 10th birthday he performed with the Royal Philharmonic Pops Orchestra at London's Barbican Centre, an event that launched a flurry of international media interest. But this initial success was tenuous, and the crucial next step for those working with Derek was to ensure that he made the difficult transition to a musically fulfilled adulthood, in which his learning disabilities would tend to work against rather than for him (as they had done hitherto) in terms of public perception; when his talents would be valued in their own right rather than through the lens of a misplaced if well-meaning curiosity. Pursuing this aim meant hundreds of hours more of concentrated effort (which Derek enthusiastically embraced): consolidating technique, extending an already eclectic repertoire, introducing a range of performers and styles to encourage the development of a new and distinctive musical "voice," and refining social and communication skills so that these were not a hindrance to music-making with others—for socially based musical

activity was becoming more and more a central feature of Derek's self-identity (cf. MacDonald *et al.*, 2002). To achieve this he had to be capable of a high level of conformance: playing what was required and when, and in an agreed key, tempo, and style! Hence, without subduing his natural predilection for doing things in his own way, Derek also had to accept the importance of copying exactly what he heard, and of performing pieces in the same fashion several times over when necessary—between rehearsals and a concert, for example, or for re-takes during the making of a film. In the event, such routine came to appeal to Derek as much as his improvisatory forays.

An unanticipated though welcome side-effect of Derek's potential for disciplined performance was his capacity for participating in music-psychological research (Ockelford, 2007b, p. 9). Here is someone who, as faithfully as he can, will reproduce on the keyboard whatever he is hearing or has heard, and will willingly make further attempts on the same or subsequent occasions. Here is a subject who will modify his reproductions as requested (playing a piece in different keys or tempi, for example), and will improvise on materials that are presented in a range of styles. Here is a musician whose ability to play by ear is so accomplished, and whose responses have such an immediacy, that one senses a rare opportunity to glean something of the workings of the musical mind in a direct and ecologically valid way (cf. Clarke, 2005)—through purely musical responses to music.

Derek's capacity for disaggregating chords—initial perceptions

Working with Derek, it quickly became evident that one of his exceptional areas of musical achievement is his capacity to hear and copy chords, of seemingly any size and complexity—a task that he undertakes with conviction, immediacy, and an apparently high level of accuracy. But how good is he? Informal tests using four-note chords of the type devised by Charness *et al.* (1988) indicated a ceiling effect, in that Derek invariably scored 100%, and increasing the size to five, six, or even seven notes, and introducing advanced chromatic harmonies, appeared to have a negligible impact—though occasional errors did emerge. Clearly, a scientific study was demanded, to probe just what was going on in detail.

Issues of methodology and analysis

Since Derek's use of expressive language is far less reliable than his capacity to produce music, it was decided to adopt a "listen and play" protocol similar to that employed by Charness *et al.* (1988) and Miller (1989), using a keyboard. Naturally, there are potential issues and constraints with this approach: chords must be "playable," but even so the technical demands of a particular combination of notes may interfere with a subject's response, particularly where large clusters are concerned. Nonetheless, given Derek's technical facility and his enthusiasm for such tasks, the "listen and play" procedure was felt to be a workable option.

A more serious issue, though, was how to analyze the results and evaluate their significance. To understand the potential processes involved here, let us investigate a series of hypothetical scenarios using zygonic theory.

Scenario 6.1

First, consider a situation in which only five notes are physically available. A chord comprising three pitches is presented, and a subject, with AP, plays the same three notes in response.

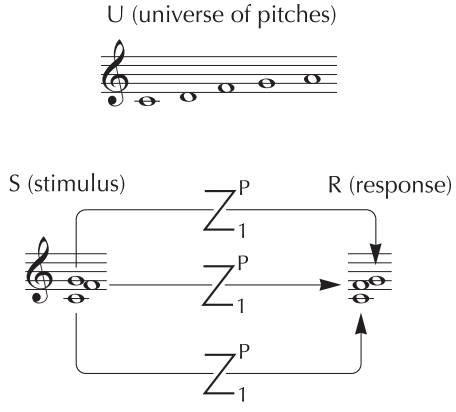


Fig. 6.1 Assumption of intentional repetition (imitation) of a three-note stimulus produced within a five-note universe of pitches.

A reasonable assumption is that this repetition is entirely intentional—the response is wholly imitative of the stimulus—and occurs through the activation of three relationships of derivation (primary zygons of pitch) as follows (see Fig. 6.1). A simple measure of the strength of derivation of the response from the stimulus is given by the number of *actual* zygonic relationships divided by the number of *potential* zygonic relationships that are required for perfect imitation. That is

$$\text{Strength of derivation} = \frac{\#\text{Z(actual)}}{\#\text{Z(potential)}} = \frac{3}{3} = 1. \tag{6.1}$$

However, given the highly constrained range of potential pitches available for a response, it may be that chance played a part in the result, and that one or more of the pitches were the same by happenstance—that *repetition* alone, rather than *imitation*, was present. In this case, zygonic relationships would *not* have played a part in the production of some or all of the notes. Clearly, then, the danger for the researcher is that sameness may be misinterpreted as intentionality (cf. p. 53) and zygonic status mistakenly accorded to connections between stimulus and response. (And the converse is also true: imitation may be construed as repetition occurring by chance.)

How can this issue be resolved? Since the only information available is one abstract pattern of sounds produced in response to another (rather than, for example, a verbal metacognitive account), we could never be *certain* which, if any, of the pitches were produced through imitation. However, if we could develop a measure of pitch repetition occurring by chance, we could at least design tests in which the probability of "false positives" occurring was minimal, as well as putting results that were obtained within a probabilistic perspective. To this end, we will now construct a model that enables probabilities to be calculated given any size of chordal stimulus, response, and pitch universe within which they operate.

Let us begin by returning to scenario in which a three-note chord, produced within a five-note universe, is imitated exactly. Although the notes occur simultaneously, it is theoretically convenient to consider them one by one. The probability that any given note (for convenience termed "Note 1") would be the same by chance is

$$P(\text{Note 1 correct}) = \frac{\#(\text{notes in stimulus})}{\#(\text{notes in domain})} = \frac{3}{5} = 0.6. \tag{6.2}$$

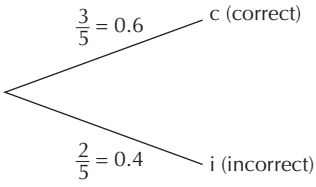


Fig. 6.2 Probabilities associated with Note 1 of a three-note chord in a five-note universe.

Conversely, the probability of Note 1 being incorrect is

$$P(\text{Note 1 incorrect}) = 1 - \frac{\#(\text{notes in stimulus})}{\#(\text{notes in domain})} = 1 - \frac{3}{5} = 0.4. \tag{6.3}$$

The probabilities associated with Note 1 can be represented graphically (see Fig. 6.2).

Now let us take a second note from the chord (Note 2). The probability of this being correct is contingent on the status of Note 1. If Note 1 is correct, then effectively we have two notes left from the stimulus and four in the response domain (see Fig. 6.3). In these circumstances, the probability of Note 2 being correct is

$$\begin{aligned} P(\text{Note 2 correct} \mid \text{Note 1 correct}) &= \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\ &= \frac{3-1}{5-1} = \frac{2}{4} = 0.5. \end{aligned} \tag{6.4}$$

Similarly, the probability of Note 2 being incorrect, given that Note 1 is correct is

$$\begin{aligned} P(\text{Note 2 correct} \mid \text{Note 1 incorrect}) &= 1 - \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\ &= 1 - \frac{2}{4} = 0.5. \end{aligned} \tag{6.5}$$

However, if Note 1 is incorrect, the number of notes from the stimulus remains the same (three), while the number of notes in the domain of potential responses is reduced by one. Hence, the position is as follows:

$$\begin{aligned} P(\text{Note 2 correct} \mid \text{Note 1 incorrect}) &= \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\ &= \frac{3-0}{5-1} = \frac{3}{4} = 0.75. \end{aligned} \tag{6.6}$$

Conversely, the probability of Note 2 being incorrect in these circumstances is

$$\begin{aligned} P(\text{Note 2 incorrect} \mid \text{Note 1 incorrect}) &= 1 - \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\ &= 1 - \frac{3-0}{5-1} = 1 - \frac{3}{4} = 0.25. \end{aligned} \tag{6.7}$$

Hence, given two notes, the probability tree is as shown in Fig. 6.4.

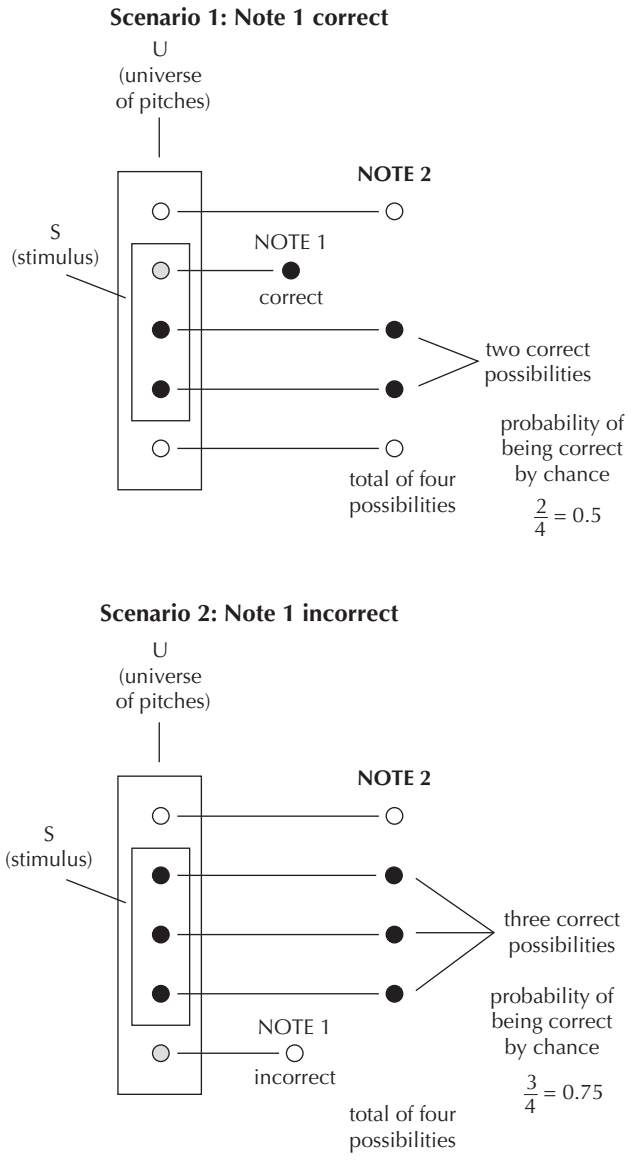


Fig. 6.3 The probability of selecting the second note in the response chord correctly by chance is conditional on the first.

Following the same principles, the probabilities associated with Note 3 are

$$\begin{aligned} &P(\text{Note 3 correct} \mid (\text{Note 2 correct AND Note 1 correct}) \\ &\quad = \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\ &\quad = \frac{3-2}{5-2} = \frac{1}{3} = 0.33 \end{aligned} \tag{6.8}$$

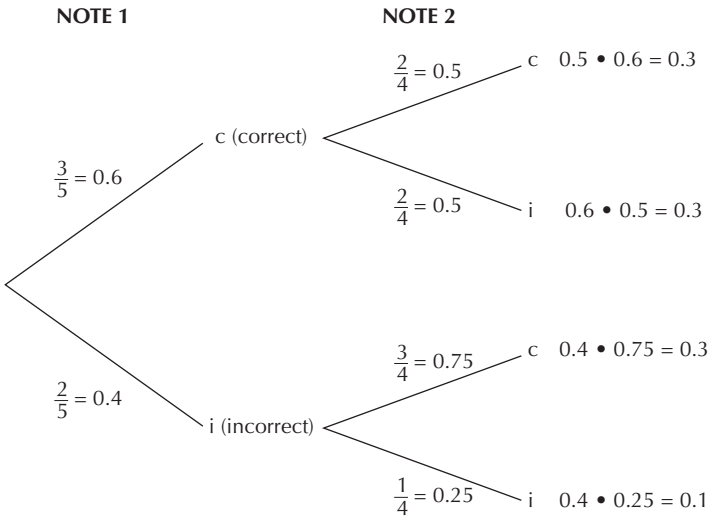


Fig. 6.4 Probabilities associated with Note 2 of a three-note chord in a five-note universe.

$$
\begin{aligned}
&P(\text{Note 3 correct} \mid (\text{Note 2 correct AND Note 1 incorrect}) \\
&\quad = \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\
&\quad = \frac{3-1}{5-2} = \frac{2}{3} = 0.67
\end{aligned} \tag{6.9}
$$

$$
\begin{aligned}
&P(\text{Note 3 correct} \mid (\text{Note 2 incorrect AND Note 1 correct}) \\
&\quad = \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\
&\quad = \frac{3-1}{5-2} = \frac{2}{3} = 0.67
\end{aligned} \tag{6.10}
$$

$$
\begin{aligned}
&P(\text{Note 3 correct} \mid (\text{Note 2 incorrect AND Note 1 incorrect}) \\
&\quad = \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\
&\quad = \frac{3-0}{5-2} = \frac{3}{3} = 1
\end{aligned} \tag{6.11}
$$

$$
\begin{aligned}
&P(\text{Note 3 incorrect} \mid (\text{Note 2 correct AND Note 1 correct}) \\
&\quad = 1 - \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})} \\
&\quad = 1 - \frac{3-2}{5-2} = 1 - \frac{1}{3} = 0.67
\end{aligned} \tag{6.12}
$$

$$P(\text{Note 3 incorrect} \mid (\text{Note 2 correct AND Note 1 incorrect})$$
$$= 1 - \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})}$$
$$= 1 - \frac{3-1}{5-2} = 1 - \frac{2}{3} = 0.33 \tag{6.13}$$

$$P(\text{Note 3 incorrect} \mid (\text{Note 2 incorrect AND Note 1 correct})$$
$$= 1 - \frac{\#(\text{Notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})}$$
$$= 1 - \frac{3-1}{5-2} = 1 - \frac{2}{3} = 0.33 \tag{6.14}$$

and

$$P(\text{Note 3 incorrect} \mid (\text{Note 2 incorrect AND Note 1 incorrect})$$
$$= 1 - \frac{\#(\text{notes in stimulus}) - \#(\text{other notes correct})}{\#(\text{notes in domain}) - \#(\text{other notes in response})}$$
$$= 1 - \frac{3-0}{5-2} = 1 - \frac{3}{3} = 0. \tag{6.15}$$

This yields the probability tree shown in Fig. 6.5.

Now, the probability of all three notes being correct (by chance) is

$$P(\text{Note 1 correct AND Note 2 correct AND Note 3 correct}) = 0.6 \times 0.5 \times 0.33 = 0.1. \tag{6.16}$$

That is, there is a 10% chance that selecting pitches at random would produce three notes in the response that were the same as those in the stimulus. Or, to put it another way, other things being equal, there is a 90% chance that the observed repetition does indeed result from imitation.

Scenario 6.2

Now consider the situation in which, again, only five notes are physically available. A chord comprising three pitches is presented, and a subject plays four notes in response, two of which are correct (Fig. 6.6).

Here, it is more difficult to gauge the degree of imitation (as opposed to repetition) in the response, and analysis can be undertaken using the probability tree shown in Fig. 6.7. This illustrates that the probability of two correct notes occurring by chance is 0.6; or, to put it another way, there is a 60% chance that the repetition is not imitative. Clearly, in such circumstances, one would be cautious about attributing intentionality to the subject's reproduction of the stimulus.

So much for the theory. There are, however, practical difficulties in seeking to use the analytical principles set out in relation to Scenarios 6.1 and 6.2 to explore chordal disaggregation on the scale needed to interrogate Derek's pitch-processing abilities. Imagine, for example, that the pitch universe in question comprised 25 notes (spanning two octaves on the keyboard), that the stimulus consisted of seven simultaneous events, that Derek played nine, and that he got six correct. To calculate the significance of this result using the diagrammatic method shown in Fig. 6.7 would

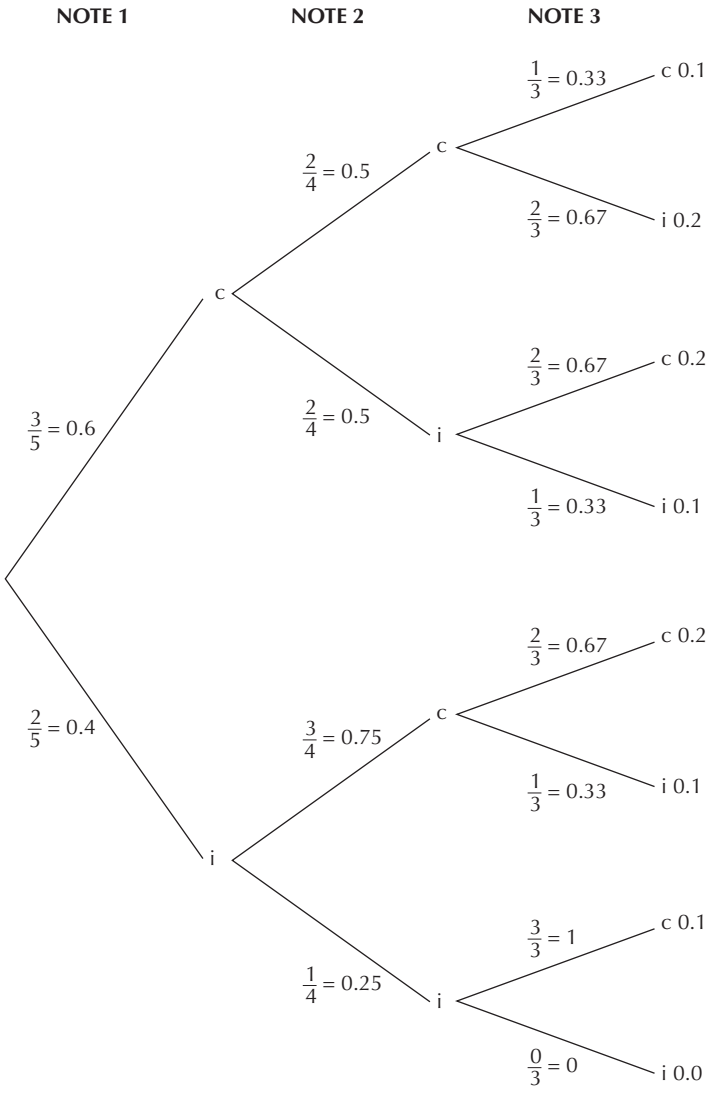
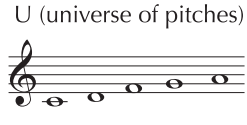


Fig. 6.5 Probabilities associated with Note 3 of a three-note chord in a five-note universe (c = correct; i = incorrect).



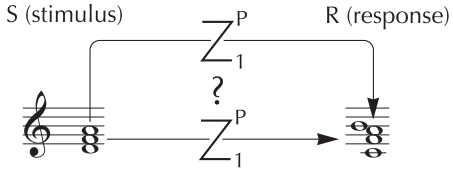


Fig. 6.6 The difficulty of gauging imitation in the case of a five-note universe, a three-note stimulus, and a four-note response, where two pitches are correct.

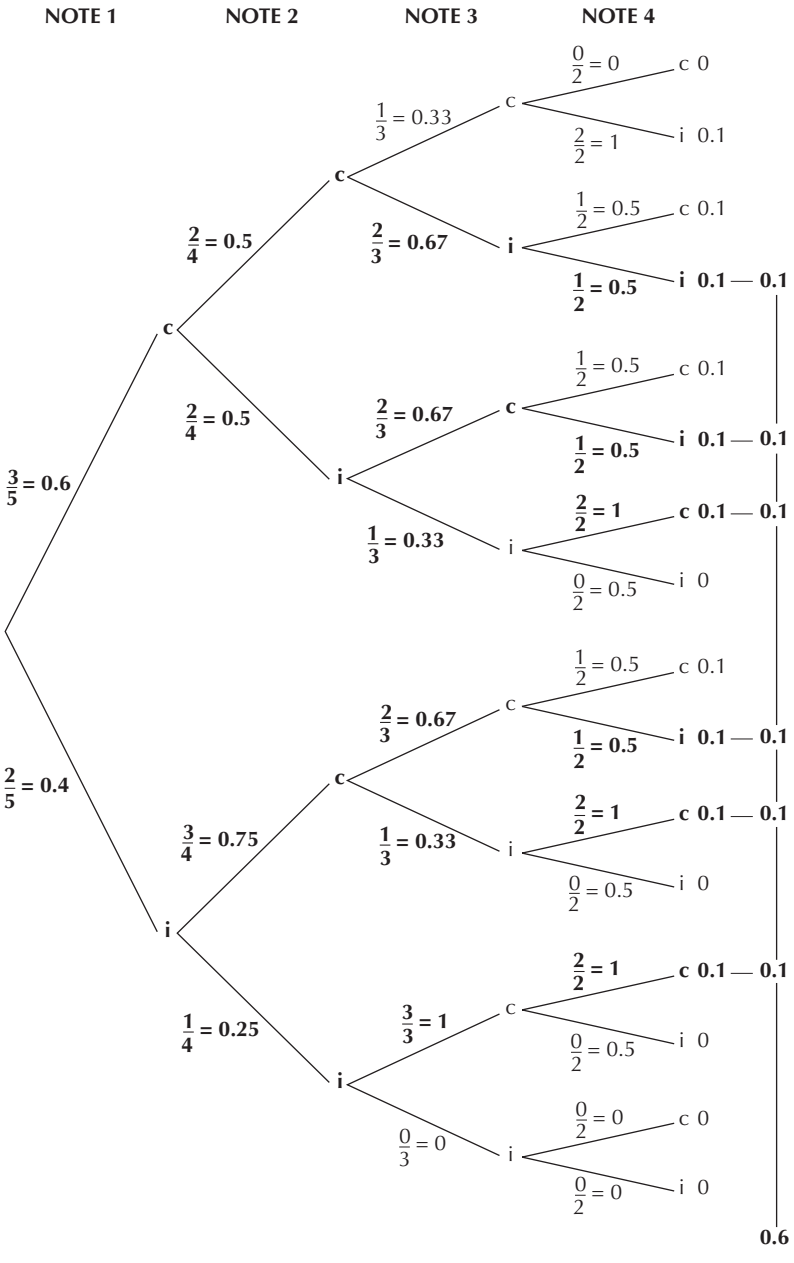


Fig. 6.7 The probability of playing two notes in a chord correctly by chance, given a pitch universe of five, a stimulus of three, and a response of four notes (c = correct; i = incorrect).

be highly labor-intensive, since the number of branches on a probability tree with two possibilities at each node (correct or incorrect) after nine events (E) is

$$2^{(E+1)} = 2^{10} = 1024. \tag{6.17}$$

However, it is possible to construct a formula involving the following variables: #U, number of pitches in the available "universe;" #S, number of pitches in the stimulus; #R, number of pitches in the response; and #C, number of pitches that are correct. In general terms, the probability of a cluster of pitches occurring correctly by chance is given by the formula

$$P = \frac{\text{number of combinations in which a cluster occurs correctly}}{\text{total number of available response combinations}}. \tag{6.18}$$

Given a response of a certain size, the total number of combinations is given by the standard formula

$$\#(\text{available response combinations}) = \frac{(\#\text{U})!}{(\#\text{R})!\,(\#\text{U} - \#\text{R})!} \tag{6.19}$$

For example, given a universe of eight pitches, and a chordal response of five notes, then

$$\#(\text{available response combinations}) = \frac{(\#8)!}{(\#5)!\,(\#8 - \#5)!} = \frac{40{,}320}{120 \times 6} = 56. \tag{6.20}$$

The number of combinations in which a cluster occurs correctly can be calculated as follows. Let us imagine that the stimulus chord contains four notes, of which three are produced correctly. This yields four sets disposed as in Fig. 6.8.

Now, let us consider the response chord in two portions, comprising a set of correct pitches and a set of incorrect pitches. The incorrect portion, which contains #R – #C members, is formed

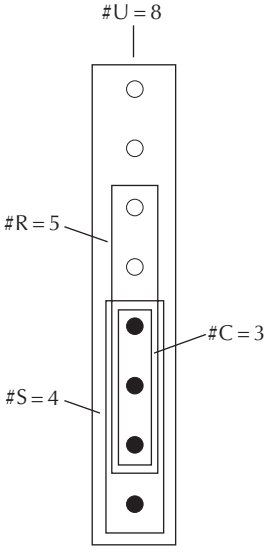


Fig. 6.8 Representation of a universe of eight pitches, a chordal stimulus of four notes, and a response of five, of which three are correct.

from the subset of notes in the universal set that are not found in the stimulus, whose size is #U – #S (see Fig. 6.9). The number of ways in which the incorrect portion of the response can be made up is given by substitution in equation (6.19):

$$\begin{aligned}&\#(\text{available combinations of the incorrect portion of the response})\\&= \frac{(\#U - \#S)!}{(\#R - \#C)!\ [(\#U - \#S) - (\#R - \#C)]!}\\&= \frac{(8-4)!}{(5-2)!\ [(8-4)-(5-2)]!} = \frac{24}{(6\ \times\ 1)} = 4.\end{aligned} \tag{6.21}$$

Similarly, the set of correct pitches in the response chord can be considered to be a subset of the stimulus chord, which can be formed in the following number of ways:

$$\begin{aligned}&\#(\text{available combinations of the correct portion of the response})\\&= \frac{(\#S)!}{(\#C)!\,(\#S - \#C)!} = \frac{4!}{2!\,(4-2)!} = \frac{24}{4} = 6.\end{aligned} \tag{6.22}$$

The total number of ways in which a correct cluster can occur is given by the product of equations (6.20) and (6.21):

$$\begin{aligned}&\#(\text{number of combinations in which a cluster occurs correctly})\\&= \frac{(\#U - \#S)!}{(\#R - \#C)!\ [(\#U - \#S) - (\#R - \#C)]!} \times \frac{(\#S)!}{(\#C)!\,(\#S - \#C)!}\\&= 4 \times 6 = 24.\end{aligned} \tag{6.23}$$

Substituting equations (6.19) and (6.23) in (6.18) gives:

$$\begin{aligned}P &= \frac{\text{number of combinations in which a cluster occurs correctly}}{\text{total number of available response combinations}}\\&= \frac{\dfrac{(\#U - \#S)}{(\#R - \#C)![(\#U - \#S) - (\#R - \#C)]!} \times \dfrac{(\#S)!}{(\#C)!(\#S - \#C)!}}{\dfrac{(\#U)!}{(\#R)!(\#U - \#R)!}}\\&= \frac{(\#S)!\ (\#R)!}{(\#U)!\ (\#C)!} \times \frac{(\#U - \#S)!\,(\#U - \#R)!}{(\#S - \#C)!\ (\#R - \#C)!} \times \frac{1}{(\#U - \#S - \#R + \#C)!}\\&= \frac{24}{56} = \frac{3}{7} = 0.43.\end{aligned} \tag{6.24}$$

That is, given a universe of eight pitches, a stimulus chord comprising five notes, a response comprising four notes, then there is a 43% chance that two of them will be correct. This can be reported alongside the proportion of repetition as follows:

$$\text{Proportion of repetition} = \frac{\#\,(\text{pitches respeated})}{\#\,(\text{total number of pitches})} = \frac{2}{4} = 0.5,\ P = 0.43. \tag{6.25}$$

Clearly, in this case, evidence of a chordal disaggregational skill is weak.

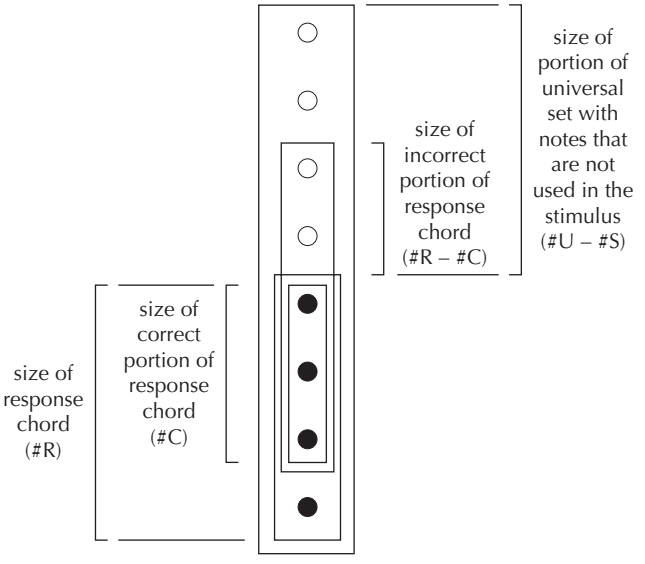


Fig. 6.9 Sizes of portions of the universal set and response that are incorrect and correct.

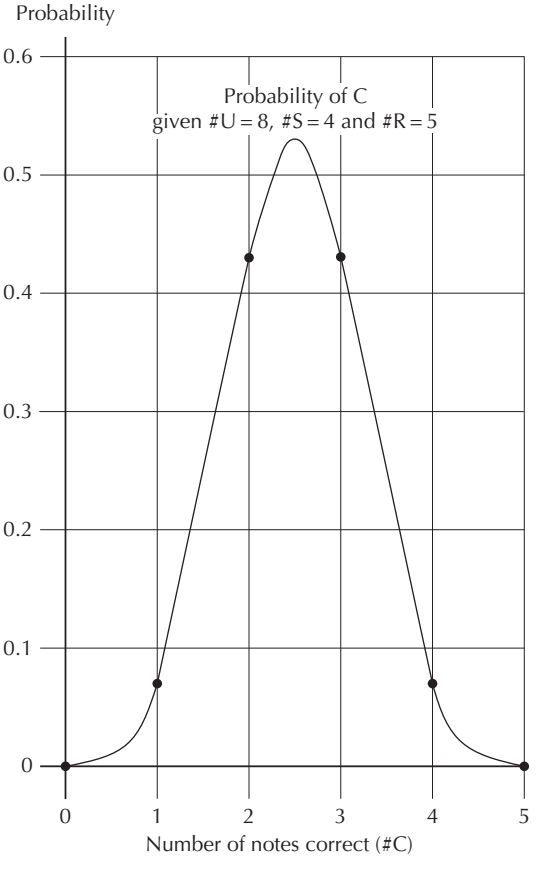


Fig. 6.10 Graph showing the probabilities of getting different numbers of notes correct in a chord by chance, given #U = 8, #S = 4 and #R = 5.

It is interesting to note how the probability of getting two pitches correct by chance varies as the number of notes in the response changes, in a manner that initially may appear to be counter-intuitive (Fig. 6.10). Given #U = 8 and #S = 4, for example, subjects are less likely to match two pitches if they play six notes than if they play four (Fig. 6.10; cf. Fig. 3.19). Similarly, if #U = 8, #S = 4 and #R = 5, then the probability of #C varies as shown in Fig. 6.11. Hence, in these conditions, a subject is more likely to get three pitches correct than one, for instance.

Given this variation, for the purposes of comparing different chordal disaggregation results, it is helpful to have a single "weighted" derivation index (Z). This is given by the product of the proportion of repetition (R) and the probability that this did not occur by chance ($1 - P$):

$$Z = R\,(1 - P). \tag{6.26}$$

Note the similarity with the formula for intentionality (Formula 3.8).

To see the formula in action, consider the hypothetical sets of results from two subjects shown in Table 6.1, given #U = 12 and #S = 5. These results show that even though the two subjects achieved the same degree of repetition (an average of 3.65 notes matched out of five, or 73%), the mean strengths of derivation over 20 trials differ significantly, $t(19) = 6.49$, $P < 0.0001$. This is due to the different strategies adopted in each case: on average, Subject 2 used around twice as

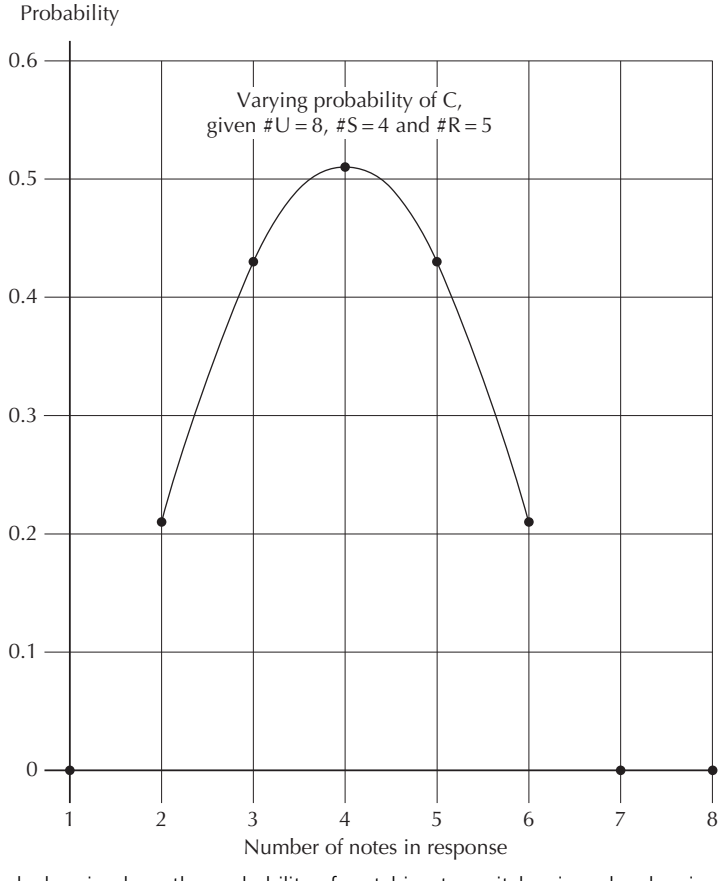


Fig. 6.11 Graph showing how the probability of matching two pitches in a chord varies according to the number of notes in the response.

Table 6.1 Two sets of hypothetical chordal disaggregation data with zygonic analyses

	Subject 1					Subject 2				
	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*
	3	3	0.60	0.05	0.57	7	3	0.60	0.44	0.33
	4	4	0.80	0.01	0.79	10	4	0.80	0.53	0.38
	2	2	0.40	0.15	0.34	6	2	0.40	0.38	0.25
	3	3	0.60	0.05	0.57	7	3	0.60	0.44	0.33
	4	4	0.80	0.01	0.79	8	4	0.80	0.35	0.52
	5	5	1.00	0.00	1.00	11	5	1.00	0.58	0.42
	3	3	0.60	0.05	0.57	7	3	0.60	0.44	0.33
	5	4	0.80	0.04	0.76	8	4	0.80	0.35	0.52
	4	4	0.80	0.01	0.79	9	4	0.80	0.48	0.42
	6	5	1.00	0.01	0.99	11	5	1.00	0.58	0.42
	2	2	0.40	0.15	0.34	5	2	0.40	0.44	0.22
	3	3	0.60	0.05	0.57	7	3	0.60	0.44	0.33
	2	2	0.40	0.15	0.34	4	2	0.40	0.42	0.23
	4	4	0.80	0.01	0.79	9	4	0.80	0.48	0.42
	3	3	0.60	0.05	0.57	6	3	0.60	0.38	0.37
	6	5	1.00	0.01	0.99	12	5	1.00	1.00	0.00
	5	5	1.00	0.00	1.00	10	5	1.00	0.32	0.68
	5	4	0.80	0.04	0.76	9	4	0.80	0.48	0.42
	3	3	0.60	0.05	0.57	3	3	0.60	0.05	0.57
	6	5	1.00	0.01	0.99	10	5	1.00	0.32	0.68
Mean	3.90	3.65	0.73	0.04	0.71	7.95	3.65	0.73	0.45	0.39

#R, number of pitches in the response; #C, number of pitches that are correct; *R*, proportion of repetition; *P*, probability of this occurring by chance; *Z*, weighted derivation index.

many notes as Subject 1 in each attempt, which has a dramatic impact on the probability of his getting notes correct by chance (see Fig. 6.12).

We are now in a position to analyze the results of the empirical work with Derek.

Derek's capacity for disaggregating chords—the results of testing

Twenty chords each of four, five, six, seven, eight, and nine notes (a total of 120 compound stimuli) were created for Derek to hear and reproduce as accurately as he could. They ranged from simple diatonic harmonies to chords of the 7th, 9th, 11th, and 13th with a range of chromatic inflexions; to polytonal aggregates reminiscent, for example, of certain compounds used in Stravinsky's *Rite*

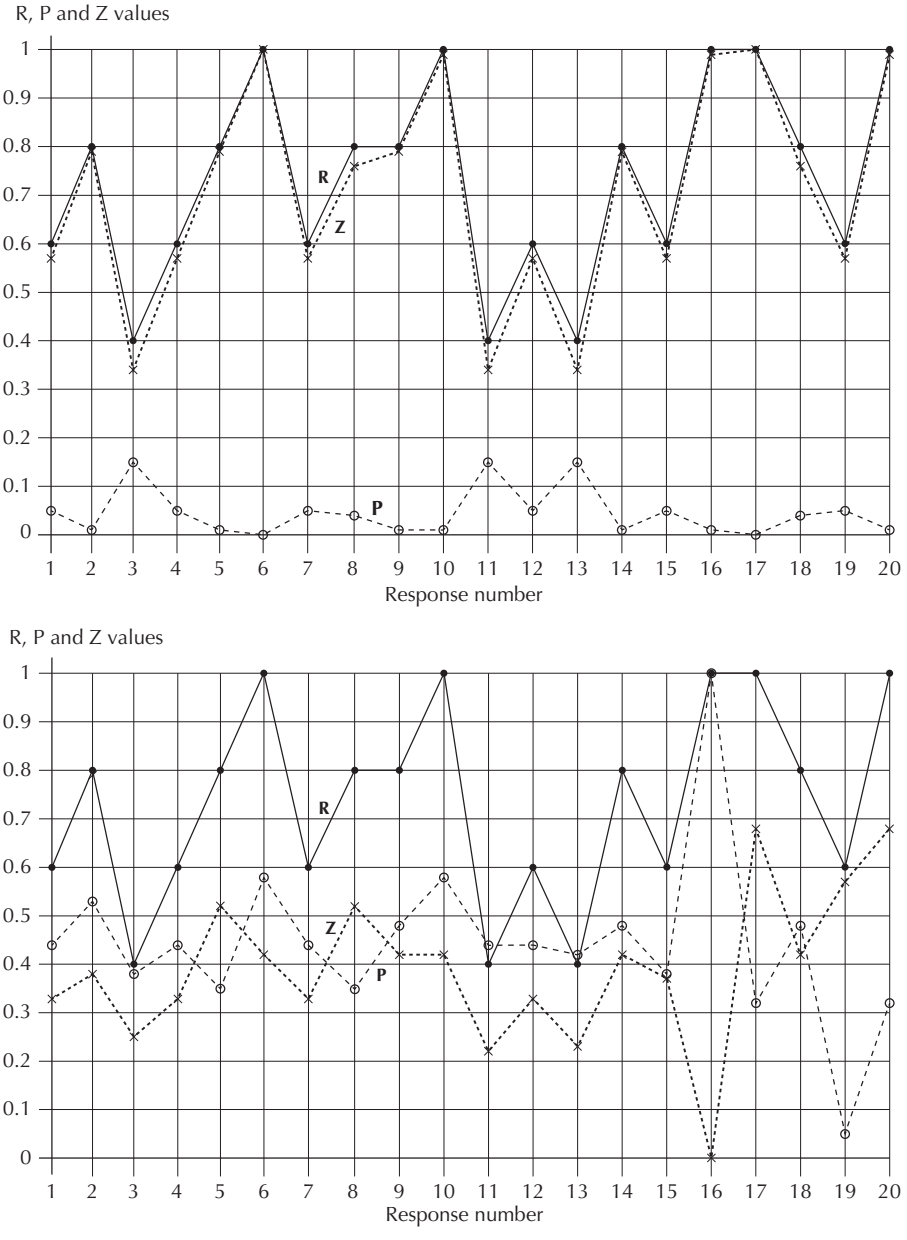


Fig. 6.12 (a) Graphical representation of Subject 1's *R*, *P*, and *Z* values, given #U = 12 and #S = 5. (b) The same for Subject 2.

of Spring, and clusters of major and minor seconds, that to most people would appear to be little more than noise. These stimuli were recorded digitally for the experiment using a Korg SP-200 88-note touch-sensitive hammer-action keyboard, set to a piano sound, linked via MIDI to a laptop computer, monitored through Edirol MA-10A speakers. Each had a duration of 1 second, separated by 9 seconds of silence from the next chord in the series.

The chords were played to Derek in batches of 20, after each of which breaks were offered (though these were declined). He was asked to copy what he heard as accurately he could. The precise nature of Derek's renditions was ascertained through the production of a score using Finale music notation software, supplemented with video and audio recordings. Derek's responses were made without hesitation and, indeed, with a certain apparent relish: after a few chords that were played "straight," he started to arpeggiate the simultaneous clusters of notes that he had heard and then began noodling playfully on each harmony in the few seconds that were available before the next stimulus sounded. This led to him being asked on a few occasions to "copy *exactly* what he heard," which had the effect of temporarily curtailing his musical peregrinations. With regard to notating his efforts for analysis, his miniature improvisations were not taken into account. Derek showed no signs of fatigue or loss of concentration over the 20 minutes or so in which the 120 chords were played, amounting to some 780 individual stimuli.

The results are shown in Fig. 6.13. Observe that in three cases Derek played the correct pitch-class but in the wrong octave, (cf. Révész, 1924/1971, pp. 78, 79) and these are scored as 0.5, since in one pitch dimension the response was correct and in another it was erroneous.

These raw results together with the weighted derivation indices are shown in Table 6.2. Here we make the assumption that #U = 25, equating to a spread of pitches separated by semitones over two octaves. Clearly this is an approximation, as the number of notes that can be played simultaneously by a pianist depends on the precise disposition of the chords concerned (since some combinations lie more comfortably under the hands than others) and the size and flexibility of the performer's hands and fingers. Nonetheless, #U = 25 gives a fair indication of the what is physically possible over a range of conditions. In Derek's case, the differences between R and Z are in any case often negligible, since the probability of such high levels of accuracy occurring by chance are vanishingly small. However, where values of R are lower, the impact on Z is greater, as we shall see.

As the size of the chords increases, Derek's responses show a general decline in accuracy (see Fig. 6.14), and a one-way ANOVA shows that their variability as a whole is significant: $F(5, 114) = 2.61$, $P = 0.03$. However, Tukey post-hoc comparisons indicate that only the difference in means between Derek's responses to the four-note chords and nine-note chords reaches significance at $P < 0.05$. This analysis accords with the intuition that Derek found the task as whole relatively easy, and that his performance was only marginally affected by chord size. Nonetheless, his reproduction of the stimuli was not perfect, and scrutiny of the patterns of derivation and non-derivation in his responses yields fascinating insights into the operation of his musical mind.

Four-note chords

At the four-note level, Derek makes no errors (through omission) at all, though on six occasions he adds extra pitches to those that are presented, producing five chords of five notes and one of six. It is worth noting that although Derek can count (in the sense of being able to recite an ascending sequence of numbers from 1 to 20, for example), he has little or no sense of numerosity (encompassing concepts such as how many?, fewer, and more). Hence for him, the notion of "copying a chord exactly" may have less to do with a numerical concept than a harmonic percept. This is shown in the nature of additions that Derek makes. With chords 4.9 and 4.19, for instance, he repeats a pitch that is already present, at a different octave. In harmonic-functional terms these supplementary notes have no effect. With chords 4.7, 4.11, and 4.17, Derek incorporates extra notes that could reasonably be inferred in the context of tertian harmony (that is, chords based on thirds, which form the bedrock of the "common practice" Western tonal system). In derivational terms, we can surmise that each stimulus triggers a memory in Derek of a more complete

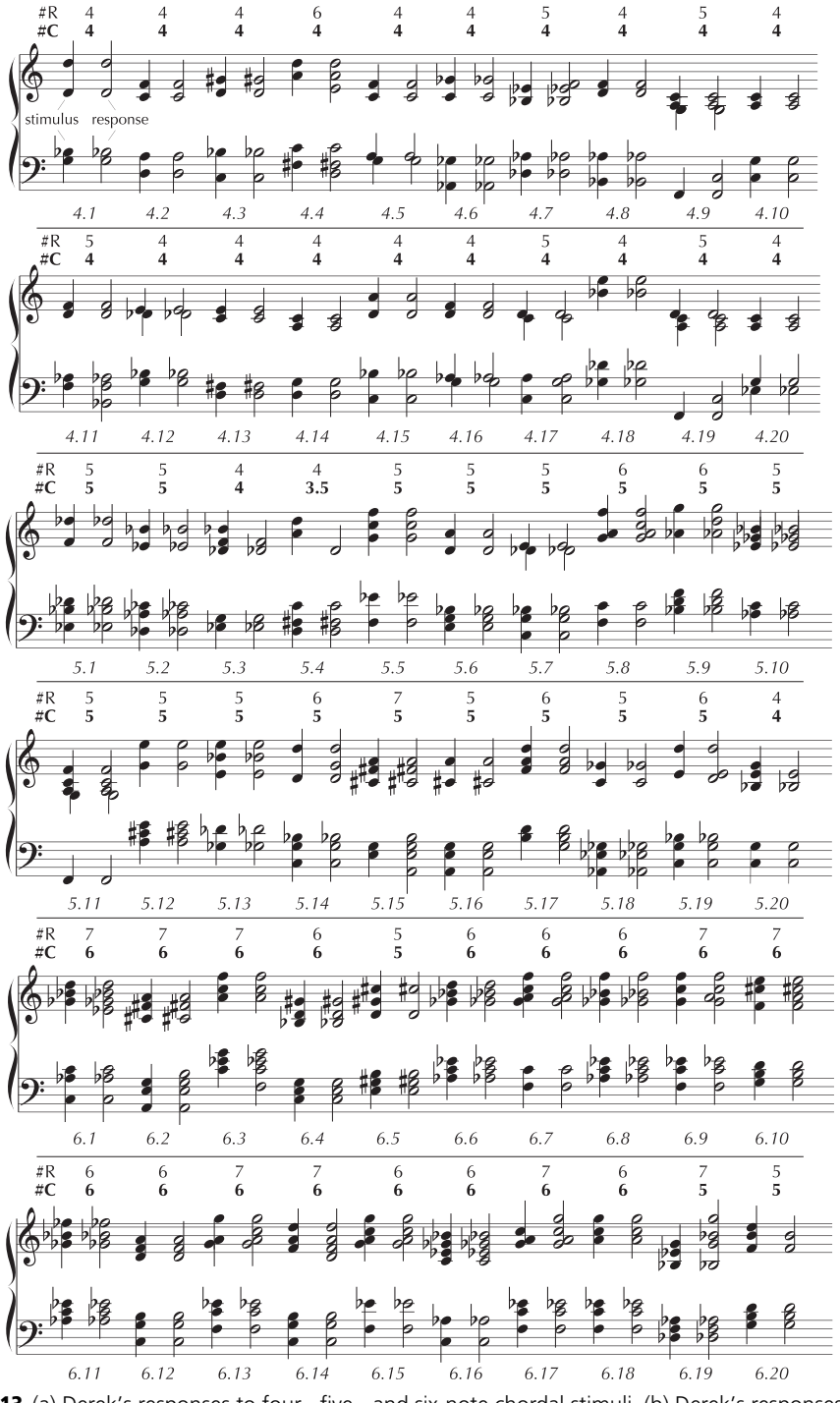



Fig. 6.13 (a) Derek's responses to four-, five-, and six-note chordal stimuli. (b) Derek's responses to seven-, eight-, and nine-note chordal stimuli.

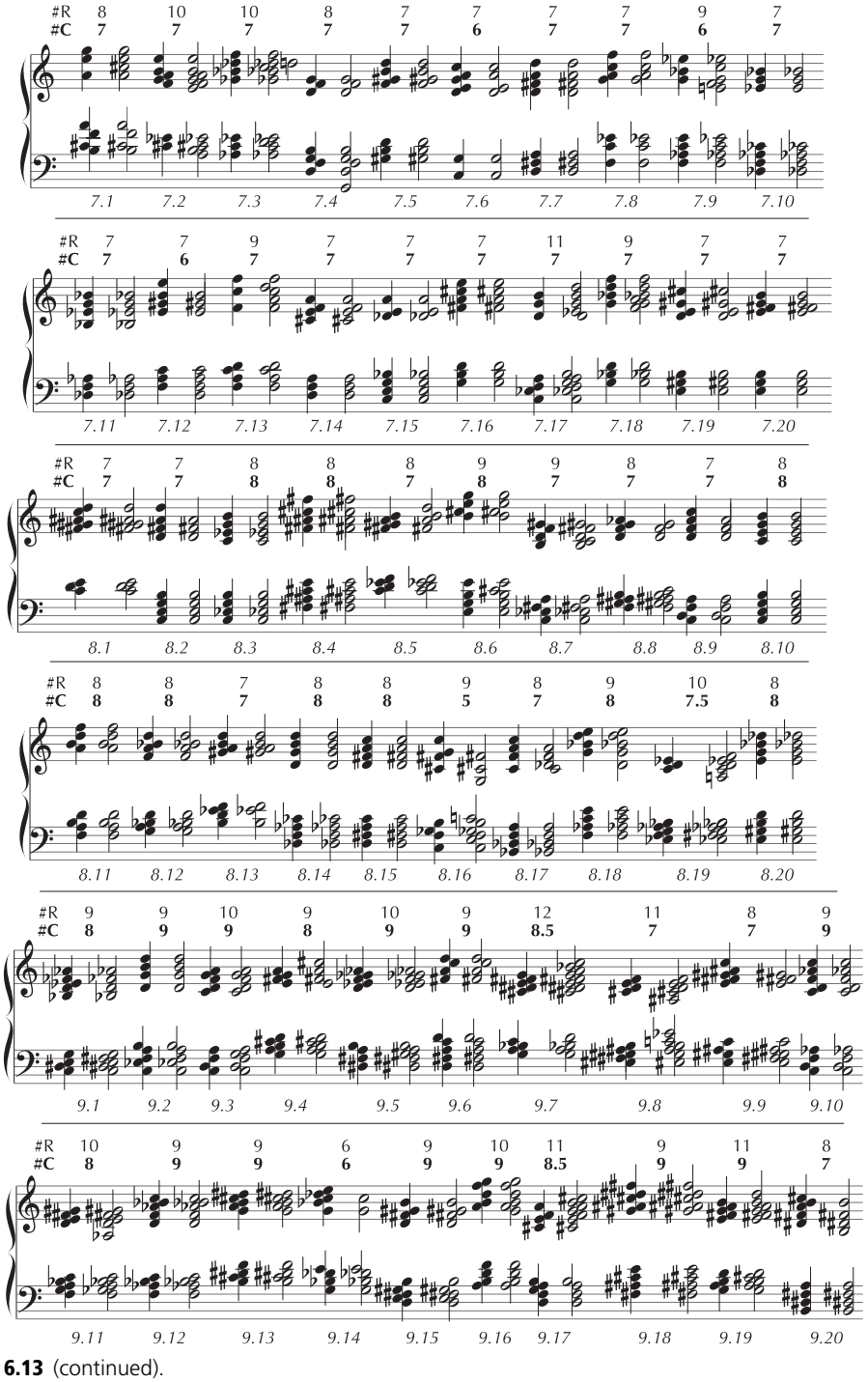


Fig. 6.13 (continued).

harmony—a set of intervals—with which the four notes he has heard are compatible. It seems that he unthinkingly draws on this recollection to enrich his response (as he would typically do in performance; see Ockelford, 2007b). With chord 4.4, Derek adopts a combination of the two strategies, adding a root (D—a pitch-class that is already present at the top of the chord) and a ninth (E) to the first inversion "dominant seventh" that acts as the stimulus.

In summary, Derek's additions are "rule-based," showing stylistic sensitivity to the Western musical vernacular with which he is familiar. Moreover, the notes he adds have only a tiny impact on the probability of his responses being correct by chance ($P = 0.0004$ in the case of one note, and $P = 0.0012$ in relation to two). Hence the raw and weighted scores are, as we have seen, to all intents and purposes the same.

Five-note chords

A similar position obtains in relation to Derek's responses to five-note chords. Here he omits three notes (out of 100) and effects one octave-transposition, giving an error score of 3.5. Two of the omissions are of the top notes of chords (5.3 and 5.20) and one (5.4) is of the second note down (although here too the top note appears an octave lower). This bias could in part be due to Derek's tendency to roll his responses up from the bass note, since from time to time he appears to miscalculate the required hand position and to run out of fingers before his response is complete. As one would expect, therefore, the lowest notes in the stimuli are invariably present in the responses, although occasionally they are supplemented with pitches below the originals: in 5.15 and 5.17, Derek adds the harmonic roots of the chords concerned. There are four other cases of addition involving a single note—5.8, 5.9, 5,14, 5.19—each doubling at the octave a pitch-class that is present in the stimulus. In 5.15, Derek adds a ninth (cf. 4.4). Again, these extra pitches show an intuitive understanding of common practice Western harmonic style, and once more they have only a tiny impact on the probability of correct notes being selected by chance.

Six-note chords

There are three errors through omission in chords 6.5, 6.19, and 6.20, which involve in one case the highest note and on two occasions the second from the top. Nine responses involve supplementary notes: eight have one note added, and one has two (where a pitch is also omitted). Doubling at the octave of a note already present occurs in 6.13, 6,17, and 6.19 (the latter involving two notes). Others (6.1, 6.2, 6.3, 6.9, 6.10, and 6.14) have additional notes that accord with the tertian harmony implied by the stimulus. These results reinforce our understanding of Derek's rule-based auditory processing set out above in relation to four- and five-note chords.

Seven-note chords

Despite their relative complexity, all but one of the seven-note stimuli can readily be construed as tertian in structure (although two, 7.12 and 7.17, are arguably bi-tonal in construction, and one, 7.1, uses the whole-tone scale). While theoretically resolvable as a chromatically altered dominant 13th in D minor, chord 7.2 will be treated for the purposes of this analysis as an atonal "cluster": an agglomeration of adjacent or nearly adjacent pitches that cannot readily be construed as pertaining to a particular key. More clusters are present in the eight- and nine-note chords, and, by comparing Derek's responses to these with those engendered by the tertian stimuli, we can glean further insights into the way that his musical mind works. Does he make more errors in relation to clusters than tertian harmonies, for example? And do any such errors tend to reinforce tonal archetypes?

Table 6.2 Derek's chordal disaggregation data, with *P* and *Z* scores, given #U = 25

Four-note chords						**Five-note chords**					**Six-note chords**				
	#R	**#C**	***R***	***P***	***Z***	**#R**	**#C**	***R***	***P***	***Z***	**#R**	**#C**	***R***	***P***	***Z***
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	4	4	0.80	0.0004	0.80	7	6	1.00	0.0000	1.00
	6	4	1.00	0.0012	1.00	4	3.5	0.70	0.0109	0.69	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	5	5	0.83	0.0001	0.83
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	5	4	1.00	0.0004	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	6	5	1.00	0.0001	1.00	6	6	1.00	0.0000	1.00
	5	4	1.00	0.0004	1.00	6	5	1.00	0.0001	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	5	4	1.00	0.0004	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	6	5	1.00	0.0001	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	7	5	1.00	0.0004	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	5	4	1.00	0.0004	1.00	6	5	1.00	0.0001	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	5	4	1.00	0.0004	1.00	6	5	1.00	0.0001	1.00	7	5	0.83	0.0021	0.83
	4	4	1.00	0.0001	1.00	4	4	0.80	0.0004	0.80	5	5	0.83	0.0001	0.83
Mean	4.35	4.00	1.00	0.0002	1.00	5.20	4.83	0.97	0.0006	0.96	6.35	6.00	0.98	0.0001	0.97
				SD	0.00				*SD*	0.09				*SD*	0.06

Table 6.2 (continued) Derek's chordal disaggregation data, with *P* and *Z* scores, given #U = 25

Seven-note chords					Eight-note chords					Nine-note chords				
#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*
8	7	1.00	0.0000	1.00	7	7	0.88	0.0000	0.87	9	8	0.89	0.0001	0.89
10	7	1.00	0.0002	1.00	7	7	0.88	0.0000	0.87	9	9	1.00	0.0000	1.00
10	7	1.00	0.0002	1.00	8	8	1.00	0.0000	1.00	10	9	1.00	0.0000	1.00
8	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	9	8	0.89	0.0001	0.89
7	7	1.00	0.0000	1.00	8	7	0.88	0.0001	0.87	10	9	1.00	0.0000	1.00
7	6	0.86	0.0003	0.86	9	8	1.00	0.0000	1.00	9	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	9	7	0.88	0.0005	0.87	12	8.5	0.94	0.0007	0.94
7	7	1.00	0.0000	1.00	8	7	0.88	0.0001	0.87	11	7	0.78	0.0147	0.77
9	6	0.86	0.0028	0.85	7	7	0.88	0.0000	0.87	8	7	0.78	0.0005	0.78
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	9	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	10	9	1.00	0.0000	1.00
7	6	0.86	0.0003	0.86	8	8	1.00	0.0000	1.00	9	9	1.00	0.0000	1.00
9	7	1.00	0.0001	1.00	7	7	0.88	0.0000	0.87	9	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	6	6	0.67	0.0005	0.67
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	9	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	9	7	0.88	0.0005	0.87	10	9	1.00	0.0000	1.00
11	7	1.00	0.0007	1.00	8	7	0.88	0.0001	0.87	11	8.5	0.94	0.0002	0.94
9	7	1.00	0.0001	1.00	9	8	1.00	0.0000	1.00	9	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	10	7.5	0.94	0.0003	0.94	11	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	8	7	0.78	0.0005	0.78
Mean 7.90	6.85	0.98	0.0002	0.98	8.10	7.53	0.94	0.0001	0.94	9.40	8.40	0.93	0.0009	0.93
			SD	0.05				*SD*	0.06				*SD*	0.10

#R, number of pitches in the response; #C, number of pitches that are correct; *R*, proportion of repetition; *P*, probability of this occurring by chance; Z, weighted derivation index.

In relation to the 20 seven-note chordal stimuli, Derek makes only three omissions in the entire set, which comprises 140 individual pitches: the top note (in chord 7.12), the second highest (7.9), and the third down (7.6). There are eight cases of additions: two of a single note (7.1 and 7.4), two of two notes (7.13 and 7.18), three of three notes (7.2, 7.3, and 7.9), and one of four notes (7.17). All except 7.12 and 7.18 involve doubling extant pitch-classes at the octave, and these two exceptions accord with tertian harmonic design.

With regard to the cluster (7.2), as well as doubling other notes at the octave, the three pitches that are added may have been generated in two other ways: through the extension of whole-tone elements in the chord, or to reinforce the potential tonal implications of the stimulus as a modified

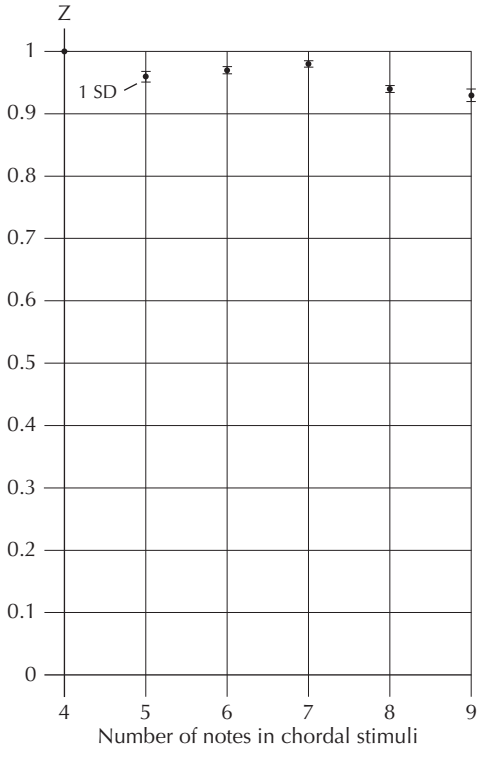


Fig. 6.14 Derek's weighted responses in the chordal disaggregation exercise.

dominant chord in D minor, by adding the root (A) in the bass. Both these strategies appear in relation to eight- and nine-note clusters considered next.

Eight-note chords

Here, 12 of the stimuli are tertian, and eight will be regarded as clusters: 8.1 (that uses a whole-tone scale), 8.5 (based on an octatonic scale, comprising alternating tones and semitones), 8.7 (comprising two diminished chords in different keys), 8.8 (an asymmetrical combination of major and minor seconds and minor thirds), 8.13 (an irregular amalgam of major and minor seconds and thirds), 8.16 (made up of four perfect fourths separated by a semitone, a tone, and another semitone), 8.19 (a major scale), and 8.20 (a combination of a dominant and diminished seventh on the same root).

Derek makes eight omissions (the top note in 8.2, 8.8, 8.9, 8.17; the second from top in 8.1 and 8.7; the third note down in 8.5; and the second from bottom in 8.13). Four exclusions are in clusters and four in tertian harmonies. The omissions pertaining to chords 8.1, 8.2, 8.8, 8.9, 8.13, and 8.17 all involve pitch-classes that are present at a different octave. Two are "mid-cluster." Additions are made to five chords: there are three cases of one supplementary note (8.6, 8.16, 8.18) and two of two notes (8.7 and 8.19). In 8.6, 8.7, and 8.17, the extra pitches double others at the octave. In 8.16 and 8.19, the additional notes are intercalated between notes in clusters.

Nine-note chords

These 20 stimuli comprise eight tertian chords and 12 clusters. One is derived from the major scale (9.19), one from the Lydian mode (9.4), and two from the whole-tone scale (9.9 and 9.13). The others (9.1, 9.2, 9.5, 9.7, 9.8, 9.11, 9.14, and 9.17) use irregular combinations of major and minor seconds and thirds almost exclusively (there is one perfect fourth in 9.2).

Derek omits pitches on seven occasions: three responses have one note missing, three have two, and one has three (a total of 12). As the data in Table 6.4 show, these are largely from the upper half of the chord, and the lowest note is never overlooked. Omissions of pitches present in other octaves occur in 9.1, 9.4, 9.20, 9.9 (twice), and 9.14 (three times). They crop up mid-cluster in 9.4 and 9.8 (twice). There is one instance of a "tertian" omission (9.20), though here the disposition of the chord that Derek did play (with one addition) meant that it would have been very difficult for him to have played the note concerned.

There are nine instances of notes being added: six cases of one note (9.1, 9.4, 9.5, 9.9, 9.16, and 9.20), three cases of two notes (9.8, 9.17, and 9.19), and one case of four notes (9.7, where one note is also omitted). Hence on four occasions Derek plays more notes than he has digits, which he achieves by playing two notes with one finger, either simultaneously or successively. Nine of the additions repeat other pitch-classes at the octave. The seven others appear in the gaps between notes in clusters.

Derek's capacity for disaggregating chords—a general discussion

Taking Derek's disaggregational performance as a whole, it is striking just how accurate he is: a task that would be quite beyond the ability of the vast majority of people he appears to find easy. In summary, he makes considerably more additions than omissions (67 as opposed to 29; see Table 6.3). Of the omissions, 20 involve pitch-classes that are present elsewhere in the stimulus. In total, therefore, out of 780 stimuli, only nine are wholly absent in Derek's responses (around 1%). With regard to additions, 41 repeat existing pitch-classes, 17 accord with the tertian harmonic context, and nine populate gaps in clusters. This equates to an average 3% addition of pitch-classes over the test as a whole. On no occasion does Derek change the fundamental harmonic nature of the tertian chords he hears, either by adding or removing notes—though he often adds to their complexity. The relative positions of the notes that Derek adds or omits offer further insights into the way he hears chords. The data presented in Table 6.4 show that, of the 29 omissions, 25 (86%) are from the upper half of chords, with only 4 (14%) from the lower half.

We have already noted Derek's tendency in the test to arpeggiate chords up from the lowest note, and the potentially confounding effect this may have had, since it would be the higher notes that were affected whenever he ran out of fingers. However, it could also be that his propensity to play notes successively starting from the bottom corresponded to the way he processed the stimuli. Such an approach would suggest a more "structural" way of hearing chords, since harmonic function is largely defined from the bass note upwards (something that is reflected in Western music theory: for example, the Baroque notion of "figured bass"). Derek's additional pitches were much more evenly spread, and included five examples of roots being added *below* the lowest note in the stimulus (and that were implied by it). However, as we can presume that Derek did not regard the additions as errors, this seems to have less cognitive significance than the omissions.

Finally, it is possible to compare Derek's responses to the *type* of chord, by making a distinction between those that could reasonably be regarded as tertian and those that formed atonal clusters (Table 6.5). Here there is a marked and statistically significant difference between both additions

Table 6.3 The frequency and nature of Derek's omissions and additions in the chordal disaggregation task

Chord size	No. of notes	No. of omissions	Omissions (%)	No. of notes omitted already present elsewhere at a different octave		Omission of pitch-classes (%)	No. of additions	Additions (%)	No. of additions at the octave	No. of "tertian" additions	No. of "non-tertian" pitch-classes added	Pitch-classes added (%)
				Present	Not present							
4	80	0	0.0	0	0	0.0	7	8.8	3	4	0	5.0
5	100	3	3.0	2	1	1.0	7	7.0	4	3	0	3.0
6	120	3	2.5	2	1	0.8	10	8.3	4	6	0	5.0
7	140	3	2.1	2	1	0.7	19	13.6	17	2	0	1.4
8	160	8	5.0	6	2	1.3	8	5.0	4	2	2	2.5
9	180	12	6.7	8	4	2.2	16	8.9	9	0	7	3.9
Sums	780	29		20	9		67		41	17	9	
Means (%)			3.7			1.2		8.6				3.3

Table 6.4 The relative positions of the notes omitted by Derek

Chord size	No of notes	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
4	80	0	0	–	–	–	–	–	0	0	0
5	100	3	0	–	–	0	–	–	0	0	3
6	120	1	2	0	–	–	–	0	0	0	3
7	140	1	1	1	–	0	–	0	0	0	3
8	160	4	2	1	0	–	0	0	1	0	8
9	180	3	3	2	1	0	0	1	2	0	12
Sums	780	12	8	4	1	0	0	1	3	0	29
				Sum of upper half = 25				Sum of lower half = 4			

and omissions in relation to chord type, with clusters attracting over twice as many missing and additional notes as tertian chords χ^2 (2, $n = 780$) = 16.04, $P = 0.0003$. This suggests that, despite his excellent sense of AP, Derek's perception of pitch is nonetheless affected by structures that are determined in relative terms (through the intervals between values), further evidence for which is presented later in this chapter (see pp. 233–5). However, it should be recognized that some of this effect may be due to the fact that clusters tend to be more complex than tertian harmonies in terms of the number of pitch-classes they employ. In the seven-, eight-, and nine-note chords, for example, the mean number of different pitch-classes used in those categorized as tertian is 5.13 ($SD = 1.15$), whereas that pertaining to clusters is 7.00 ($SD = 1.00$). This difference is significant: $t(46) = 6.55$, $P < 0.0001$.

Comparing Derek's results with another savant and a neurotypical musician with AP

Clearly, Derek's results are in themselves of interest and potential importance, particularly to those working with him, since they offer an insight into the way that he processes groups of pitches produced simultaneously. However, it is worth comparing his chordal disaggregational ability with that of other savants and other musicians with AP, and an extensive study is currently under way to this end (see Mazzeschi *et al.*, 2011). Here, the findings from two other people are reported (previously summarized in Ockelford, 2008b, pp. 218–25): A, a musical savant, and S, an accomplished jazz pianist with AP.

A, in his late 30s at the time of the test, has been totally blind from birth with the condition Leber's congenital amaurosis (Leber, 1869; Stone, 2007) and has moderate learning difficulties. His principal area of performing expertise is percussion, particularly the timpani, drum kit, and vibraphone, although he plays a number of instruments competently, including the recorder, clarinet, saxophone, and piano. When he was younger, he performed in a number of youth orchestras and bands, and he has a wide-ranging knowledge of Western classical and popular music. A has "universal" AP that functions effectively whatever the source of sound, and it was known that he could hear and reproduce complex harmonies. Both his short-term and long-term memories are outstanding. For example, he was able to learn the first Debussy *Arabesque* (1888) on the piano by

Table 6.5 Derek's differing responses to different types of chord: (a) tertian chords and (b) clusters

(a) Tertian chords

Chord size	Total no. of notes	No. of chords	No. of notes in tertian chords	No. of omissions	No. of additions	Sums	Percentage
4	80	20	80	0	7	7	8.8
5	100	20	100	3	7	10	10.0
6	120	20	120	3	10	13	10.8
7	140	19	133	3	16	19	14.3
8	160	14	112	3	2	5	4.5
9	180	8	72	4	1	5	6.9
Sums	780	101	617	16	43	59	
Means (%)				2.6	7.0		9.6

(b) Clusters

Chord size	Total no. of notes	No. of chords	No. of notes in clusters	No. of omissions	No. of additions	Sums	Percentage
4	80	0	0	–	–	–	–
5	100	0	0	–	–	–	–
6	120	0	0	–	–	–	–
7	140	1	7	0	3	3	42.9
8	160	6	48	5	6	11	22.9
9	180	12	108	8	15	23	21.3
Sums	780	19	163	13	24	37	
Means (%)				8.0	14.7		22.7

hearing the music a page at a time. However, A's keyboard technique is not as fluent as Derek's, and having learnt the *Arabesque* aurally in a relatively short space of time, he then spent many weeks practicing it from memory, and was never able to achieve a standard of performance with which he was satisfied.

In terms of the chordal disaggregation task, like Derek, A was content to tackle all 120 stimuli without a break. With his greater level of general awareness and understanding, A followed the instructions he was given more faithfully, with no musical digressions. However, as the test progressed, with more and more notes needing to be played, the limitations of his keyboard technique became increasingly evident, and it was clearly an effort for him to get his fingers over the right keys in time. Observing him in action, it appeared that A was physically groping to re-create the sounds that he could evidently continue to hear in his head for some seconds at least after the stimulus had ceased. In fact, on more than one occasion, he was still striving for the correct combination of notes when the next chord sounded. Hence, in scoring A's responses (unlike Derek's), it was largely the *last* thing he played each time that was taken to be his intended response. It is my

belief that, with more time, A could have achieved better results, and that problems of coordination gave a somewhat restricted view of his auditory processing capacity. That being said, A's results were, nonetheless, remarkable (see Fig. 6.15).

A's raw results and their associated weighted derivation indices are shown in Table 6.6. Again, the assumption is that #U = 25. The differences between *R* and *Z* are on average even smaller than in Derek's case, since, as we shall see, A played fewer additional notes. As the number of notes per stimulus increases, A's responses show a general decline in accuracy, and a one-way ANOVA shows that their variability as a whole is significant: $F(5, 114) = 14.33$, $P < 0.0001$. Tukey post-hoc comparisons indicate that there is no significant difference between four-, five-, six-, and seven-note chords. However, each of these differs significantly from both eight- and nine-note chords ($P < 0.001$), and eight- and nine-note chords are themselves significantly different ($P < 0.01$). These statistics support the observation that the deterioration in A's results as chords grow in size is more marked than Derek's, and a two-way ANOVA shows that the difference between the two is significant: $F(11, 228) = 5.49$, $P < 0.001$, within which both the eight- and nine-chord results show individual significant differences ($P < 0.001$) (see Fig. 6.16).

Further interrogation of the data shows other key differences and similarities in the way that the two savants process simultaneous groups of pitches and seek to reproduce them (see Table 6.7). First, with regard to notes omitted and added, A fails to include 87 pitches (three times as many as Derek), but adds only 29 (as opposed to Derek's 67). The difference between these distributions is highly significant: $\chi^2\ (1, n = 212) = 40.75$, $P < 0.0001$. Given this difference, A's pattern of additions (at the octave or in accordance with tertian principles) is comparable to Derek's, although A adds disproportionately more pitch-classes to clusters (12 out of 29 as opposed to 9 out of 67): $\chi^2\ (1, n = 117) = 4.37$, $P = 0.037$. Since the ways in which A and Derek add pitch-classes to clusters do not, and could not, conform to stylistically determined harmonic principles (in other words, it is more likely that these additions are idiosyncratic errors rather than intentional enrichments to recognizable harmonies), this disparity suggests that A was finding clusters disproportionately more difficult than tertian stimuli in comparison with Derek (though see comments later).

In terms of the position of the notes in the stimuli that are omitted, there is a close correlation between A's and Derek's results (see Table 6.8), with both savants showing an increasing tendency to omit pitches the higher they are in the chord ($R^2 = 0.70$, $P = 0.005$) (see Fig. 6.17). Unlike Derek, A did not arpeggiate chords up from the lowest pitch, so the fact that he, too, did not omit any of the bass notes in the stimuli suggests that the two men intuitively processed the harmonies in a comparable, structural way (see previous comments), their differing production strategies notwithstanding.

A further comparison of the omissions and additions in relation to the manner in which tertian harmonies and clusters were reproduced shows that A is four times more likely (24.5% as opposed to 6.0%) to omit notes from clusters than from tertian harmonies, while Derek is three times mores likely (8% as opposed to 2.6%) (Table 6.9). Moreover, A is almost six times more likely to add notes to clusters than tertian stimuli, whereas Derek is around twice as likely. While neither of these differences is statistically significant, when taken with the previous data in relation to A's greater tendency to add pitch-classes to clusters than tertian harmonies, they do add weight to the notion that Derek found clusters relatively (as well as absolutely) easier than A.

A further comparator was another male, S, an accomplished jazz pianist in his mid-20s, known to have universal absolute pitch, and used to learning by ear. S's results are shown in Fig. 6.18. S took a short break between each set of stimuli.

S's results and the weighted derivation indices that pertain to them are shown in Table 6.10. The differences between *R* and *Z* become more substantial as the size of the chords increases.

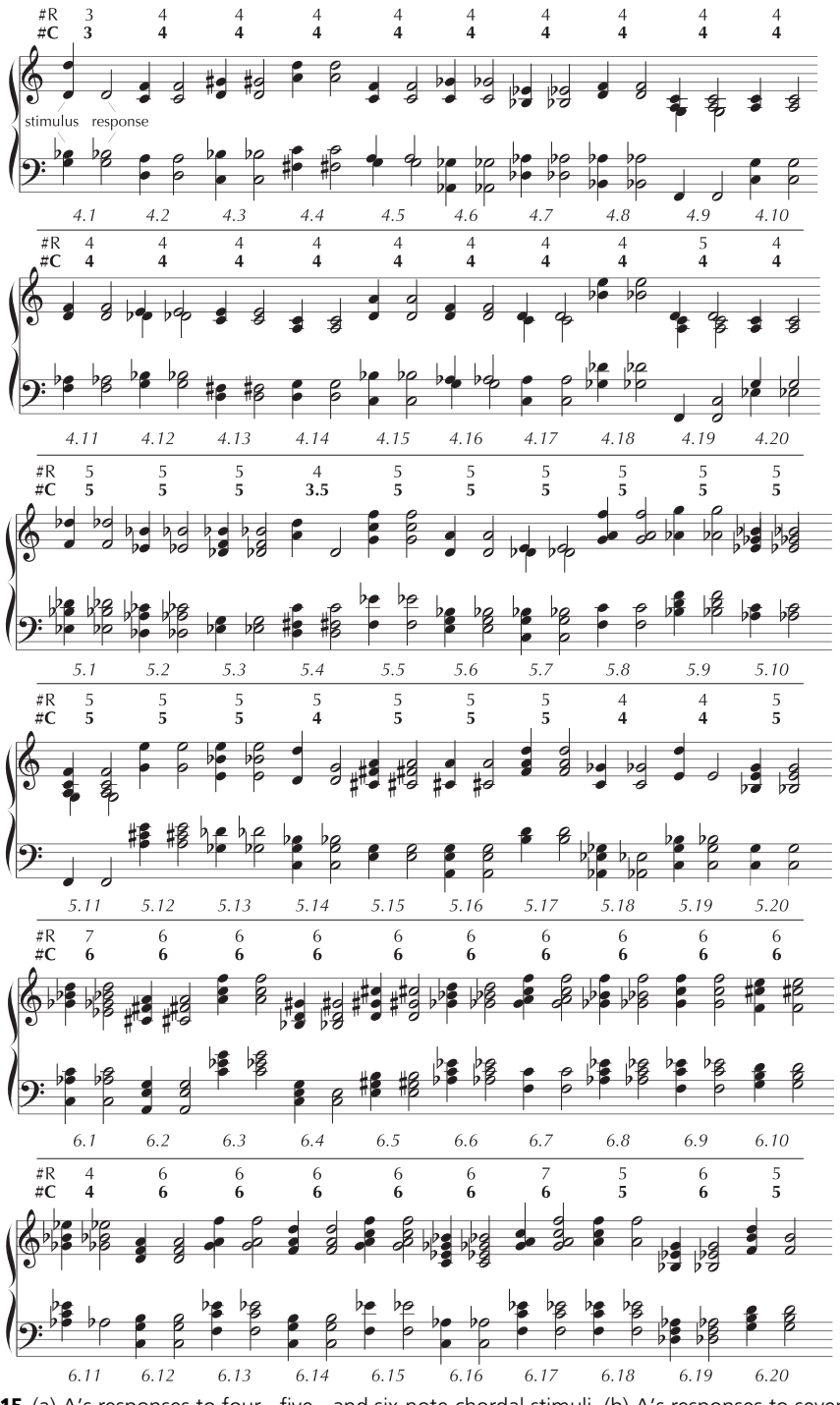



Fig. 6.15 (a) A's responses to four-, five-, and six-note chordal stimuli. (b) A's responses to seven-, eight-, and nine-note chordal stimuli.

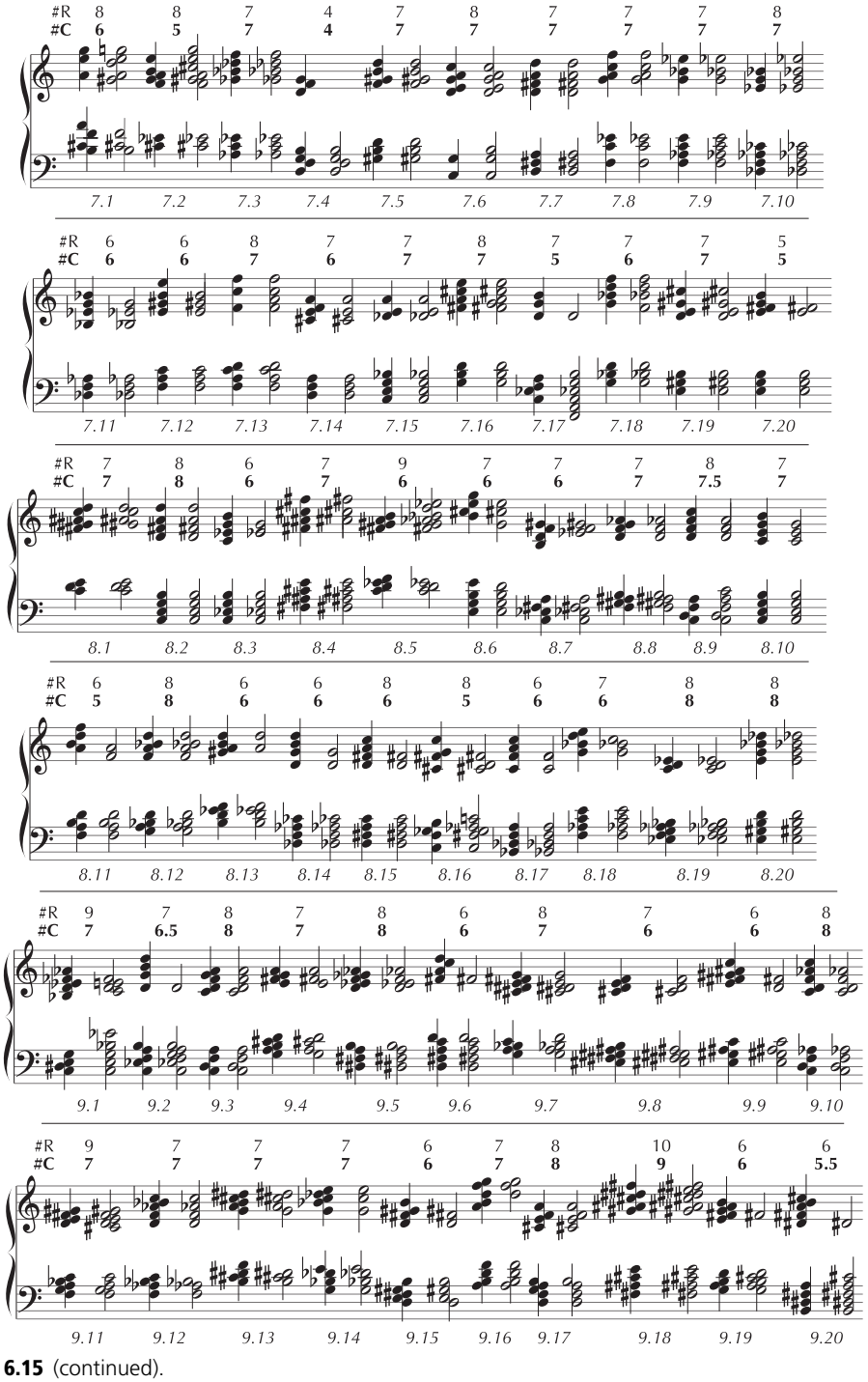



Fig. 6.15 (continued).

Table 6.6 A's chordal disaggregation data, with *P* and *Z* scores

Four-note chords						Five-note chords					Six-note chords				
	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*
	3	3	0.75	0.0017	0.75	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	4	3.5	0.70	0.0109	0.69	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	4	4	0.67	0.0012	0.67
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	4	0.80	0.0019	0.80	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	7	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	4	4	0.80	0.0004	0.80	5	5	0.83	0.0001	0.83
	5	4	1.00	0.0004	1.00	4	4	0.80	0.0004	0.80	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	5	5	0.83	0.0001	0.83
Mean	4.00	3.95	0.99	0.0002	0.99	4.85	4.78	0.96	0.0007	0.95	5.90	6.00	0.97	0.0001	0.97
				SD	0.06				*SD*	0.10				*SD*	0.09

Table 6.6 (continued) A's chordal disaggregation data, with *P* and *Z* scores

Seven-note chords					Eight-note chords					Nine-note chords				
#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*
8	6	0.86	0.0010	0.86	7	7	0.88	0.0000	0.87	9	7	0.78	0.0021	0.78
8	5	0.71	0.0158	0.70	8	8	1.00	0.0000	1.00	7	6.5	0.72	0.0006	0.72
7	7	1.00	0.0000	1.00	6	6	0.75	0.0002	0.75	8	8	0.89	0.0000	0.89
4	4	0.57	0.0028	0.57	7	7	0.88	0.0000	0.87	7	7	0.78	0.0001	0.78
7	7	1.00	0.0000	1.00	9	6	0.75	0.0093	0.74	8	8	0.89	0.0000	0.89
8	7	1.00	0.0000	1.00	7	6	0.75	0.0010	0.75	6	6	0.67	0.0005	0.67
7	7	1.00	0.0000	1.00	7	6	0.75	0.0010	0.75	8	7	0.78	0.0005	0.78
7	7	1.00	0.0000	1.00	7	7	0.88	0.0000	0.87	7	6	0.67	0.0028	0.66
7	7	1.00	0.0000	1.00	8	7.5	0.94	0.0000	0.94	6	6	0.67	0.0005	0.67
8	7	1.00	0.0000	1.00	7	7	0.88	0.0000	0.87	8	8	0.89	0.0000	0.89
6	6	0.86	0.0000	0.86	6	5	0.63	0.0054	0.62	9	7	0.78	0.0021	0.78
6	6	0.86	0.0000	0.86	8	8	1.00	0.0000	1.00	7	7	0.78	0.0001	0.78
8	7	1.00	0.0000	1.00	6	6	0.75	0.0002	0.75	7	7	0.78	0.0001	0.78
7	6	0.86	0.0003	0.86	6	6	0.75	0.0002	0.75	7	7	0.78	0.0001	0.78
7	7	1.00	0.0000	1.00	8	6	0.75	0.0035	0.75	6	6	0.67	0.0005	0.67
8	7	1.00	0.0000	1.00	8	5	0.63	0.0352	0.60	7	7	0.78	0.0001	0.78
7	5	0.71	0.0067	0.71	6	6	0.75	0.0002	0.75	8	8	0.89	0.0000	0.89
7	6	0.86	0.0003	0.86	7	6	0.75	0.0010	0.75	10	9	1.00	0.0000	1.00
7	7	1.00	0.0000	1.00	8	8	1.00	0.0000	1.00	6	6	0.67	0.0005	0.67
5	5	0.71	0.0004	0.71	8	8	1.00	0.0000	1.00	6	5.5	0.61	0.0028	0.61
Mean 6.95	6.30	0.90	0.0014	0.90	7.20	6.58	0.82	0.0029	0.82	7.35	6.95	0.77	0.0007	0.77
			SD	0.13				*SD*	0.12				*SD*	0.10

#R, number of pitches in the response; #C, number of pitches that are correct; *R*, proportion of repetition; *P*, probability of this occurring by chance; *Z*, weighted derivation index.

As was the case with Derek and A, as the number of notes per stimulus increases, so S's responses show a general decline in accuracy, and a one-way ANOVA shows that their variability as a whole is significant: $F(5, 114) = 8.03$, $P < 0.0001$ (see Fig. 6.19). Tukey post-hoc comparisons indicate that there is no significant difference between four-, five-, six-, and seven-note chords. However, the eight-note chords differ significantly from the four-note chords ($P < 0.001$), the five-note chords ($P < 0.05$), and the six-note chords ($P < 0.05$). The nine-note chords differ significantly from the four-note chords ($P < .001$), the five-note chords ($P < 0.01$), and the six-note chords ($P < 0.001$). These statistics corroborate the observation that the decline in S's results as the size of the stimulus increases is more pronounced than Derek's or A's. As the linear trend lines shown

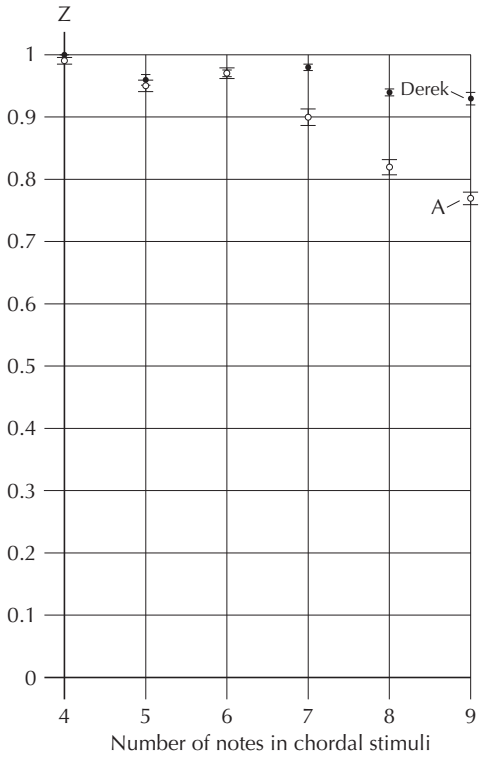


Fig. 6.16 A's (and Derek's) weighted responses in the chordal disaggregation exercise.

in Fig. 6.19 indicate, in Derek's case the reduction was on average 1.5% per additional note from a starting point of no errors; A's responses declined in accuracy by approximately 4% for each note added from an initial score of 99%; while the fidelity of S's efforts, beginning with a success rate of just 86% for four-note chords, diminished by about 7% for every increase in chord size, such that, with nine-note chords, he was achieving only a 50% success rate (corrected for chance). The difference between the three sets of scores is significant: $F(17, 342) = 19.62$, $P < 0.001$, with the individual differences between S and Derek, and S and A both being significant at the $P < 0.001$ level.

Detailed analysis of S's data reveals important areas of similarity and difference in the way that he processes chords compared with the two savants. First, with regard to notes omitted and added (see Table 6.11), there is an issue of the sheer volume of errors: S omits 226 of the 780 pitches (29%), which is almost eight times more than Derek and around two-and-a-half times more than A, and he adds 195 notes, which is almost three times as many as Derek and a little under seven times as many as A. But more than this, the *nature* of many of the additions is different too. *All* of Derek's and A's additions to tertian chords correspond with the harmony of the stimulus in question, either by enhancing the presence of particular pitch-classes by repeating them at the octave, by filling in implied gaps, or by incorporating extra notes to form higher discords. Hence a "7th" chord may become a "9th" (see, for example, Derek's response 4.4 in Fig. 6.13), but in essence it remains unchanged (it is still a chord of D). In contrast, on 61 occasions, S adds pitches that *change* the nature of the underlying harmony. For instance, in his response 5.13, the chord that originally sounds like F♯^{7} becomes G♯^{13} through the addition of the notes G♯ and B♯ (and the omission of D♭ and B♭).

Table 6.7 The frequency and nature of A's omissions and additions in the chordal disaggregation task, and a comparison with Derek's results

Chord size	No. of notes	No. of omissions	Omissions (%)	No. of additions	Additions (%)	No. of additions at the octave	No. of "tertian" additions	No. of "non-tertian" pitch-classes added	Pitch-classes added (%)
Omissions and additions: A									
4	80	1	1.3	1	1.3	1	0	0	0.0
5	100	4	4.0	0	0.0	0	0	0	0.0
6	120	4	3.3	2	1.7	1	1	0	0.8
7	140	12	8.6	10	7.1	6	1	3	2.9
8	160	26	16.3	8	5.0	4	1	3	2.5
9	180	40	22.2	8	4.4	2	0	6	3.3
Sums	780	87		29		14	3	12	
Means (%)			11.2		3.7				1.9
Omissions and additions: Derek									
Sums		29		67		41	17	9	
Means (%)			3.72		8.59				3.3
Ratios: A/Derek									
		3		0.43		0.34	0.18	1.33	

This implies that not only were the savants better at attending to the detail of the stimuli, as the theory of "weak central coherence" would predict (Frith, 2003, Happé, 1999), but also to the sensations of the chords as *Gestalts* as well (Heaton, 2003). Moreover, in S's responses, we find the addition of "non-tertian" pitch classes not only to clusters but to tertian harmonies too, thereby taking the stimuli beyond the confines of Western common practice (see, for example, chord 8.1, where the addition of E♭, E♮, C, B♭ and G♯ compromises the sense of a tertian chord).

In summary, then, there are three ways in which the subjects add material to tertian harmonies: (1) rule-based in specific terms, where the underlying harmonic nature of the stimulus is maintained; (2) rule-based in general terms, in that the chord remains tertian but changes in substance; and (3) not rule-based. Only the first procedure is adopted by Derek and A. S, however, uses all three (see Table 6.11).

Clearly, with only three subjects it is impossible to say whether the results set out here represent a general feature of savant versus non-savant behavior, or merely reflect the idiosyncratic characteristics of the cognitive styles of the men in question. Annamaria Mazzeschi's doctoral research at the Institute of Education, London, with six savants and a larger cohort of neurotypical musicians with advanced AP skills is seeking to gather further evidence pertaining to this phenomenon (see later).

Table 6.8 The relative positions of the notes omitted by A, and a comparison with Derek's results

Chord size	No. of notes	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
Omissions (by position in chord): A											
4	80	1	0	–	–	–	–	–	0	0	1
5	100	2	1	–	–	1	–	–	0	0	4
6	120	1	1	0	–	–	–	1	1	0	4
7	140	4	4	1	–	3	–	0	0	0	12
8	160	7	6	4	5	–	3	0	1	0	26
9	180	7	14	4	2	6	4	2	1	0	40
Sums	780	22	26	9	7	10	7	3	3	0	87
			Sum upper half = 64					Sum lower half = 13			
Omissions (by position in chord): Derek											
sums		12	8	4	1	0	0	1	3	0	29
			Sum upper half = 25					Sum lower half = 4			
Ratios: A/Derek											
				3.00					2.56		3.25

Turning now to the pattern of omissions of pitches relative to their location in the chordal stimuli, further significant differences emerge between Derek and A on the one hand and S on the other (see Table 6.12).

We noted earlier that both savants show a tendency to omit more pitches the higher their relative position in chord concerned (Fig. 6.17), and that this trend is highly correlated ($R^2 = 0.70$). In order to facilitate comparison between the three subjects, it is helpful to present the results summarized in Table 6.12 as percentages (see Table 6.13 and Fig. 6.20). Here, it is evident S's approach differs markedly from Derek's and A's (and no significant correlations between them exist). Across all stimuli, S's omissions appear to be more or less equally spaced in terms of chordal position. However, by categorizing pitches more simply as "top," "inner," or "bottom," and examining trends of omission by chord size, more subtle differences between the subjects become apparent (see Fig. 6.21). With both Derek and A, top notes are omitted consistently more often than inner notes, and the lowest notes are not absent at all. With S, though, the pattern of omissions changes as the stimulus size increases, whereby top notes change from being omitted least frequently to most often.

This quantitative analysis, showing that S's performance is best in relation to the outermost pitches in all but the largest chords (when his accuracy diminishes throughout the range, but particularly with respect to the highest notes), is borne out by his account of what occurred (he was alone in being able to reflect verbally on his response to the task). He described how he attended primarily to the top and bottom notes and subsequently "fitted in" the inner ones

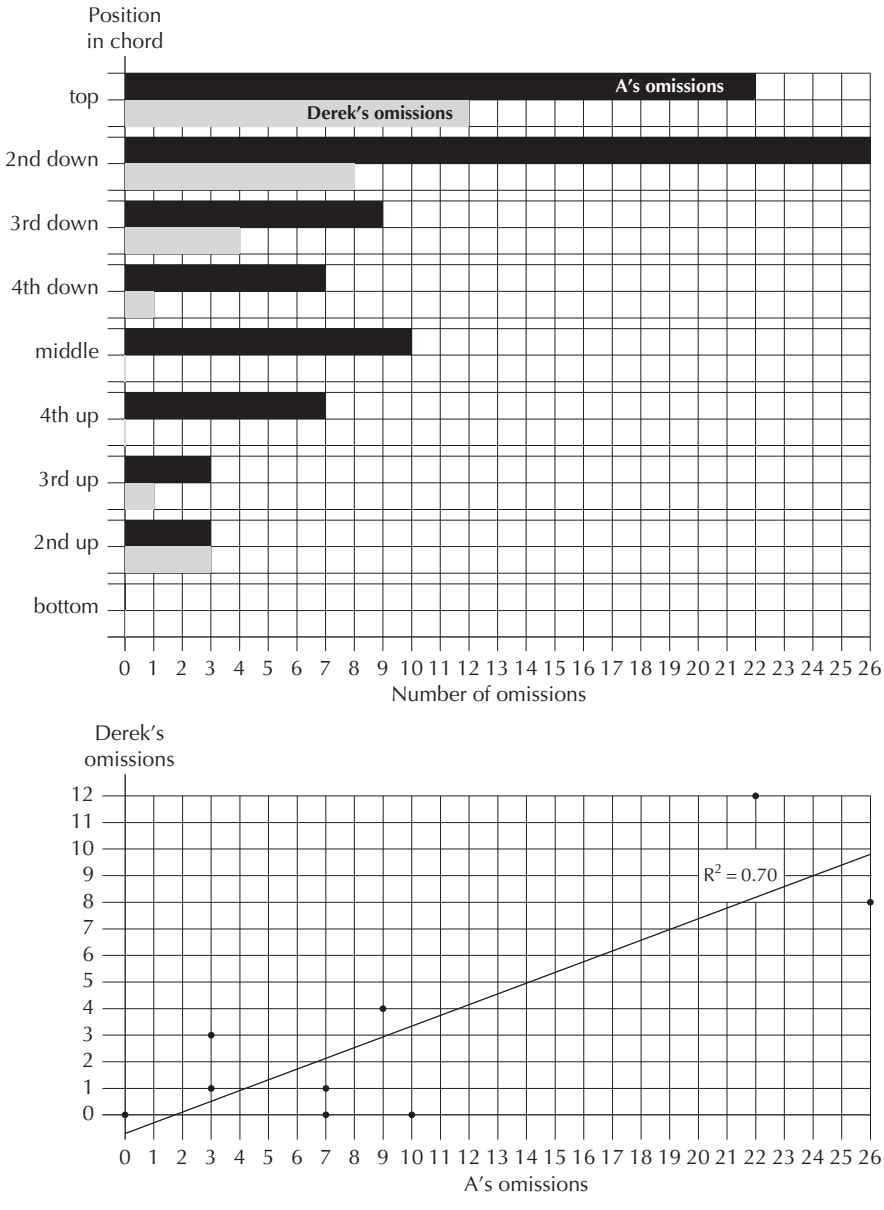


Fig. 6.17 The correlation between Derek's and A's patterns of omission of notes pertaining to their chordal positions.

Table 6.9 The pattern of errors made by A in relation to tertian chords (a) and clusters (b), and a comparison with Derek's results

(a) Tertian chords

Chord size	Total no. of notes	No. of chords	No. of notes in tertian chords	No. of omissions	No. of additions	Sums	Percentage
Errors by A							
4	80	20	80	1	1	2	2.5
5	100	20	100	4	0	4	4.0
6	120	20	120	4	2	6	5.0
7	140	19	133	10	7	17	12.1
8	160	14	112	16	2	18	11.3
9	180	8	72	12	1	13	7.2
Sums	780	101	617	47	13	60	
Means (%)				6.0	1.7		7.7
Errors by Derek							
Sums	780	101	617	16	43	59	
Means (%)				2.6	7.0		9.6
Ratios: A/Derek							
				2.94	0.30		

(b) Clusters

Chord size	Total no. of notes	No. of chords	No. of notes in clusters	No. of omissions	No. of additions	Sums	Percentage
Errors by A							
4	80	0	0	–	–	–	–
5	100	0	0	–	–	–	–
6	120	0	0	–	–	–	–
7	140	1	7	2	3	5	71.4
8	160	6	48	10	6	16	33.3
9	180	12	108	28	7	35	32.4
Sums	780	19	163	40	16	56	
Means (%)				24.5	9.8		34.4
Errors by Derek							
Sums	780	19	163	13	24	37	
Means (%)				8.0	14.7		22.7
Ratios: A/Derek							
				3.08	0.67		

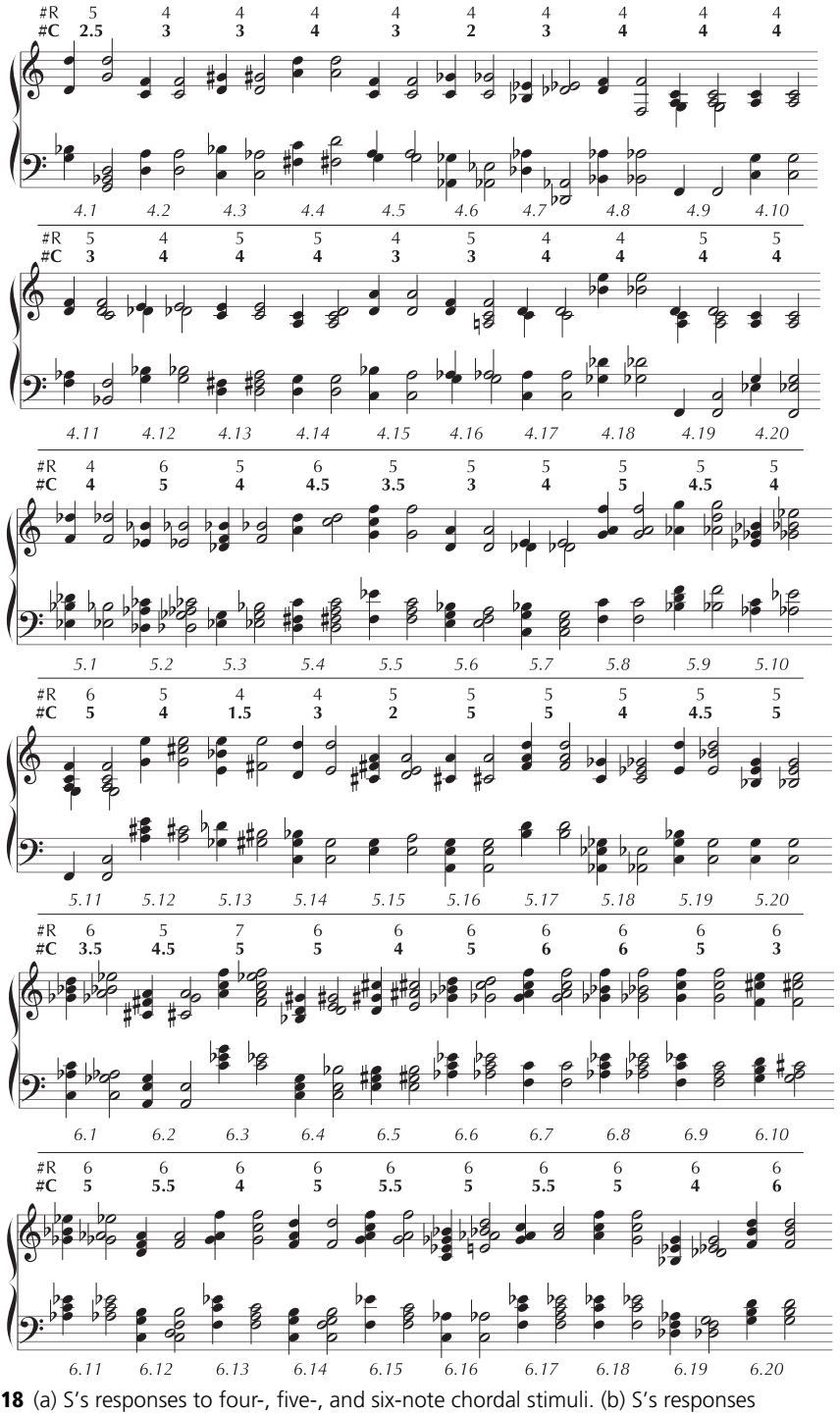



Fig. 6.18 (a) S's responses to four-, five-, and six-note chordal stimuli. (b) S's responses to seven-, eight-, and nine-note chordal stimuli.

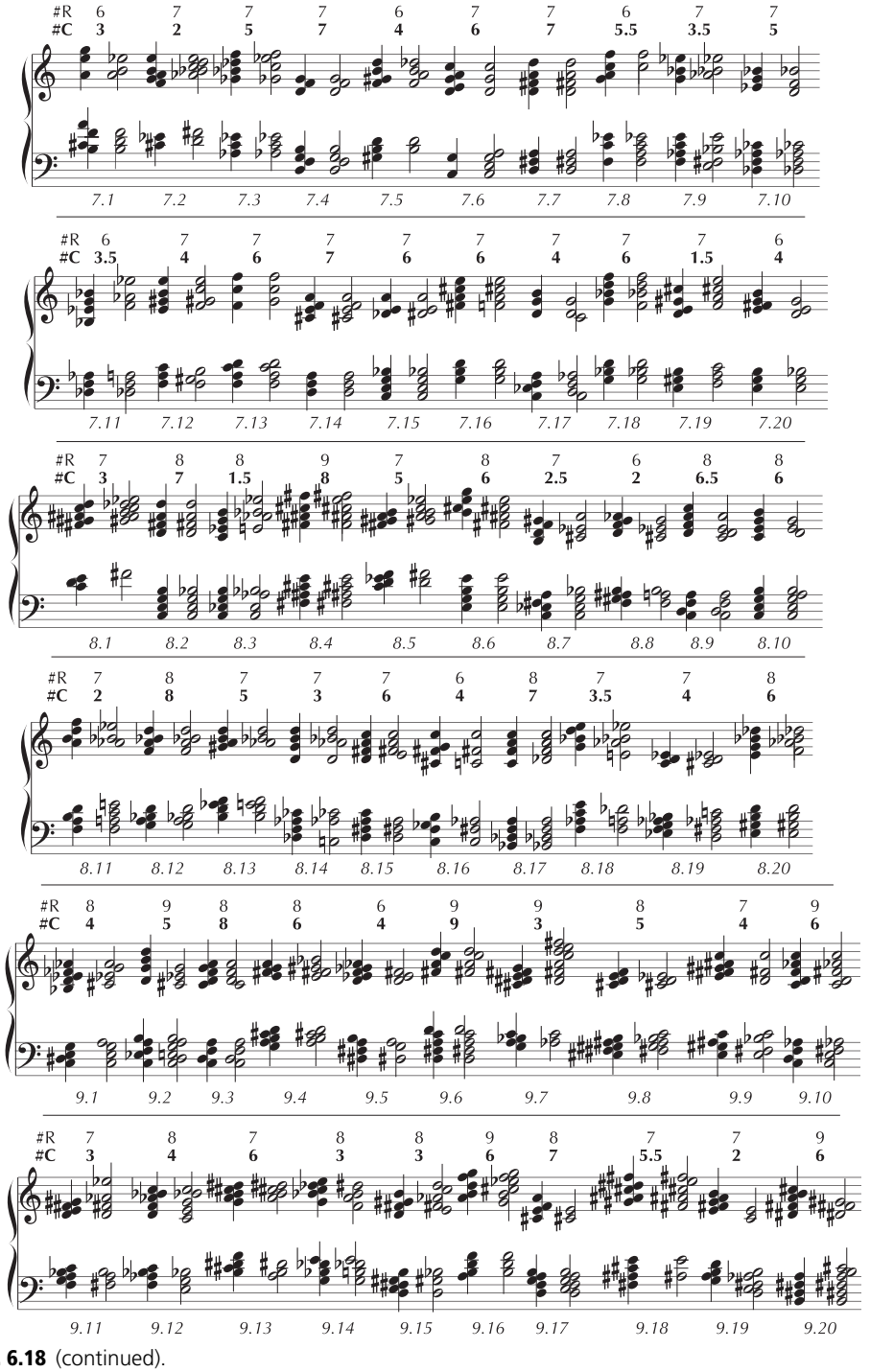



Fig. 6.18 (continued).

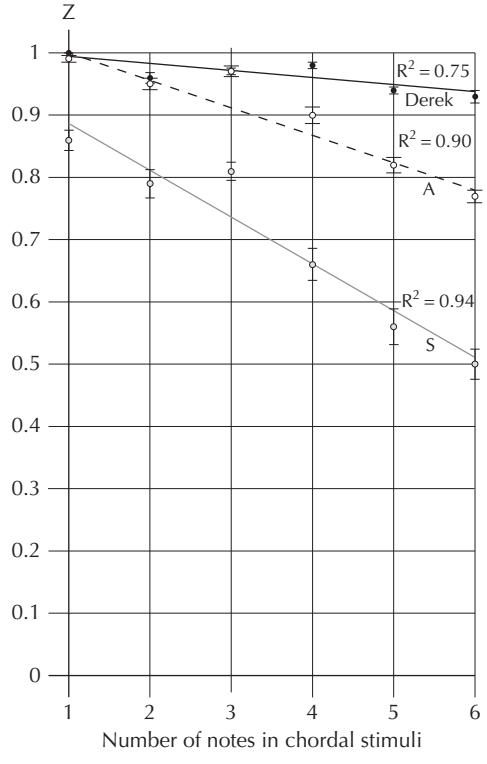


Fig. 6.19 S's, A's, and Derek's weighted responses in the chordal disaggregation exercise.

as best he could.[1] This approach became more difficult to implement with the large clusters, however, when the top note (in particular) was difficult to disembed from those immediately adjacent to it.

Although on the basis of the results from three subjects it is not possible to say whether savants and neurotypical musicians with AP tend to approach chordal disaggregation differently with respect to the relative positions of pitches in the stimuli concerned, initial evidence from Mazzeschi's work mentioned earlier suggests that this may be the case. Data from six savants (including Derek and A) and 17 musicians of an advanced performing standard on the piano with AP (including S) are summarized in Fig. 6.22, which shows the mean accuracies with which all top, inner, and bottom notes were reproduced across the 120 stimuli, weighted using equation (6.26) (Mazzeschi *et al.*, 2011). While the savants as a group consistently outperform the neurotypical musicians, savants perform best on bottom notes and are least successful with top ones, whereas with the neurotypical musicians the opposite is the case. It is of interest to note that neuropsychological research with "typically developing" 7-month-old infants (Marie and Trainor, 2012) suggests that the perceptual dominance of the highest voice in simultaneous textures, typical of adults (Palmer and Holleran, 1994), is present early on, and one can speculate

[1] The same approach was subsequently described by a further control with AP, a fluent pianist, Y, who tried a similar exercise (though with insufficient trials for purposeful analysis).

Table 6.10 S's chordal disaggregation data, with *P* and *Z* scores

Four-note chords						**Five-note chords**					**Six-note chords**				
	#R	**#C**	***R***	***P***	***Z***	**#R**	**#C**	***R***	***P***	***Z***	**#R**	**#C**	***R***	***P***	***Z***
	5	2.5	0.63	0.0567	0.59	4	4	0.80	0.0004	0.80	6	3.5	0.58	0.0450	0.56
	4	3	0.75	0.0066	0.75	6	5	1.00	0.0001	1.00	5	4.5	0.75	0.0010	0.75
	4	3	0.75	0.0066	0.75	5	4	0.80	0.0019	0.80	7	5	0.83	0.0021	0.83
	4	4	1.00	0.0001	1.00	6	4.5	0.90	0.0010	0.90	6	5	0.83	0.0006	0.83
	4	3	0.75	0.0066	0.75	5	3.5	0.70	0.0096	0.69	6	4	0.67	0.0145	0.66
	4	2	0.50	0.0996	0.45	5	3	0.60	0.0358	0.58	6	5	0.83	0.0006	0.83
	4	3	0.75	0.0066	0.75	5	4	0.80	0.0019	0.80	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
	4	4	1.00	0.0001	1.00	5	4.5	0.90	0.0002	0.90	6	5	0.83	0.0006	0.83
	4	4	1.00	0.0001	1.00	5	4	0.80	0.0019	0.80	6	3	0.50	0.1094	0.45
	5	3	0.75	0.0158	0.74	6	5	1.00	0.0001	1.00	6	5	0.83	0.0006	0.83
	4	4	1.00	0.0001	1.00	5	4	0.80	0.0019	0.80	6	5.5	0.92	0.0036	0.91
	5	4	1.00	0.0004	1.00	4	1.5	0.30	0.2997	0.21	6	4	0.67	0.0145	0.66
	5	4	1.00	0.0004	1.00	4	3	0.60	0.0158	0.59	6	5	0.83	0.0006	0.83
	4	3	0.75	0.0066	0.75	5	2	0.40	0.2146	0.31	6	5.5	0.92	0.0036	0.91
	5	3	0.75	0.0158	0.74	5	5	1.00	0.0000	1.00	6	5	0.83	0.0006	0.83
	4	4	1.00	0.0001	1.00	5	5	1.00	0.0000	1.00	6	5.5	0.92	0.0036	0.91
	4	4	1.00	0.0001	1.00	5	4	0.80	0.0019	0.80	6	5	0.83	0.0006	0.83
	5	4	1.00	0.0004	1.00	5	4.5	0.90	0.0002	0.90	6	4	0.67	0.0145	0.66
	5	4	1.00	0.0004	1.00	5	5	1.00	0.0000	1.00	6	6	1.00	0.0000	1.00
Mean	4.35	3.48	0.87	0.0112	0.86	5.00	4.03	0.81	0.0294	0.79	6.00	4.88	0.8125	0.0108	0.81
				SD	0.17				*SD*	0.22				*SD*	0.15

Table 6.10 (continued) S's chordal disaggregation data, with *P* and *Z* scores

	Seven-note chords					Eight-note chords					Nine-note chords				
	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*	#R	#C	*R*	*P*	*Z*
	6	3	0.43	0.1613	0.36	7	3	0.38	0.2773	0.27	8	4	0.44	0.2120	0.35
	7	2	0.29	0.3743	0.18	8	7	0.88	0.0001	0.87	9	5	0.56	0.1122	0.49
	7	5	0.71	0.0067	0.71	8	1.5	0.19	0.2394	0.14	8	8	0.89	0.0000	0.89
	7	7	1.00	0.0000	1.00	9	8	1.00	0.0000	1.00	8	6	0.67	0.0093	0.66
	6	4	0.57	0.0302	0.55	7	5	0.63	0.0158	0.62	6	4	0.44	0.0854	0.41
	7	6	0.86	0.0003	0.86	8	6	0.75	0.0035	0.75	9	9	1.00	0.0000	1.00
	7	7	1.00	0.0000	1.00	7	2.5	0.31	0.3483	0.20	9	3	0.33	0.3293	0.22
	6	5.5	0.79	0.0004	0.79	6	2	0.25	0.3763	0.16	8	5	0.56	0.0652	0.52
	7	3.5	0.50	0.1274	0.44	8	6.5	0.81	0.0008	0.81	7	4	0.44	0.1468	0.38
	7	5	0.71	0.0067	0.71	8	6	0.75	0.0035	0.75	9	6	0.67	0.0230	0.65
	6	3.5	0.50	0.0781	0.46	7	2	0.25	0.3604	0.16	7	3	0.33	0.3180	0.23
	7	4	0.57	0.0594	0.54	8	8	1.00	0.0000	1.00	8	4	0.44	0.2120	0.35
	7	6	0.86	0.0003	0.86	7	5	0.63	0.0158	0.62	7	6	0.67	0.0028	0.66
	7	7	1.00	0.0000	1.00	7	3	0.38	0.2773	0.27	8	3	0.33	0.3392	0.22
	7	6	0.86	0.0003	0.86	7	6	0.75	0.0010	0.75	8	3	0.33	0.3392	0.22
	7	6	0.86	0.0003	0.86	6	4	0.50	0.0538	0.47	9	6	0.67	0.0230	0.65
	7	4	0.57	0.0594	0.54	8	7	0.88	0.0001	0.87	8	7	0.78	0.0005	0.78
	7	6	0.86	0.0003	0.86	7	3.5	0.44	0.1824	0.36	7	5.5	0.61	0.0106	0.60
	7	1.5	0.21	0.3562	0.14	7	4	0.50	0.0990	0.45	7	2	0.22	0.3271	0.15
	6	4	0.57	0.0302	0.55	8	6	0.75	0.0035	0.75	9	6	0.67	0.0230	0.65
Mean	6.75	4.80	0.69	0.0646	0.66	7.40	4.80	0.60	0.1129	0.56	7.95	4.98	0.55	0.1289	0.50
				SD	0.26				*SD*	0.29				*SD*	0.24

#R, number of pitches in the response; #C, number of pitches that are correct; *R*, proportion of repetition; *P*, probability of this occurring by chance; *Z*, weighted derivation index.

on the stage of musical development at which the listening style of the savants who participated in Mazzeschi *et al.*'s research departed from the usual route. It is also important to acknowledge that more detailed analysis of individual chord-disaggregation results would be required to ascertain whether the "bottom up" approach to hearing chords is unique to savants (which seems unlikely) or is also a feature of *some* neurotypical musicians with AP (whose data are hidden within the means reported in Fig. 6.22)—perhaps the more successful ones. If so, this could provide a useful pointer to those seeking to teach or learn aural skills to music pupils and students.

Table 6.11 The frequency and nature of S's omissions and additions in the chordal disaggregation task, and a comparison with Derek's and A's results

Chord size	No. of notes	No. of omissions	Omissions (%)	No. of additions	Additions (%)	No. of additions at the octave	No. of "tertian" additions that correspond with existing harmony	No. of "tertian" additions that yield different harmonies	No. of "non-tertian" pitch-classes added	Pitch-classes added (%)
Omissions and additions: S										
4	80	8	10.0	13	16.3	5	5	2	1	10.0
5	100	17	17.0	17	17.0	7	5	5	0	10.0
6	120	23	19.2	23	19.2	17	4	2	0	5
7	140	41	29.3	37	26.4	8	4	17	8	20.7
8	160	61	38.1	49	30.6	2	9	25	13	29.4
9	180	76	42.2	56	31.1	3	5	11	37	29.4
Sums	780	226		195		42	3	61	58	
Means (%)			29.0		25.0					15.6
Omissions and additions: Derek										
Sums		29		67		41	17	0	9	
Means (%)			3.72		8.59					3.3
Ratios: S/Derek										
		7.79		2.91		1.02	0.18	–	6.44	4.73
Omissions and additions: A										
Sums		87		29		14	3	0	12	
Means (%)			11.2		3.7					1.9
Ratios: S/A										
		2.60		6.72		3.0	1	–	4.83	8.21

Table 6.12 The relative positions of the notes omitted by S, and comparison with Derek's and A's results

Chord size	No of notes	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
Omissions (by position in chord): S											
4	80	0	3	–	–	–	–	–	5	0	8
5	100	0	3	–	–	9	–	–	5	0	17
6	120	1	7	4	–	–	–	8	3	0	23
7	140	5	6	7	–	10	–	5	4	4	41
8	160	8	9	7	14	–	8	5	6	4	61
9	180	10	11	8	8	9	6	6	11	7	76
Sums	780	24	39	26	22	28	14	24	34	15	226
			Sum upper half = 111					Sum lower half = 87			
Omissions (by position in chord): Derek											
Sums		12	8	4	1	0	0	1	3	0	29
			Sum upper half = 25					Sum lower half = 4			
Ratios: S/Derek											
				4.44					21.75		7.79
Omissions (by position in chord): A											
Sums		22	26	9	7	10	7	3	3	0	87
			Sum upper half = 64					Sum lower half = 13			
Ratios: S/A											
				1.73					6.69		2.60

Table 6.13 The percentages of notes omitted by Derek, A, and S per chordal position

Subject	Top note	2nd down	3rd down	4th down	Middle note	4th up	3rd up	2nd up	Bottom note	Sums
Derek	41.38	27.59	13.79	3.45	0.00	0.00	3.45	10.34	0.00	100
A	25.29	29.89	10.34	8.05	11.49	8.05	3.45	3.45	0.00	100
S	10.62	17.26	11.50	9.73	12.39	6.19	10.62	15.04	6.64	100

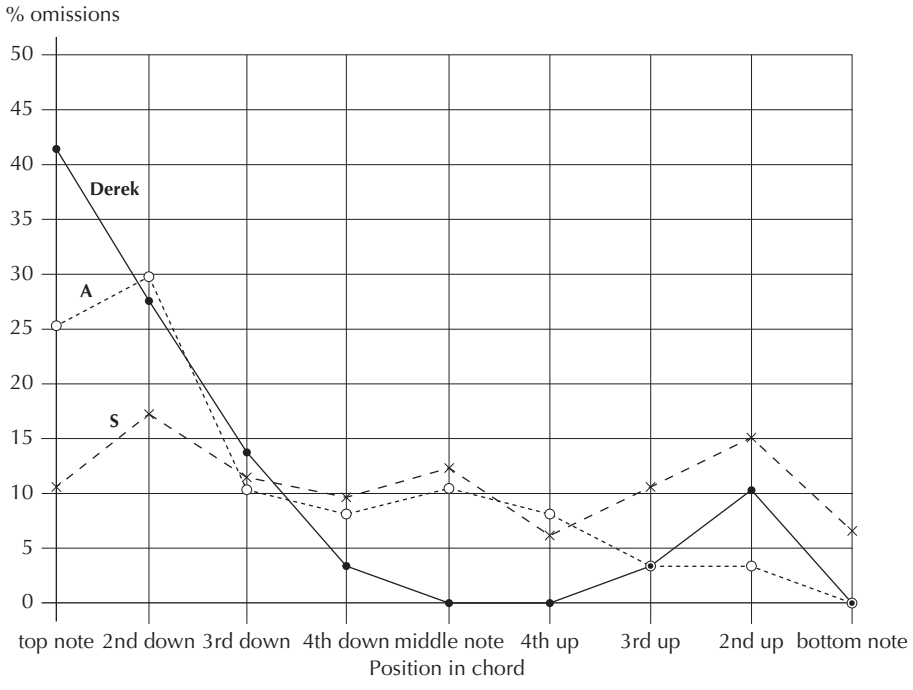


Fig. 6.20 Graphical representation of the percentage of notes omitted by Derek, A, and S from different positions in the chord.

These general findings are supported by the case study of Avni, a 7-year-old girl with Williams syndrome[2] whom I recently began teaching the piano, which was undertaken by Anna Powell, a masters student in applied music psychology at the University of Roehampton, 2010–2011. At the time of the study, Avni's cognitive abilities were independently assessed as being around 2 years behind what would typically be expected for her chronological age, and included a specific language impairment; her behavioral phenotype was judged to be otherwise typical of William's syndrome, with strengths in social skills and face recognition, but marked difficulties with motor coordination and restricted visuospatial skills. Avni's parents reported that she had been fascinated with sound and music for as long as they could remember, and exhibited early signs of hyperacuisis,[3] often becoming obsessed with or distressed by certain everyday sounds. At the age of 5, Avni became engrossed with a toy piano she had at home, although attempts at tuition at this stage were not successful. Powell studied the emerging "savant-like" musical abilities of Avni over the course of her first 27 weekly music lessons with me (Powell, 2011), $2\frac{1}{2}$ years later.

[2] Williams syndrome was first identified in 1961 in the context of cardiology by Williams, Barratt-Boyes, and Lowe (Williams *et al.*, 1961). It is now known to be caused by a deletion of genetic material from region q11.23 of chromosome 7. Physically, people with Williams syndrome have supravalvular aortic stenosis and "elfin" facial features (Bellugi *et al.*, 2000). Functionally, it is a "neurodevelopmental genetic disorder . . . characterized by peaks and valleys in mental function: substantial impairment in cognitive domains such as reasoning, arithmetic ability, and spatial cognition, alongside relatively preserved skills in social domains, face processing, language and music" (Levitin *et al.*, 2004, p. 223).

[3] An "abnormally strong affective response to certain categories of sounds" (see Hopyan *et al.*, 2001).

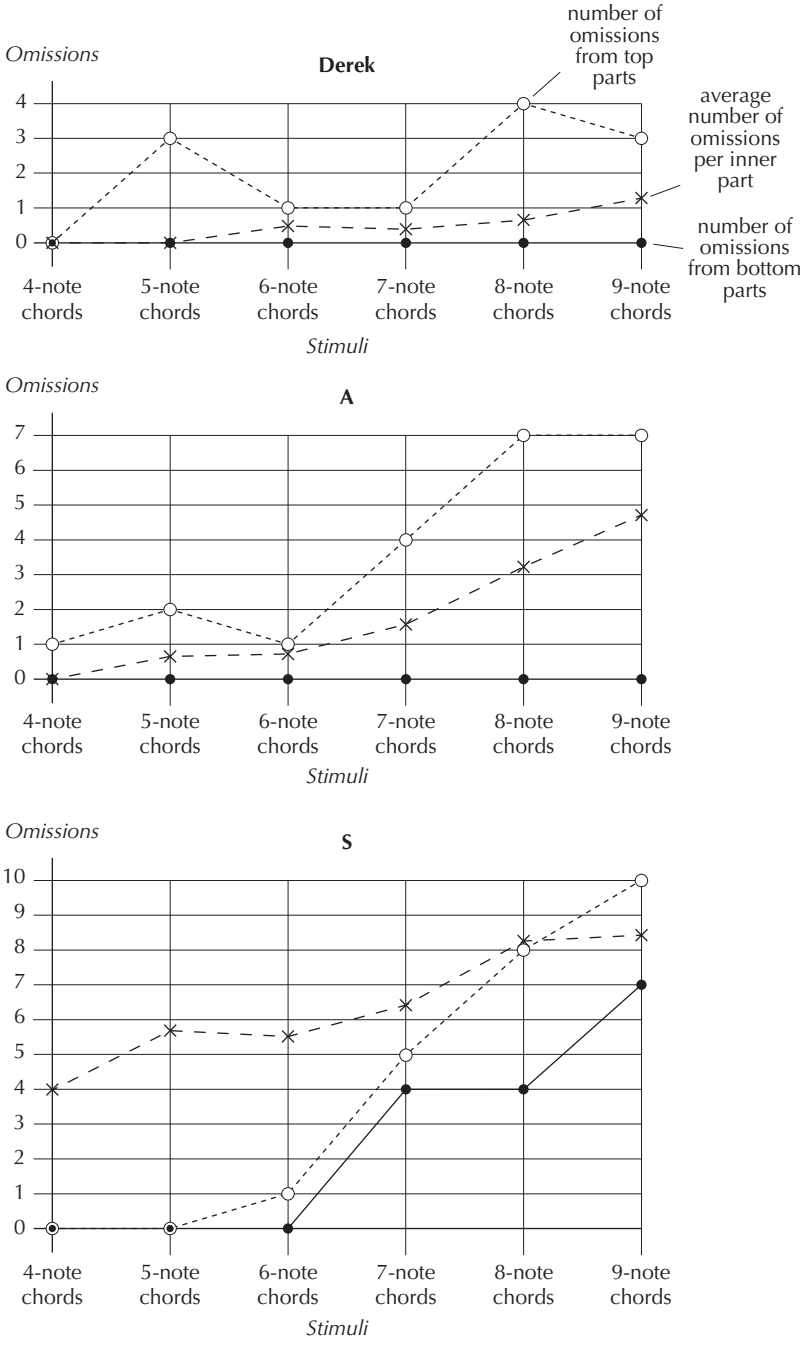


Fig. 6.21 Comparison of omissions by "top," "inner," and "bottom" notes per chord size by subject.

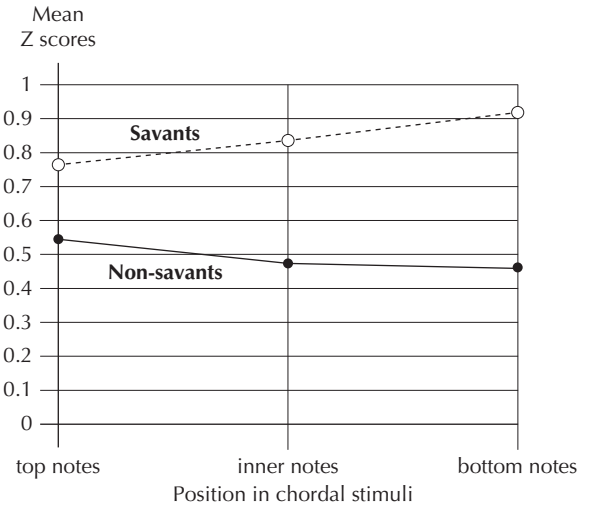


Fig. 6.22 Comparison of omissions by "top," "inner," and "bottom" notes per chord size by subject type (savant or neurotypical musician) (after Mazzeschi *et al*., 2011).

My initial, informal, assessment of Avni, judging from the way that she attempted to reproduce on the piano music that she had heard (her motor coordination and visuospatial difficulties notwithstanding), was that she had AP, and I decided to test this in lesson 13. First I asked Avni to close her eyes while I played a note on the piano, and then open her eyes and copy the note that I had struck (something which occurred four times). Then I played seven notes on a tone chime and, again, asked her to reproduce them on the piano. The stimuli and her responses are shown in Table 6.14 (cf. Powell, 2011, pp. 43, 44).

Table 6.14 Avni's responses to pitches played on the piano and tone-chime

Stimulus		**Response**
Instrument	**Pitch**	
Piano	B♭4	C5
Piano	C4	C5
Piano	G4	E5 . . . C6 . . . A5 . . . G5
Piano	A4	A5
Tone-chime	A5	A4
Tone-chime	A5	F4 . . . B4 . . . A4
Tone-chime	D6	D5
Tone-chime	E6	G4 . . . F4 . . . E4
Tone-chime	F♯6	F♯4
Tone-chime	G♯6	G4 . . . A4 . . . G♯4
Tone-chime	A6	A4

Powell speculates that Avni's errors may have been due to her still-developing awareness of where the notes are located on the keyboard, rather than an inability to identify the pitch concerned. However, even if we include all of Avni's multiple responses to some of the stimuli, by applying the principles developed in Chapter 3 to populate the zygonic formula of intentionality, $I = R(1 - P)$, we have:

$$R = \frac{10}{20} = 0.5 \tag{6.27}$$

and

$$P = \left(\frac{1}{12}\right)^{10}\left(\frac{11}{12}\right)^{10}\frac{20!}{10! \times 10!} = 0.000001 \tag{6.28}$$

that together yield an intentionality (I) of

$$I = 0.5(1 - 0.000001) = 0.5. \tag{6.29}$$

These figures suggest that Avni does indeed have AP, despite her capacity to repeat pitches being only around 50%, which, we may surmise, can be ascribed to the impairments in her motor and visuospatial functioning. Clearly, this is an important contextual factor in seeking to gauge her efforts at musical learning, interaction, and performance. In this regard, the most striking feature that Powell perceived in Avni's preferred means of approaching new material was her tendency to attempt to play new pieces by first reproducing the bassline (in preference to the melody). For example, I played *Somewhere Over the Rainbow* to Avni in lesson 8 and asked her parents to encourage her to listen to the song on *YouTube* to facilitate her learning at home. Powell describes the next lesson thus (Powell, 2011, pp. 48, 49):

> The following week, when [Adam] suggested that they play *Somewhere Over the Rainbow*, [Avni] began to pick out a bass line in the lower register of the piano. She was playing in C major and it was not very clear what she intended to do. [Adam] started to play the melody in E♭ major (as he had done in the previous week) to remind her of the tune but [Avni] stopped him and instructed him to start on C, while she continued to pick her way through a bass line in C major. It seemed that she had assimilated the overall harmonic structure of the piece rather than just the melody, and she was eager to reproduce this harmonic bass line. Avni's mother informed us that, in fact, she had played several different arrangements of *Somewhere Over the Rainbow* to Avni during the previous week, which explained why she had learned the piece in a different key. Her eagerness to play the bass line, rather than the melody, in the first instance, demonstrates [Avni's] keen sense of harmony, and the facility that she has in reproducing that harmony.

Finally, we return to the chordal disaggregation study, and compare S's results with Derek's and A's with respect to harmonic type (tertian or cluster) (see Table 6.15). In responding to tertian chords, S omits 147 pitches out of 617 (23.8%) and 79 out of 163 in clusters (48.5%)—a ratio of 2.04. Although Derek omits far fewer notes, his tertian : cluster omission ratio is higher, at 3.08, while A's ratio is higher still, at 4.08. With regard to additions, S's tertian : cluster ratio is 1.56, lower than Derek's, at 2.1, and A's, at 5.76 (see Fig. 6.23).

These results could be taken to imply that the two savants, Derek and A, were more sensitive to tonal harmonic structures than the neurotypical musician, S. Evidence that this finding, made in relation to three individuals, may have more general applicability to the two populations, is again to be found in Mazzeschi *et al.* (2011), who found that there is a greater average difference between savants' omissions relating to tertian chords and clusters than that pertaining to neurotypical musicians' responses to the same two types of stimuli (see Fig. 6.24).

Table 6.15 The pattern of errors made by S in relation to tertian chords (a) and clusters (b), and comparisons with Derek and A

(a) Tertian chords

Chord size	Total no. of notes	No. of chords	No. of notes in tertian chords	No. of omissions	No. of additions	Sums	Percentage
Tertian chords: S							
4	80	20	80	8	13	21	26.3
5	100	20	100	17	17	34	34.0
6	120	20	120	23	23	46	38.3
7	140	19	133	36	32	68	51.1
8	160	14	112	30	28	58	51.8
9	180	8	72	33	25	58	80.6
Sums	780	101	617	147	138	285	
Means (%)				23.8	22.4		46.2
Tertian chords: Derek							
Sums	780	101	617	16	43	59	
Means (%)				2.6	7.0		9.6
Ratios S/Derek							
				9.19	3.21		
Tertian chords: A							
Sums	780	101	617	47	13	60	
Means (%)				6.0	1.7		7.7
Ratios: S/A							
				3.13	10.62		

Table 6.15 (continued) The pattern of errors made by S in relation to tertian chords (a) and clusters (b), and comparisons with Derek and A

(b) Clusters							
Chord size	**Total no. of notes**	**No. of chords**	**No. of notes in clusters**	**No. of omissions**	**No. of additions**	**Sums**	**Percentage**
Clusters: S							
4	80	0	0	–	–	–	–
5	100	0	0	–	–	–	–
6	120	0	0	–	–	–	–
7	140	1	7	5	5	10	142.9
8	160	6	48	31	21	52	108.3
9	180	12	108	43	31	74	68.5
Sums	780	19	163	79	57	136	
Means (%)				48.5	35.0		83.5
Clusters: Derek							
Sums	780	19	163	13	24	37	
Means (%)				8.0	14.7		22.7
Ratios: S/Derek							
				6.08	2.38		
Clusters: A							
Sums	780	19	163	40	16	56	
Means (%)				24.5	9.8		34.4
Ratios: S/A							
				1.98	3.56		

Conclusion

Overall, the data strongly suggest that even the nine-note chords did not define the limits of Derek's (or A's) chordal disaggregational abilities, and the opportunity to test Derek further, informally, came in the course of filming for CBS's *60 Minutes* television program that was aired in the United States in 2005. As the account of the program on the CBS website puts it:

> Ockelford keeps trying to figure out how Derek's brain processes music. Most people—musicians included—can make out about two or three notes at a time. Ockelford devised a test to see how many notes Derek could hear at once, and then repeat. Stahl[4] gave the test to Derek, initially playing four notes at the same time. Derek was able to instantly play back all notes. Next, Stahl played Derek 10 notes at the same time, which sounded like noise. Derek was able to repeat that too.

[4] Lesley Stahl, the presenter of the segment.

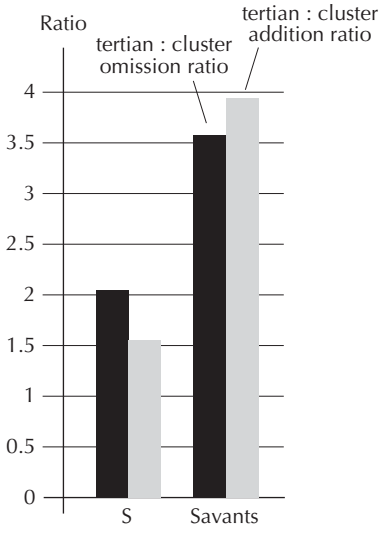


Fig. 6.23 Tertian : cluster ratios (additions and omissions) differ between S and the two savants.

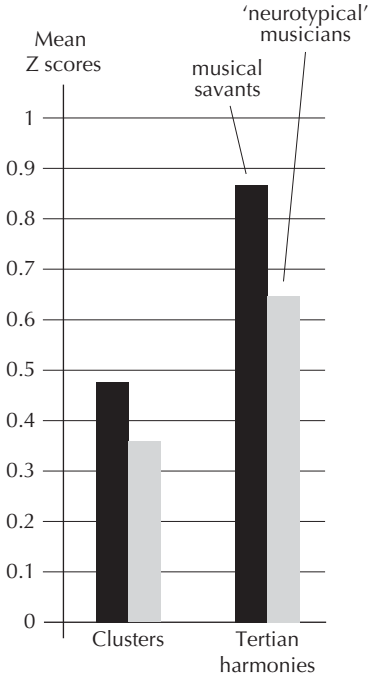


Fig. 6.24 Neurotypical musicians' responses to tertian harmonies and clusters show a greater differential than those pertaining to savants.

"Derek's hearing a different sound world. For us, we can perhaps hear the melody and the bass and the drums. But he can actually hear 10 different instruments at once. That's incredible," Ockelford said.

But even though he could repeat exactly what Stahl played, when asked to count the notes, Derek was lost. Stahl played a four-note chord and Derek said, "Two, is it one, is it?"

"He could separate the notes out... and yet, he couldn't tell me how many. He couldn't even tell me there were four", Stahl said.

"That really shows Derek's brain in action, doesn't it?" Ockelford said.[5]

Derek's brain was certainly in action as he reproduced the two 10-note chords that Lesley Stahl played for him—both with 90% accuracy, and therefore very much in line with the trend identified in Fig. 6.14. Accordingly, it seems very likely that his ability to disaggregate chords was greater than this, and more than his 10 fingers would allow him to display. Derek's habit of arpeggiating chords appeared to offer a way forward, however, since by playing notes as a series that he had heard simultaneously, his digital limitations could be circumvented. And in a television documentary entitled *The Musical Genius*, that was also made about him in 2005, and screened on Channel 5 in the UK, Derek reproduced chords played by a full symphony orchestra with no hesitation, by scurrying up and down the keyboard. Although these efforts were not formally analyzed, it was clear to the many musicians who were present that Derek's efforts were entirely consistent with what they were playing—though (as with the earlier chord experiments) he did not appear to be limited by only what he heard, gleefully embellishing on the 20 or so distinct parts that were sounding.

There is no doubt that the remarkable speed and ease with which Derek can process extensive aggregations of simultaneous notes is a huge benefit to him in playing by ear. This highly unusual perceptual skill is necessary though not in itself sufficient to enable him to assimilate pieces so efficiently by ear in the way that he does, however, and further experiments were undertaken—and are planned for the future—to explore other elements in his array of musical abilities. An account of one of these follows in Chapter 7.

[5] See "The Mysterious Gift of Musical Savants" at <http://www.cbsnews.com/stories/2006/06/12/60minutes/main1703281_page5.shtml>.

Chapter 7

Exploring learning, memory, and creativity in a musical savant

Introduction

Although the tag has proved irresistible to newspaper headline writers and television producers, one thing that Derek Paravicini certainly is *not* is a "human iPod," any more than other musical savants are, or have ever been. Yet belief in their capacity for "perfect recall"—the ability to listen to a piece of music once, play it straight back flawlessly, and remember it indefinitely—has been at the core of musical savant folklore at least since Mark Twain's account of "Blind Tom," the 19th-century American Negro pianist (see p. 86): "it was said that he could accurately play any piece of music, howsoever long and difficult, after hearing it once; and that six months later he could accurately play it again, without having touched it in the interval" (Twain, 1897, p. 17). I have an abiding suspicion of the veracity of such tales of savants' "eidetic memory" for sound, however. Unless the audience, too, were blessed with extraordinary musical powers, how would they know whether the reproduction were truly accurate or not? And in whose interests would it be to say that the feat had been less than perfectly accomplished? To suggest that Blind Tom had managed to reproduce (for example) merely the gist of a piece would have made far less compelling a story (Ockelford, 2007a, p. 158).[1]

Comparable accounts clouded understanding of the *real* abilities and achievements of savants in the 20th century too. Take, for example, Leslie Lemke, born in Milwaukee in 1952. He was delivered prematurely, which left him blind, with learning difficulties and cerebral palsy. Leslie was adopted at 6 months by May Lemke, who brought all her considerable experience as a governess to bear in raising a child with a host of developmental challenges (rather as Derek's "Nanny" was to do three decades later; see Ockelford, 2007a). Like Derek, too, he proved to have a remarkable musical talent, which (rather later than in Derek's case) attracted considerable media interest.

In 1981, when he was 29 years old, Leslie featured in an ABC program entitled *That's Incredible*. Here is a transcript from the segment:

Voiceover: [*Shot of Leslie in sitting room*] Another thing May did right was to buy Leslie a musical instrument.

[1] Ten years after Tom's death, in 1918, Anna Amalie Tutein, who taught him from 1886, wrote: "I must also dispel the idea that Tom could repeat anything having heard it once. The lessons were two hours in length, and it was often necessary for me to play over the compositions fifty times before he would acquire them. He could, however, remember an astonishing number of measures. I would 'feed' him eight or ten measures at a time and then he would play them over several times and we would go on with the others. After he had a fair impression of the piece I would play it as an entirety and he would listen intently." (Tutein, 1918, p. 91).

May Lemke: [*In sitting room*] It was a second-hand piano. And I put it in there. And each night I would go in and "ping, ping" like that, you know. Just me, I'd be doing that. I wasn't playing no music at all, just going up and down like that.

And he was around 16 years old. He couldn't talk or walk or anything. And, er, we went to bed. And, er, we heard music. [*The main theme of Tchaikovsky's Piano Concerto No. 1 fades in under May's voice.*] I couldn't believe it. And I said to Joe, I said, "Did you leave television on?" And he said, "no." And I got up, you know, thinking I was going to turn off some music.

[*Fervently*] And that boy had got out of that bed—how he did it I don't know—[*visuals cut to Leslie performing at the keyboard*] and he was playing that piano.

Voiceover: How and why Leslie could suddenly play a piano concerto that he had only heard, is beyond explanation.

From this clip, the implications for Leslie's musical abilities in the context of his disabilities are clear. Here is someone who could not walk or talk, and who had never had piano lessons (although he would have heard his adoptive mother playing isolated notes that did not amount to music), who had nonetheless managed to get himself out of bed in the middle of the night and, having crawled over to the piano, had played Tchaikovsky's 1st piano concerto, having heard it only once earlier that evening. This is the stuff of which savant legends are made!

Darold Treffert's version of affairs (Treffert, 1989, pp. 103–15) is (initially) more measured. Referring to medical notes and the recollections of May's sister Mary Larsen, Treffert paints a picture of the young Leslie, aged $2\frac{1}{2}$, who was already singing, enunciating words clearly, and who could crawl. By $5\frac{1}{2}$, he was able to walk, and had a widening repertoire of songs; he could repeat the Pledge of Allegiance, say his prayers, and engage in limited, echolalic conversation. At some point, between the ages of 7 and 8, he was given a piano. May, who could play by ear very well, helped him identify the notes by running his fingers up and down the keyboard, and played and sang for him. By the age of 8, Leslie had learnt to play the bongos, ukulele, concertina, xylophone, and accordion. By the time he was 12, he was an accomplished singer and pianist. Moreover, according to Treffert, he "loved music and would listen, sitting with his characteristic posture, for hours and hours to records and the radio" (Treffert, 1989, p. 106).

Here, then, is someone who is rather more able than his adoptive mother would have us believe, and who had had support and encouragement to play the piano (and other instruments)—perhaps even tuition of a more formal nature—from May for around 8 years. But what of the key event in May's story concerning the piano concerto, which Leslie is said to have learnt and performed after a single hearing? Here is Treffert's account (Treffert, 1989, pp. 106, 107):

> One evening, when Leslie was about 14,[2] he watched a movie on television called *Sincerely Yours*, starring Dorothy Malone and Basil Rathbone. May and Joe watched it too but then retired. At about 3.00am May awoke, thinking that Joe had left the television on. She went to the living room to check. There sat Leslie. He had crawled over to the piano and was playing Tchaikovsky's Piano Concerto No. 1—the theme song to *Sincerely Yours*—vigorously and flawlessly. Leslie had heard it one time. That was sufficient. He played it through from beginning to end.
>
> To this day, if you ask Leslie to play that piece, you get not only the song, but the whole television introduction, mimicked exactly as he heard it in true echolalic fashion: "Tonight's movie is *Sincerely Yours*, starring Dorothy Malone and Basil Rathbone. As he falls in love with the beautiful black-haired woman . . . [you can hear in the background the . . . strains of Tchaikovsky's Piano Concerto No. 1]. And now, the Sunday Night Movie is proud to present . . .. "

[2] Note the discrepancy with May's account.

Here, Treffert appears to have got caught up in the wish to perpetuate the Lemke myth, rather than weighing the evidence dispassionately. To begin with, why would the 14- or 16-year-old Leslie have crawled over to the piano when he could walk? Then, how could anyone know whether the reproduction of the music was flawless or not? What we *can* be sure of is that Basil Rathbone played no part in the film, and the music we hear over the opening titles is not Tchaikovsky's 1st piano concerto, but an instrumental version of *Sincerely Yours*, the title song of the film, written by Liberace (who is the male lead). Clearly, then, Leslie's verbal and musical "echolalia" was (as we would expect from the evidence presented in this chapter) more a question of creative reconstruction than simple repetition.

Still, it appears that Leslie *did* play a recognizable version of the Tchaikovsky. How could this be, and what is the music likely to have comprised? When the concerto finally appears in *Sincerely Yours*, 1 hour and 45 minutes into the action (just before the end of the film), it is in drastically abridged form, running to just $4\frac{1}{2}$ minutes of the full 30 that Tchaikovsky conceived. Liberace, with orchestra, plays the opening 77 bars of the first movement (which includes hearing the main theme three times), and then the last 59 bars—the climactic ending—of the finale. Most importantly, perhaps, it seems unlikely, given Leslie's predilection for listening to records and the radio "for hours and hours," that he would *not* have heard the concerto (in part or as a whole) on other occasions, as it is among the most popular of Tchaikovsky's compositions and, indeed, arguably one of the best known of all piano concertos. Beyond that, the opening melody, which makes up most of Liberace's version, became even more widely celebrated through its use in the 1941 song *Tonight We Love* by Ray Austin and Freddy Martin. This reached number five in the American charts, and was subsequently recorded by Jane Froman (in the same year), Billy Vaughan and his orchestra (1958), Caterina Valente (1959), and George Shearing (1960), among others.

It is the sensational elements of May's story, though, not the implicit caveats, that caught the popular imagination and became established in the public mind. And it is the notion of "perfect recall" that has colored Derek Paravicini's work with the media for much of his life. Regrettably, I have to confess to playing a part in unwittingly perpetuating the myth . . ..

Derek first appeared on television in 1988 when he was 9 years old as a guest on the British television series *People*. The producer, Lucy Pilkington, assumed that Derek, as a musical savant, would have the powers of instant, faultless memorization that the stories of Tom, Leslie, and others had indicated were characteristic of their condition, and she was keen to show this by playing Derek a recording of music that he had not heard before and having him repeat it on camera. The conundrum the production team faced was how to identify a piece that would be generally known to the audience (so they would have some idea as to whether he was playing it correctly or not) that Derek had not heard.

Since, at this stage in his development, Derek did not use verbal labels reliably, the most effective way to ascertain whether he knew a piece or not was to play him the first few notes, and observe whether he was able to continue. This was not an option for the *People* program-makers, however, since it was important that Derek should not have heard the music before, even in part. Hence the only option was to put the names of a range of different pieces to Derek, and see which (if any) he made no attempt to play. Eventually a title was identified to which he did not react: *Memory* from the musical *Cats*, by Andrew Lloyd Webber.

A recording was duly obtained and played to Derek who, much to my surprise, immediately produced a very creditable rendition of the song, playing the tune without error—including the middle section—and successfully adapting the arpeggios in the accompaniment to suit his small hands. Had I, after all, underestimated his abilities? Lucy Pilkington was in no doubt! However, after the program had aired I discovered that that the piece was a favorite at home: here, though,

Derek's mother referred to it as *Midnight*. This explained his initial lack of response to the title *Memory*. But in just a few seconds of broadcast time, the serpent of perfect recall had emerged again, and with such irrepressible energy that it continues to inveigle its way into the public perception of Derek's abilities some quarter of a century later (Fig. 7.1).

I have already mentioned that the problem with myths such as these is not only that they give people a false idea of what musical savants can do, but that they also distract from their just as remarkable (though perhaps less immediately obvious) powers of musical learning, memory, and creativity. For example, although he almost certainly did not learn them by listening to each just once, and although certain information may be imperfectly encoded or simply missing, Derek really does have a library of several thousands of pieces of music, melodies, and other fragments that are held in his long-term memory. Indeed, because much of the music he can remember is "uncataloged" (it often emerges in the course of rehearsing that he is familiar with a piece but does not know what it is called or who wrote it), it is impossible to know just how extensive his repertoire is. Moreover, in contrast to the position that obtains with many musicians, Derek's entire repertory is immediately accessible to him for public performance. He doesn't need to practice pieces in order to be able to play to them to a high standard; indeed, I suspect that a fair proportion of the music that he is requested by audiences to play, he performs (unbeknown to them) for the first time, often spontaneously producing his own keyboard arrangements of music that was originally written for larger forces, such as bands, orchestras, or choirs, and which he may well not have heard for years.

As someone who has watched Derek perform on many hundreds of occasions, it appears to me that he rarely (if ever) plays pieces in *exactly* the same way twice; in fact, part of the distinctiveness of Derek's public performances, and one of the reasons, I believe, for their enduring

Fig. 7.1 The myth of musical savants' perfect recall is embedded in popular consciousness. © 2012 Ripley Entertainment Inc.

public interest, is his willingness to improvise on familiar material, often in styles (and keys) suggested by the audience. Nonetheless, some elements of his concerts, particularly those that involve playing with groups of other musicians, may have to be more or less precisely scripted. In 2011, for example, Derek premiered a piano concerto (entitled *Blue*) written for him by the composer Matthew King at the Queen Elizabeth Hall in London with the Orchestra of St John's conducted by John Lubbock. This single-movement piece, around 15 minutes long, takes themes of Gershwin as its inspiration, weaving them into new, vibrant textures, of considerable rhythmic, melodic, and harmonic complexity, through which the piano and orchestra share a virtuoso dialog.

Derek had to learn the piece entirely by ear, rehearse it with the orchestra with little or no understanding of much of the technical language that Western classical musicians habitually use to convey ideas to one another, and perform it with the 25 or so other players and their conductor with no visual prompts to aid the precision ensemble that was required. The piano part alone comprises almost 11,000 notes, which speed by at an average rate of over 12 events per second. Moreover, to perform successfully with the orchestra meant that Derek had to memorize not only his own part, but also enough of the orchestral score to ensure that his contribution meshed with those of the other musicians. Indeed, one of the main difficulties that Derek faced (and that has always beset him) was being able to resist trying to realize the entire texture—piano and orchestra—on the keyboard. Evidently, he found that attempting to pick out strands from the fabric of the music that was encoded in his memory as a whole was very challenging.

So how did Derek learn the concerto, and how accurately did he perform it? I estimate that he spent around 100 hours in total working on *Blue* over a period of about 9 months, largely by listening to a synthetic rendition (made using the software Sibelius) away from the piano and then, increasingly, as his knowledge of the piece developed, by attempting to play along with it. The first version of *Blue* appeared in the form of a piano duet (the orchestration only being completed 3 months before the first performance). Clearly, it was necessary for Derek to be able to distinguish in sound which part was for solo piano and which was intended for a future orchestra, so the latter was transformed temporarily into the sound of a Fender Rhodes, courtesy of Sibelius. This was replaced with the orchestral parts as they became available, and in the last 2 weeks, Derek practiced with a recording in which the solo piano part was muted. A particular challenge in the two final rehearsals, when a live orchestra replaced the synthesized one, was that the instrumental balance sounded quite different from that to which Derek had grown accustomed. Some of the cues he had come to rely upon (in the horns, for example) were much harder to hear, whereas other parts (in particular the first violins) were disconcertingly prominent. The apparent facility with which he adjusted to these changes was in itself remarkable.

Attempting to master *Blue* proved, by some margin, to be the most demanding enterprise upon which Derek had ever embarked. The piece is both technically very challenging and difficult to memorize—not least on account of the sweeping passages of cross-rhythms that reappear kaleidoscopically, each time using subtly different combinations and permutations of notes. Some of the figuration is extremely rapid and (very unusually) half-speed versions were produced to assist Derek as he intuitively worked out the fingering patterns that best suited his playing.

Derek's performance was deemed by the orchestra, composer, and audience alike to be a huge success. For sure, he did not reproduce every note that was written, but neither did he *confine* himself to King's score. I was sitting next to Derek throughout the concert (and during the rehearsals) and my impression was that there were more additions than omissions. But, as with the chordal disaggregation experiment reported in Chapter 6, all the changes that Derek introduced made perfect musical sense.

So, here we have a savant accomplishment that is surely worthy not only of public acclaim (see <http://www.bbc.co.uk/news/entertainment-arts-15086761>)[3] but of scientific investigation too: just how do the processes of Derek's learning and recall work and, since he invariably transforms what he hears, how is this linked to his creativity?

The *Fragments of Genius* studies[4]

In 2004, I embarked upon a series of studies with colleagues at Goldsmith's College (Linda Pring) and the Institute of Education (Graham Welch and Evangelos Himonides) in London, which sought to explore systematically just how Derek, other savants, and (for the sake of comparison) non-savant musicians with AP, process, remember, and reproduce music. We felt that it was important—essential, even—to adopt as ecologically valid an approach as possible, to enable Derek and the other savants to offer us accounts of their musicality through means and in contexts with which they were familiar and felt comfortable. To try to impose experimental paradigms that would have required them to engage in activities significantly beyond their usual experience would have been ethically questionable, and would almost certainly have resulted in levels of performance below their capacity.

Extended observation indicated that Derek typically learns pieces in one (or more) of four ways:

1 By listening to an entire piece (or movement or section) and then attempting to play it back straight away—a process that can be repeated as often as necessary for him to learn the piece, potentially involving multiple attempts over an extended period. We called this approach "listen and play."
2 By hearing and copying successive fragments of a piece over as many sessions as are required for Derek to learn the complete work. This we termed "a bit at a time."
3 By listening and playing at the same time ("ghosting"): again, over as many sessions as are required for him to commit the music to memory. We referred to this method as "play along."
4 By listening to a piece on a number of occasions over a period time before attempting to play it. This strategy we dubbed "just listen."

How could these modi operandi be captured experimentally? Previous studies of how musical savants learn (Miller, 1989; Young and Nettelbeck, 1995) had focused on *short-term* memory, using the protocol developed by Sloboda *et al*. (1985). This entailed playing through an entire piece followed by segments, and having the savant reproduce as much of the material as he or she could remember after each hearing. These three studies utilized the same two pieces, Grieg's *Melodie*, Op. 47, No. 3, from his *Lyric Pieces*, and Bartók's *Whole Tone Scale* from Book 5 of his *Mikrokosmos.* Sloboda *et al*. used an error measure that was the sum of additions, omissions, stumbles, and pauses across all trials. This enabled them to compare the global accuracy with which the two pieces were reproduced, within and between subjects (the savant Noel Patterson and AS—a professional pianist). A similar approach appears to have been adopted by Young and Nettelbeck, who were able to compare the overall performance of their savant subject (TR) with the efforts of Noel and AS. Miller adopted a more complex measure that involved note-matching, in which at least half the notes in a given bar had to be reproduced correctly for that bar's score to count. His analysis was conducted in four-bar segments.

[3] Note that even in this short clip the "perfect recall" myth gets an airing!

[4] Named in homage to Michael Howe's (1989) book on savants.

In contrast, no formal *long-term* musical memory studies had been carried out with savants when we embarked on the *Fragments of Genius* project. Miller (1989), in describing his work with 5-year-old Eddie, gives an account of the young boy's efforts to recall a series of short "preludes" (beginners' pieces "for developing pianistic precision," 8 to 32 bars in length, in each of the 12 major and minor keys, by John Thompson, Op. 34), a year after having learnt them. Eddie's memory of the preludes was apparently quite variable, with 22 of the miniatures being recalled with 50% accuracy or more, including some with no errors at all. In one instance, only a third of the notes were recalled, and one prelude had, as far as Eddie was concerned, disappeared without trace.

For more formal research into long-term musical memory, we turned to studies such as that by Ginsborg (2002), extended more recently in the work of Chaffin (2007), for example, and Chaffin and Ginsborg (2011); this research involves expert performers in self-directed practice who are able to use notation, and who can reflect and comment on their musical thinking. This is not an approach that we could have used with Derek and savants like him, however, since they require constant support in rehearsal, are unable to read music, and have very limited powers of metacognition. As we observed earlier, the only usable data they are likely to yield is the music that they produce.

Of greater relevance to our potential work with savants—despite being concerned with the visual and verbal (rather than musical) domains—were Bartlett's classic long-term "experiments on remembering" (Bartlett, 1932), in particular his "method of repeated reproduction," adapted from Philippe (1897). Bartlett's subjects read twice through a 335-word short story, *The War of the Ghosts,* before being asked to repeat it at intervals ranging from 15 minutes to $6\frac{1}{2}$ years. However, apart from consistency in the timing of the initial reproduction, no attempt was made to secure uniformity in the length of interval between efforts at recall between subjects (Bartlett, 1932, p. 65).

Whether one regards this approach as ecologically sound or irredeemably unsystematic depends, of course, on one's epistemological stance, but a number of Bartlett's findings appeared to be of potential interest to our forthcoming studies of Derek and other savants. For example (Bartlett, 1932, p. 93):

> 1 It . . . appears that accuracy of reproduction . . . is the rare exception and not the rule.
>
> 2 In a chain of reproductions obtained from a single individual, the general form, or outline, is remarkably persistent, once the first version has been given.
>
> [. . .]
>
> 4 With frequent reproduction the form and items of remembered detail very quickly become stereotyped and thereafter suffer little change.
>
> 5 With infrequent reproduction, omission of detail, simplification of events and structure, and transformation of items into more familiar detail, may go on almost indefinitely, or so long as unaided recall is possible.
>
> 6 At the same time, in long-distance remembering, elaboration becomes rather more common in some cases; and there may be increasing importation, or invention . . .
>
> [. . .]
>
> 8 Detail is outstanding when it fits in with a subject's pre-formed interests and tendencies. It is then remembered, though often transformed, and it tends to take a progressively earlier place in successive reproductions.

In summary, then, to understand better how Derek learns pieces would mean undertaking a new suite of research projects based on points 1–4 in the first list, that would capture data pertaining both to short- and long-term memory, made in response to novel (though stylistically familiar)

musical stimuli. These data would be in the form of music, necessitating appropriate means of recording and transcription, and the development of analytical techniques that would permit the derivation of material to be assessed quantitatively and qualitatively in relation to the stimuli, the subject's other responses and, potentially, stylistically congruent pieces, memories of which might be aroused and fragments and features pressed into action (cf. Bartlett, 1932, Clause 8).

Of the four conditions, the findings pertaining to "listen and play" will be reported in full here in relation to Derek and S (the neurotypical pianist with AP who participated in the chordal disaggregation experiment in Chapter 6). Previous accounts of the "listen and play" study (for example, Ockelford and Pring, 2005; Ockelford, 2007b, 2012a) were concerned only with Derek's responses. Analysis is currently under way in relation to Derek's learning "a bit at a time" (by Annamaria Mazzeschi and colleagues), and Ruth Peskett and co-workers are gathering data pertaining to the "play along" condition.

The "listen and play" study

Stimulus

A piece was especially composed for the "listen and play" experiment and given a name that Derek (and, potentially, other savants) would find memorable: the *Chromatic Blues*. It was important to create new material since, as we have seen, it is difficult to find pieces that one can safely assume that he (and other subjects) will not have heard before, however fleetingly. Moreover, composing an original piece meant that it would be possible to create others of commensurate complexity and length for the other experiments (i.e. conditions 2, 3, and 4), thereby offering some equivalence between them for the purposes of comparison. The following criteria were used to inform the composition of *Chromatic Blues*. These were determined through our awareness of the repertoires with which Derek and S are known to be acquainted, and informal accounts of their memory and technical ability.

- The style should, broadly speaking, be drawn from "mainstream" Western classical, jazz, or popular music that would be familiar to Derek and S.
- Additionally, there should be specific features that were deemed to be unusual within the given style—potentially offering higher degrees of salience.
- The structure should be relatively easy to discern, including both the repetition and transformation of key materials, thereby enabling the researchers to gauge the impact of these relationships on the learning process.
- The piece should be of sufficient complexity for Derek and S to find challenging but possible to learn after a number of hearings, with respect to length, structure, and content. If it were too difficult the subjects may become discouraged and perform poorly; too easy, and we may unwittingly induce a "ceiling" effect, in which very few or even no errors were made. Yet it is the errors (and their analysis) that hold the key to improving our understanding of how musical learning and memory work.
- It should be well within the subjects' physical capacity to play, so that technical considerations would not interfere with issues of music-processing.

Created within these constraints, *Chromatic Blues* is shown in Fig. 7.2.

Statistically, *Chromatic Blues* comprises 312 events that occur within 49 seconds (an average rate of 6.4 events per second). The structure of the piece is shown in Fig. 7.3. I recorded *Chromatic* Blues using the same equipment used in the chordal disaggregation study: a Korg SP-200 88-note

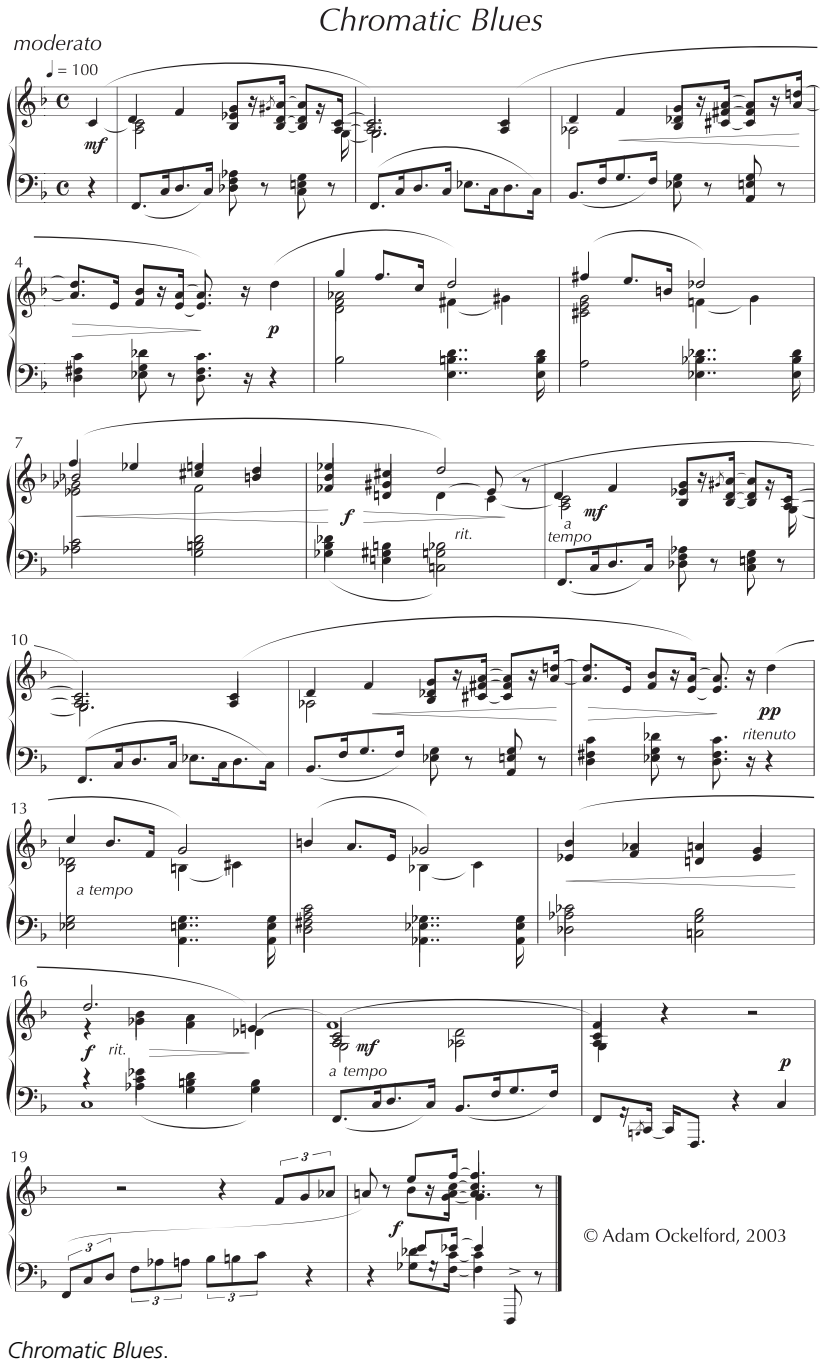



Fig. 7.2 *Chromatic Blues*.

segment	$A_{1.1}$	$B_{1.1}$	$A_{2.1}$	$B_{2.2}$	C
function	**Theme A** exposition	**Theme B** exposition	**Theme A** reprise	**Theme B** transposed, extended	**Coda**
tonal regions	I → (V of ii)	♭VII → V	I → (V of ii)	♭III → V	I
range (beat.bar)	0.4 – 4.3	4.4 – 8.3	8.4 – 12.3	12.4 – 18.3	18.4 – 20.4
excerpts analyzed	Excerpt 1 0.4 – 2.3	Excerpt 2 4.4 – 6.4	Excerpt 3 8.4 – 10.3	Excerpt 4 12.4 – 14.3	Excerpt 5 18.4 – 20.4

Fig. 7.3 The structure of *Chromatic Blues*.

touch-sensitive hammer-action keyboard, set to a piano sound, linked via MIDI to a laptop computer, monitored through Edirol MA-10A speakers. The accuracy of the rendition was verified through the production of a score using the music notation software Finale.

Schedule

We believed that the piece would take Derek and S several sessions to learn, and we wanted to ascertain how learning, memory, and recall worked in both the short and long term. To this end, we decided to have an initial period of relatively intense exposure, with 10 sessions over a period of a month. After this time, which we assumed would constitute the main learning period, we intended to have gaps of increasing length: around 3, 6, 12, and 24 months. In practice, Derek's availability and that of our research assistant (Katherine Woolf), meant that his "listen and play" had an additional month's break between Sessions 5 and 6. The whole research was conducted over 14 sessions, comprising 26 trials, that occurred over a period of approximately 4 years (see Table 7.1). S's schedule is discussed later (see Table 7.11).

Procedure

Following the first session, every other one[5] followed the same, four-stage protocol:

(a) Derek/S was asked to play *Chromatic Blues* as well as possible, using the Korg keyboard on which the piece was recorded, in a quiet room with no distractions. The results were recorded in digital audio and in MIDI format. Derek/S was thanked, though no comment was made as to how to accurate his rendition was thought to be.

(b) Derek/S was asked to listen carefully to the recording of *Chromatic Blues*.

(c) Derek/S was asked to play *Chromatic Blues* as well as possible. He was thanked, but with no evaluative comment.

(d) Derek/S was asked to listen carefully to the recording of *Chromatic Blues* again.

In the first session, Stage (a) was, of course, omitted.

[5] Except the 10th session, when time permitted only stages (a) and (b) to be completed.

Table 7.1 Derek's learning schedule

Session number	Trials	Days since previous session	Time period
1	1	–	≈ 2 weeks
2	2 and 3	2	
3	4 and 5	5	
4	6 and 7	2	
5	8 and 9	7	
6	10 and 11	25	≈ 1 month
7	12 and 13	2	≈ 2 weeks
8	14 and 15	5	
9	16 and 17	2	
10	18	5	
11	19 and 20	96	≈ 3 months
12	21 and 22	198	≈ 6 months
13	23 and 24	342	≈ 1 year
14	25 and 26	777	≈ 2 years
Totals	**26**	**1468**	≈ **4 years**

Predictions in relation to Derek's attempts to learn *Chromatic Blues*

As *Chromatic Blues* was consciously constructed to be too difficult for Derek to learn immediately, and, in accordance with Bartlett's Clause 1 (that accuracy of reproduction is the "rare exception"), we predicted that, at his first attempt, he would:

(i) recall some *fragments* accurately (either "chunks" of or "strands" in the texture), most likely to be the first, last or otherwise most salient—for example on account of their being unusual in the context of the general style of the piece, provided that they were relatively short and simple;[6]

(ii) recall some *features* accurately (for example, the metrical and tonal frameworks that *Chromatic Blues* utilized);

(iii) recall other fragments *approximately* (utilizing transformations that ultimately involved the omission, addition, or alteration of material—see Ockelford, 2009b); and, partly as a consequence,

(iv) recall other features *approximately* (for example, length and form).

[6] It was hypothesized that material that was both unusual *and* long and/or complex would be difficult to remember.

We further predicted, based on observation of Derek's interactions with musicians over many years, that, irrespective of how little of the original *Chromatic Blues* he could remember, he would produce material that "made sense" musically. This is because Derek, as a wholly intuitive performer, seems to find it very difficult to produce, and seemingly impossible to sustain, musical "nonsense" when playing the piano, rather as native speakers find it hard to make up ungrammatical, nonsensical sentences. Hence we anticipated that he would:

(v) adapt the material that he was recalling; and, where necessary,

(vi) interpolate other material.

Just how Derek, quite non-consciously, would resolve these potentially conflicting demands lay at the heart of our investigation. We hypothesized that most information about his mental processing would become evident precisely at those moments where the capacity of his working memory, which would serve him well up to a point, was exceeded. Just where would these crises of cognitive functioning occur? What strategies would he adopt to continue the musical flow at these moments of difficulty? What subsequent compromises would need to be made between material that was remembered and elements that were newly created, and how were these competing forces to be prioritized?

What the sources of the interpolated material would be was an important issue, and we predicted he would be likely to use

(vii) material taken from elsewhere in *Chromatic Blues*; and

(viii) fragments or features of other (stylistically congruent) pieces.

So much for our predictions relating to Derek's first attempt to recall *Chromatic Blues*. In terms of subsequent sessions, we expected that:

(ix) his performances would improve over time with repeated exposure to the original piece; but that

(x) the extraneous material that he introduced would interfere with his subsequent efforts to recall the piece (in accordance with Bartlett's Clause 2).

It was impossible to say just what form this interference would take, and how, over successive hearings and attempts at recall, the material that was introduced would gradually be "lost" and replaced with fragments or features of the original stimulus or be transformed into the "correct" material. We did, however, predict that improvement would take two forms:

(xi) incremental, as elements of the piece that had been virtually correct would become even more faithful to the original; and

(xii) in larger, discrete steps as substantial chunks that were incorrect were replaced with "authentic" material.

Results

To give an idea of what Derek's renditions were like, here are transcriptions of five of them (Trials 1, 2, 5, 7, and 21) (see Figs. 7.4–7.8).

In order to limit the amount of quantitative data to be analyzed, only excerpts were transcribed from most of Derek's responses: bars 0.4 to 2.3 (Excerpt 1), 4.4 to 6.4 (Excerpt 2), 8.4 to 10.3 (Excerpt 3), 12.4 to 14.4 (Excerpt 4), and 18.3 to 20.4 (Excerpt 5) (see Fig. 7.3). These extracts, amounting to 50% of the piece, were chosen since they are representative of *Chromatic Blues*, varying in salience according to their position within the piece (including the beginning and the

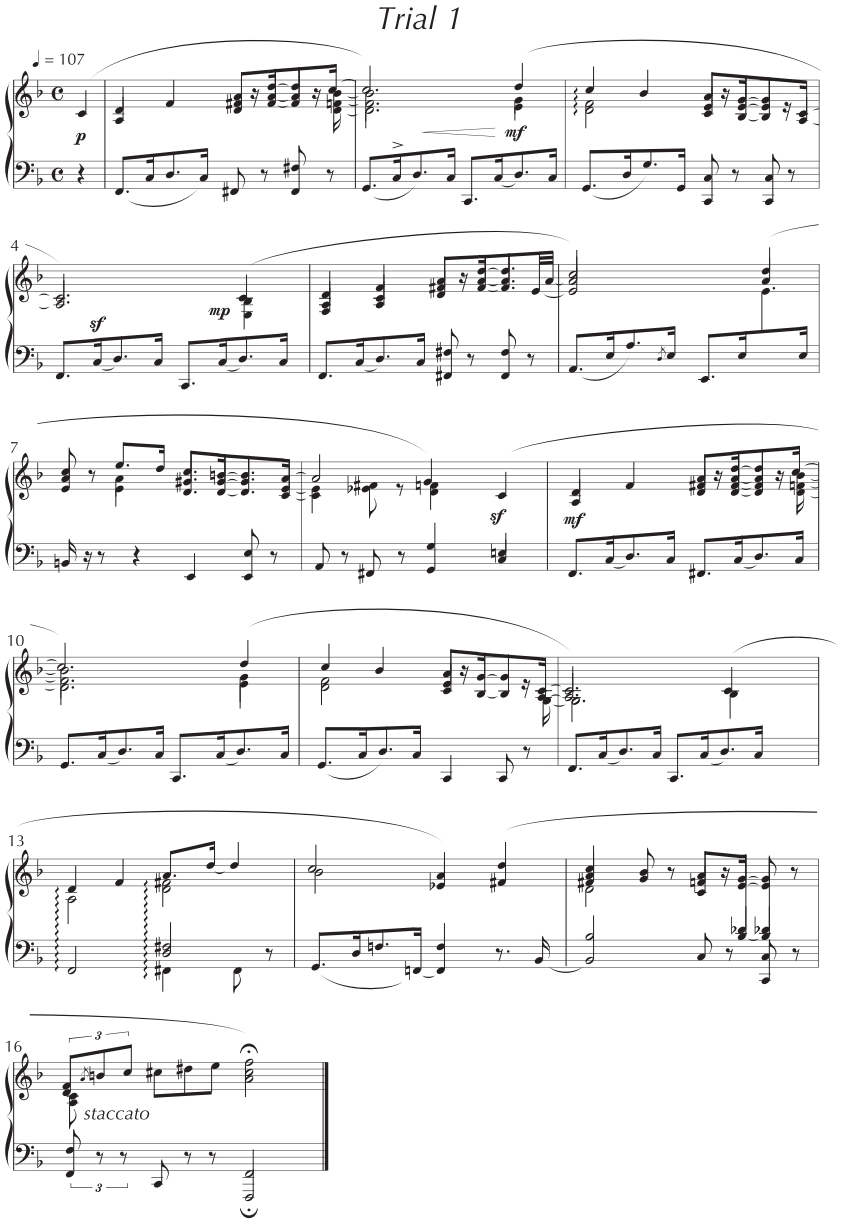



Fig. 7.4 Derek's 1st rendition of *Chromatic Blues*.

end), their musical complexity, and stylistic conformity. Also, Excerpt 1 was identical to Excerpt 3 in the original, while Excerpt 4 was a transposed and extended version of Excerpt 2, enabling comparisons to be drawn within each rendition. Transcriptions were undertaken by the research team using the notated output available via Finale from the MIDI files, which offered an accurate account of pitch and perceived time, but which needed modification in order to correspond to the conventions of Western rhythmic notation.

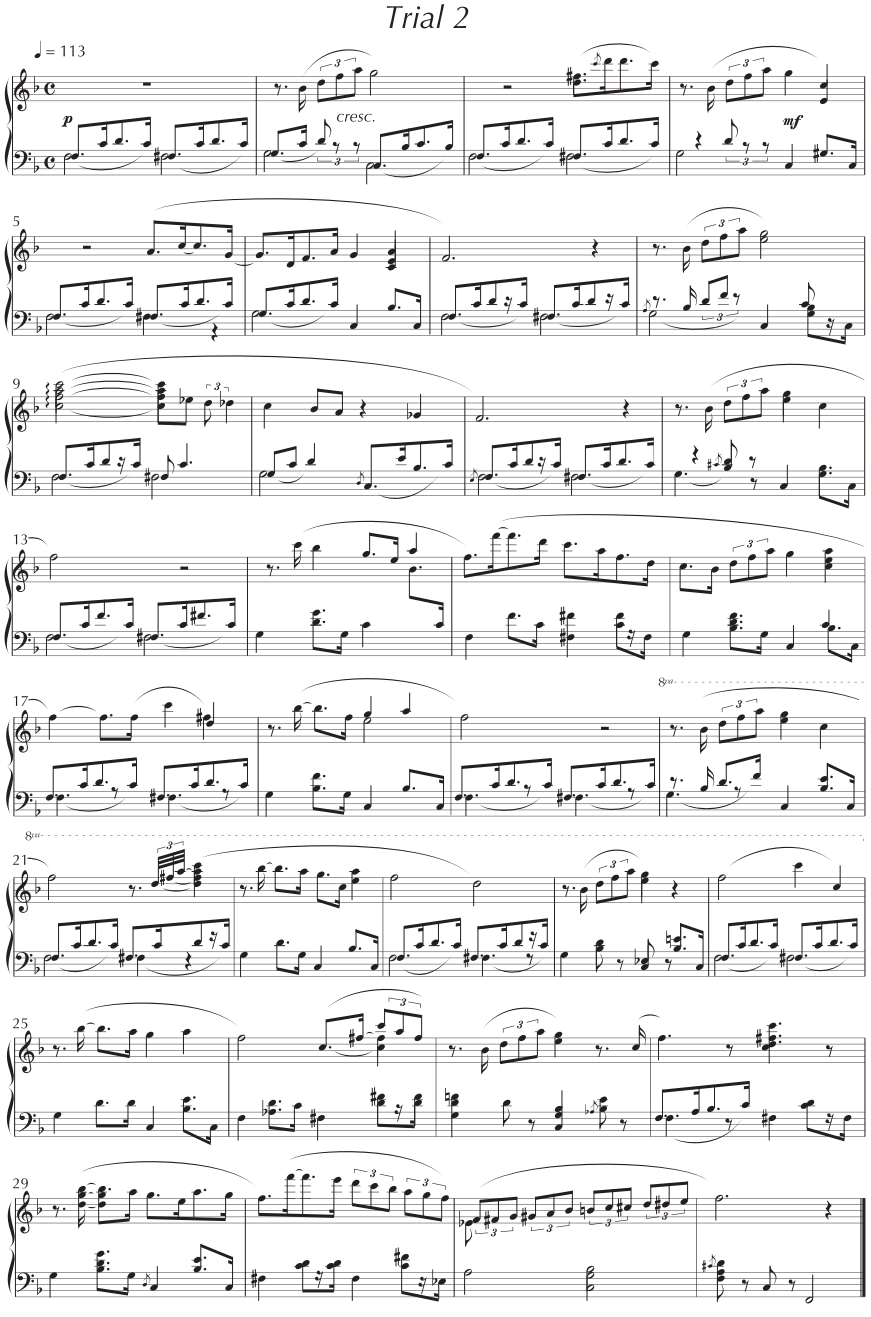



Fig. 7.5 Derek's 2nd rendition of *Chromatic Blues*.

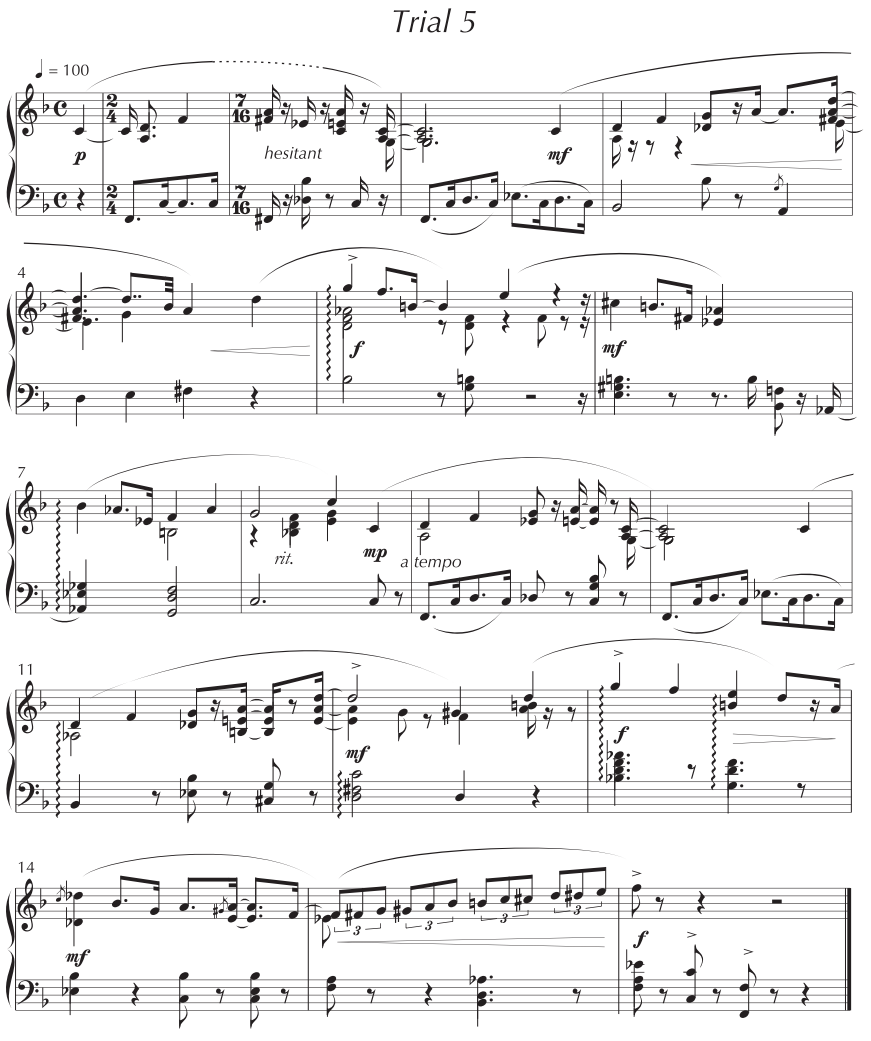



Fig. 7.6 Derek's 5th rendition of *Chromatic Blues*.

Analysis

How can we assess fidelity of recall? For the chordal disaggregation experiment we used a measure *R*, the "derivation index," based on the number of items that were correctly recalled divided by the number of items in the stimulus (see Formula 6.1). *Additional* items in the response figured in a probability equation whose output was used to temper the raw derivation score in recognition of the fact that items may have been repeated by chance. This gave rise to a "weighted" derivation index (see Formula 6.26):

$$Z = R(1 - P). \tag{7.1}$$

In the chord study, probability was important because the presence of each additional item increased the likelihood of the others being repeated by chance. With *series* of stimuli (such as

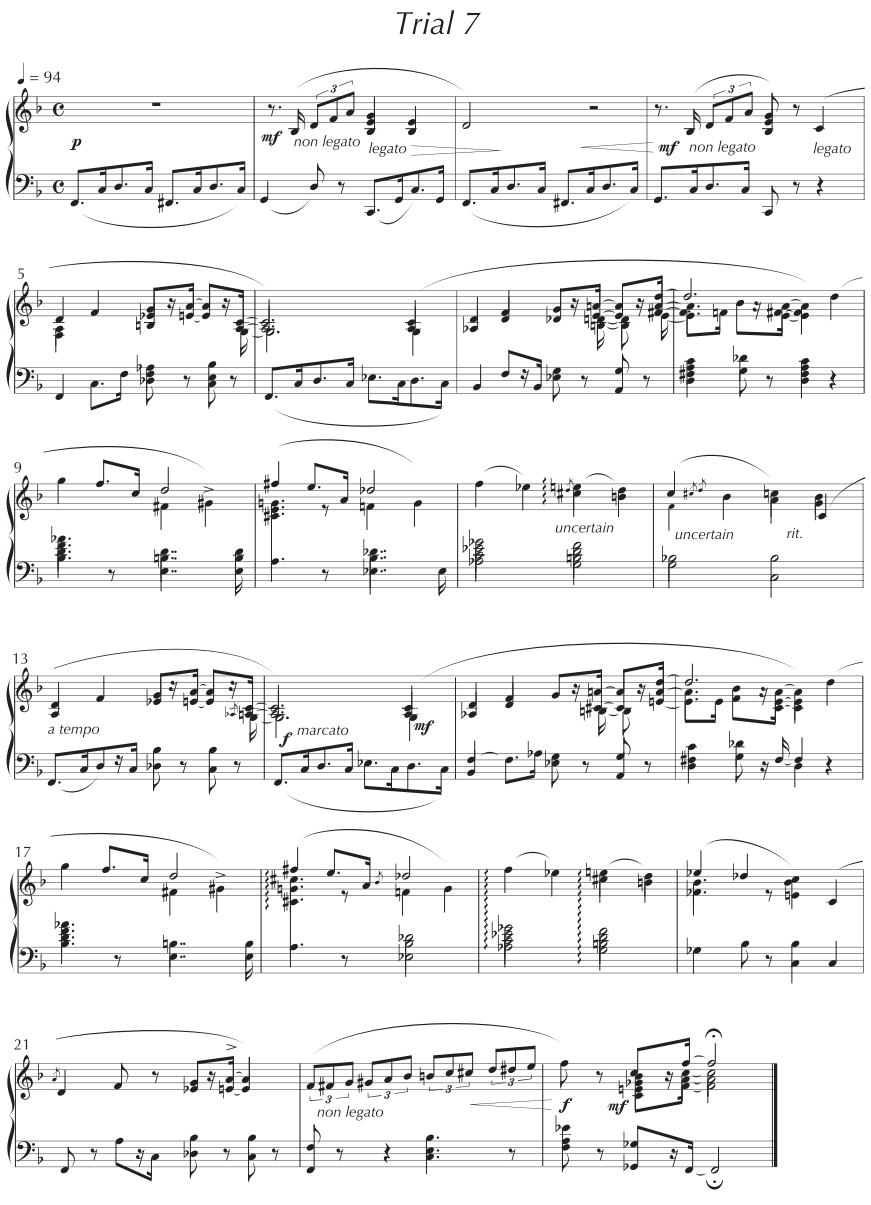



Fig. 7.7 Derek's 7th rendition of *Chromatic Blues*.

those that comprise *Chromatic Blues*), however, this is not the case, since the probability of each item's occurrence is independent of the others. Hence random repetition is likely to play a far smaller part in the calculation of derivation.

For example, given a pentatonic pitch universe (comprising five pitch-classes), a *chordal* stimulus of three notes and a response of three, two of which are correct, then the derivation factor is 0.67, the probability of this occurring by chance is 0.6, and the weighted derivation factor is 0.4 (see Fig. 7.9). However, with a *melodic* stimulus of three notes and a response of three, two

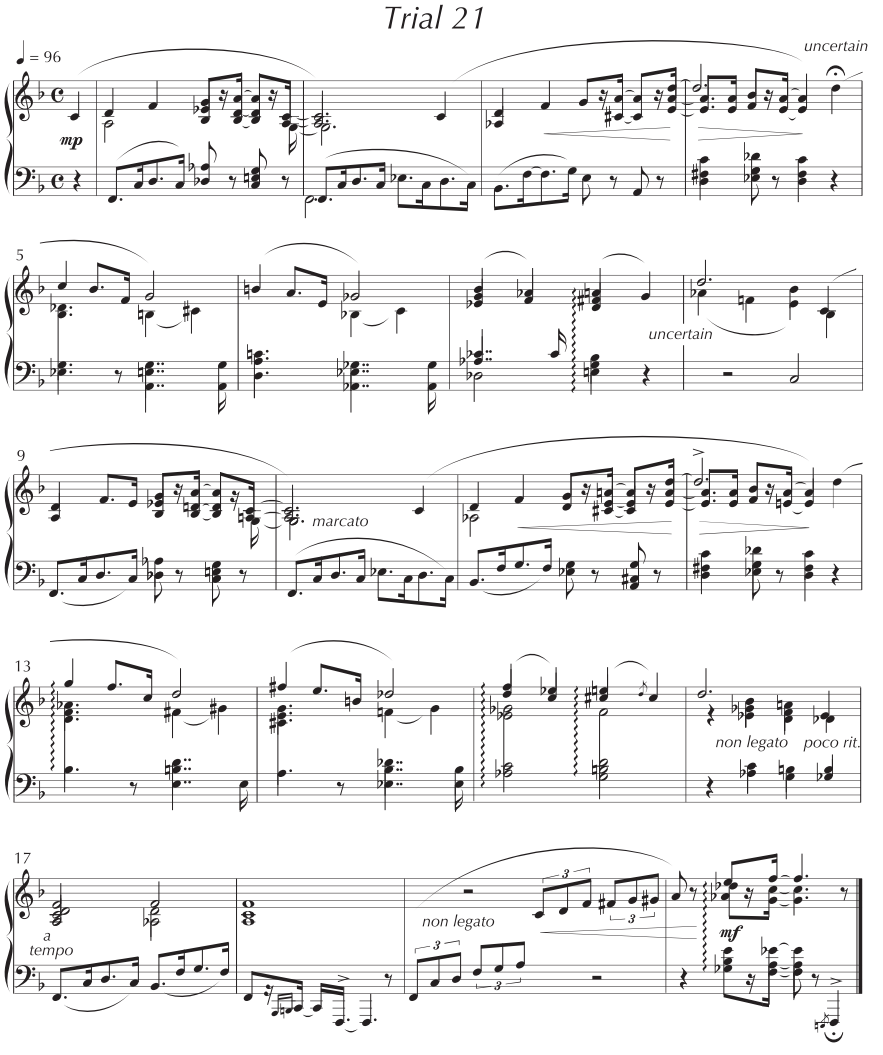



Fig. 7.8 Derek's 21st rendition of *Chromatic Blues*.

of which are again correct, then, although the derivation factor is still 0.67, the probability of this occurring by chance is only 0.096, and the weighted derivation factor is 0.61. Extending this principle to the universe of 12 pitch-classes available in *Chromatic Blues* means that the probability of melodic repetition occurring by chance will be vanishingly small.

However, it is clearly important to devise a measure of derivation that takes into account not only the number of matches to a given series, but errors in the form of additions too, since, intuitively, these weaken the strength with which one series is judged to derive from another. To this end, consider again the formula of "influence" (I^{nf}) originally presented as Formula (4.4):

$$I^{nf} = \frac{A(\text{♪}) \text{—}Z\text{⟶} B(\text{♪})}{A(\text{♪}) \text{—}Z\text{⟶} B(\text{♪}) + A'(\text{♪}) \text{—}\cancel{(Z)}\text{⟶} B(\text{♪})}. \tag{7.2}$$

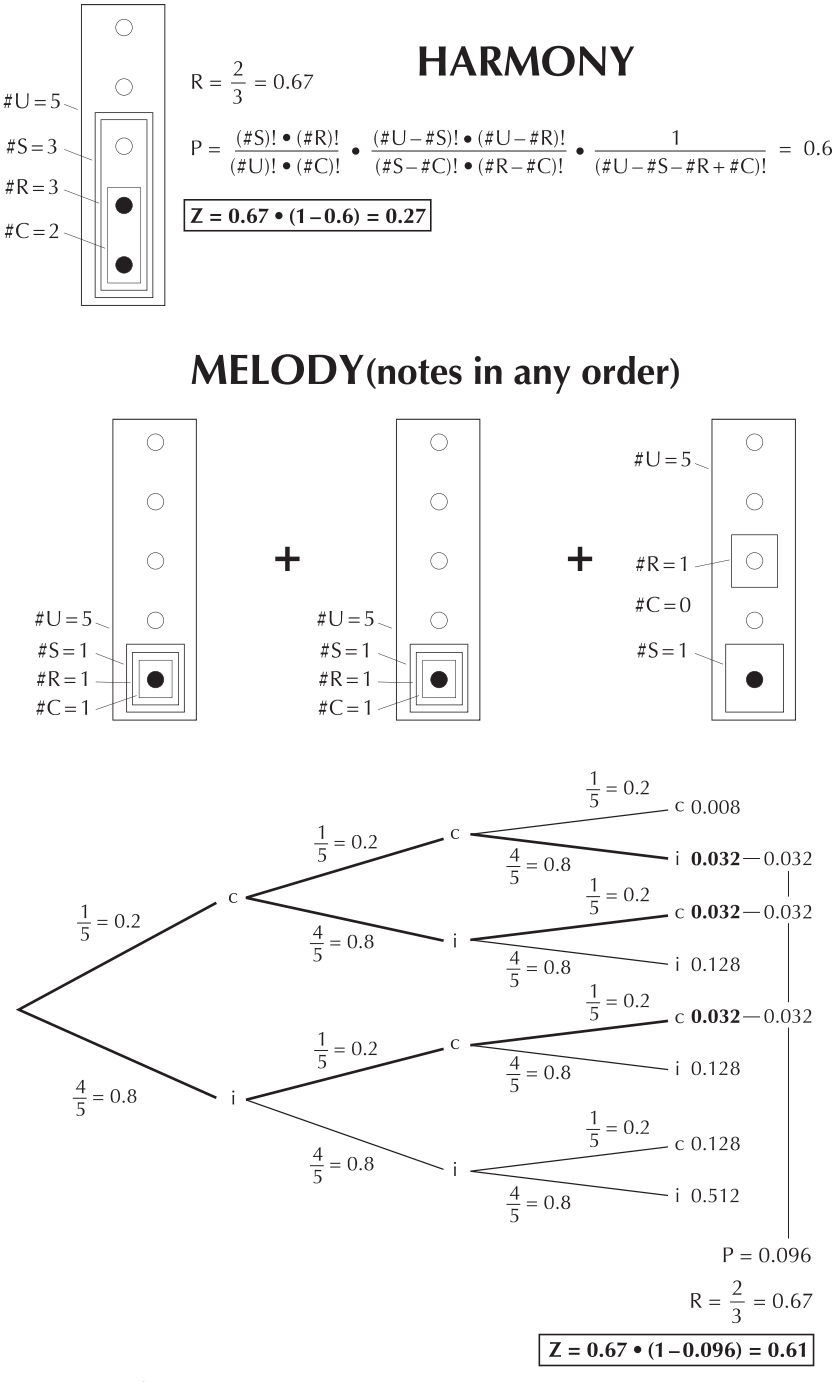


Fig. 7.9 The impact of chance in pitch imitation is much greater in harmonic contexts than melodic (c = correct; i = incorrect).

This expresses only how strongly A influences B, and is therefore not concerned with items in A that do not occur in B (omissions). Including "omissions from A" in Formula (7.2) gives the following equation:

$$\mathrm{ZYG} = \frac{\mathrm{A}(\text{♪}) \text{—}\not{\mathrm{Z}}\longrightarrow \mathrm{B}(\text{♪})}{\mathrm{A}(\text{♪}) \text{—}\not{\mathrm{Z}}\longrightarrow \mathrm{B}(\text{♪}) + \mathrm{A}'(\text{♪}) \text{—}\not{(\mathrm{Z})}\longrightarrow \mathrm{B}(\text{♪}) + \text{omissions from A}}. \tag{7.3}$$

This I term a "general" measure of zygonicity or "ZYG". (Examples of more specific forms of ZYG, which measure particular forms of derivation between sets and series of notes—for instance, ZYG_1, ZYG_1–SEQ, ZYG_2 and ZYG_2–SEQ—are set out in Ockelford, 2005, p. 94.) Its simplest form of expression is:

$$\mathrm{ZYG} = \frac{\text{no. of zygonic relationships between groups}}{\text{no. of actual and potential relationships between groups}} = \frac{\#\mathrm{Z}}{\#\mathrm{Rel}}. \tag{7.4}$$

The notion of zygonicity can be applied to any aspect of music whose derivation is felt to be important to measure. In the case of the "listen and play" study, it was decided that ZYG should be ascertained by considering pitch (as a combination of pitch-class and octave) and rhythm (taking into account durations and inter-onset intervals), because these were the variables regarded as having the greatest salience in the task that Derek was asked to undertake: together they define *Chromatic Blues* in a way that other perceived aspects of sound (loudness and timbre, for example) do not; see Boulez (1963/1971, p. 37) and Ockelford (1999, p. 4). Given this, the algorithm used to determine the zygonicity of an excerpt in the response from one in the stimulus is as follows (Stages 1–9):

1 With regard to rhythm: align the two series of "onset + duration" events to ensure maximal congruence. Events from one series that have no equivalent in the other may be discounted in the matching process that follows (Stage 2), though need to be included as spawning "potential rhythmic relationships" (in Stage 3). If an event is omitted, the following onset can be measured from the next most recent event to have occurred, or, in the case of two onsets of more, from a new "data zero".

2 For each match count 1. For an incorrect duration but correct onset, count 0.5. Total score = #Z(R) (that is, the number of zygonic relationships of rhythm).

3 Let the total number of sequential actual and potential rhythmic relationships between excerpts equal #Rel.

4 The derivation index for rhythm is ZYG(R) (zygonicity of rhythm), where

$$\mathrm{ZYG(R)} = \frac{\#\mathrm{Z(R)}}{\#\mathrm{Rel}}. \tag{7.5}$$

5 The derivation index for pitch is similarly determined as follows. Align the two series of pitch events to ensure maximal congruence, if necessary omitting those from either series that have no equivalent in the other.

6 For each match count 1. For an incorrect octave but correct pitch-class, count 0.5. Discounting exact or partial matches involving pitch-class, identify among any remaining pitch events'

intervallic matches.[7] These must be between sequentially adjacent events; the minimum number of events involved in any intervallic match is two. For each event involved in an intervallic match, count 0.5. The total congruence score is #Z(P).

7 Let the total number of sequential actual and potential pitch relationships between excerpts be equal to #Rel (as in Stage 3 above).

8 The derivation index for pitch is ZYG(P) (zygonicity of pitch), where

$$\mathrm{ZYG(P)} = \frac{\#\mathrm{Z(P)}}{\#\mathrm{Rel}}. \tag{7.6}$$

9 The derivation index for pitch and rhythm is ZYG(P + R) (zygonicity of pitch and rhythm), where

$$\mathrm{ZYG(P+R)} = \frac{\#\mathrm{Z(P)} + \#\mathrm{Z(R)}}{\#\mathrm{Rel} \times 2}. \tag{7.7}$$

This procedure considers each note of Derek's response separately in relation to pitch and rhythm and to what extent this can be deemed to derive from the corresponding note in the stimulus. It was decided to undertake the analysis separately in relation to three textural strands—the melody (at the top), the inner parts (considered as a single item), and the bassline (at the bottom), in accordance with the data pertaining to chordal disaggregation outlined in Chapter 6, and with the findings of Huron and Fantini (1989) and Huron (2001a), who give more general empirical evidence of our capacity to process a textural density of three auditory streams. Inevitably, this method of calculating zygonicity has limitations. For example, material that was originally heard in the bass may find its way into the inner parts of the reproduction, and the algorithm would only pick this up if movement between parts were treated as a special case. Overall, however, the results do appear to be intuitively as well as logically satisfying, and a worked example for Excerpt 1 is shown in Fig. 7.10. The measures of zygonicity for all five excerpts from Trial 1 are shown in Table 7.2.

We now examine the nature of the musical derivation that lies behind these figures, compare the results with the predictions that were made with respect to Derek's learning and recall, and consider the consequences for our understanding of his musical memory and creativity. As the analysis in Fig. 7.10 indicates, certain aspects of Excerpt 1 can be considered to be derived in a straightforward manner from the opening of *Chromatic Blues*, with events being imitated in sequence. Rhythmically, for example, the origin of 80% of Derek's material is attributable in this way, over twice the proportion (39%) that occurs in the domain of pitch. The extent to which this imbalance is typical of Derek's (and S's) performance across the rest of Trial 1 and the other trials is considered below. The bassline is reproduced most successfully (completely accurate with regard to rhythm and 67% in relation to pitch), followed by the melody (86% and 50% respectively), with the inner parts being least successful (58% rhythmic accuracy and only 8% pitch). Again, the extent to which Derek's privileging of the bassline in perception or recall (or both) is characteristic of his cognitive style (as data from the chordal disaggregation study suggest) or occurs because the bassline is the most repetitive strand in the musical fabric (and, as we shall see, utilizes a stylistically archetypal pattern), will be considered further as more evidence is presented

[7] This constitutes an important difference from the way in which derivation was considered in the chordal disaggregation study where intervallic matches were ignored (since there we were considering absolute pitch).

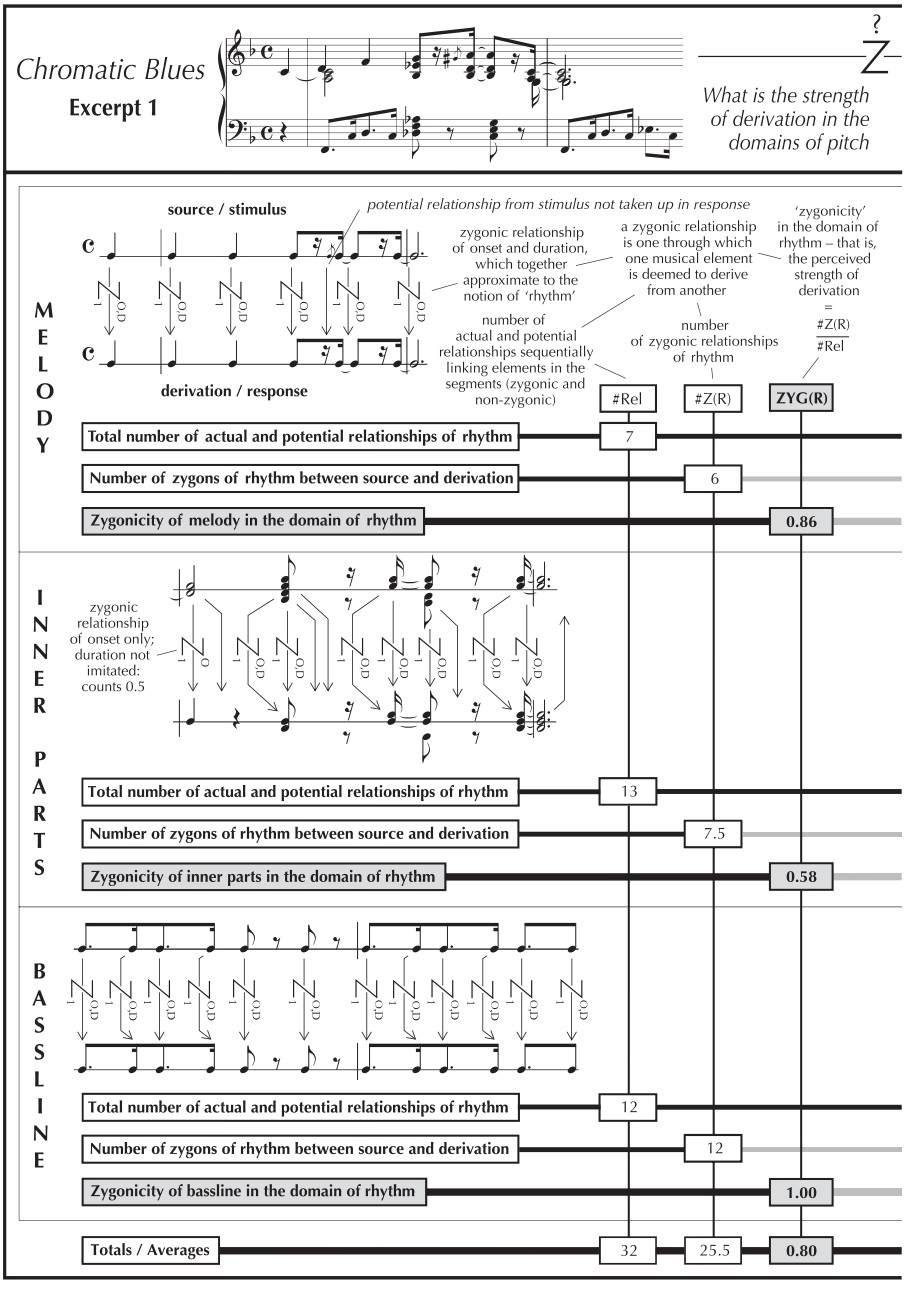


Fig. 7.10 Protocol for calculating the strength of derivation of one excerpt from another.

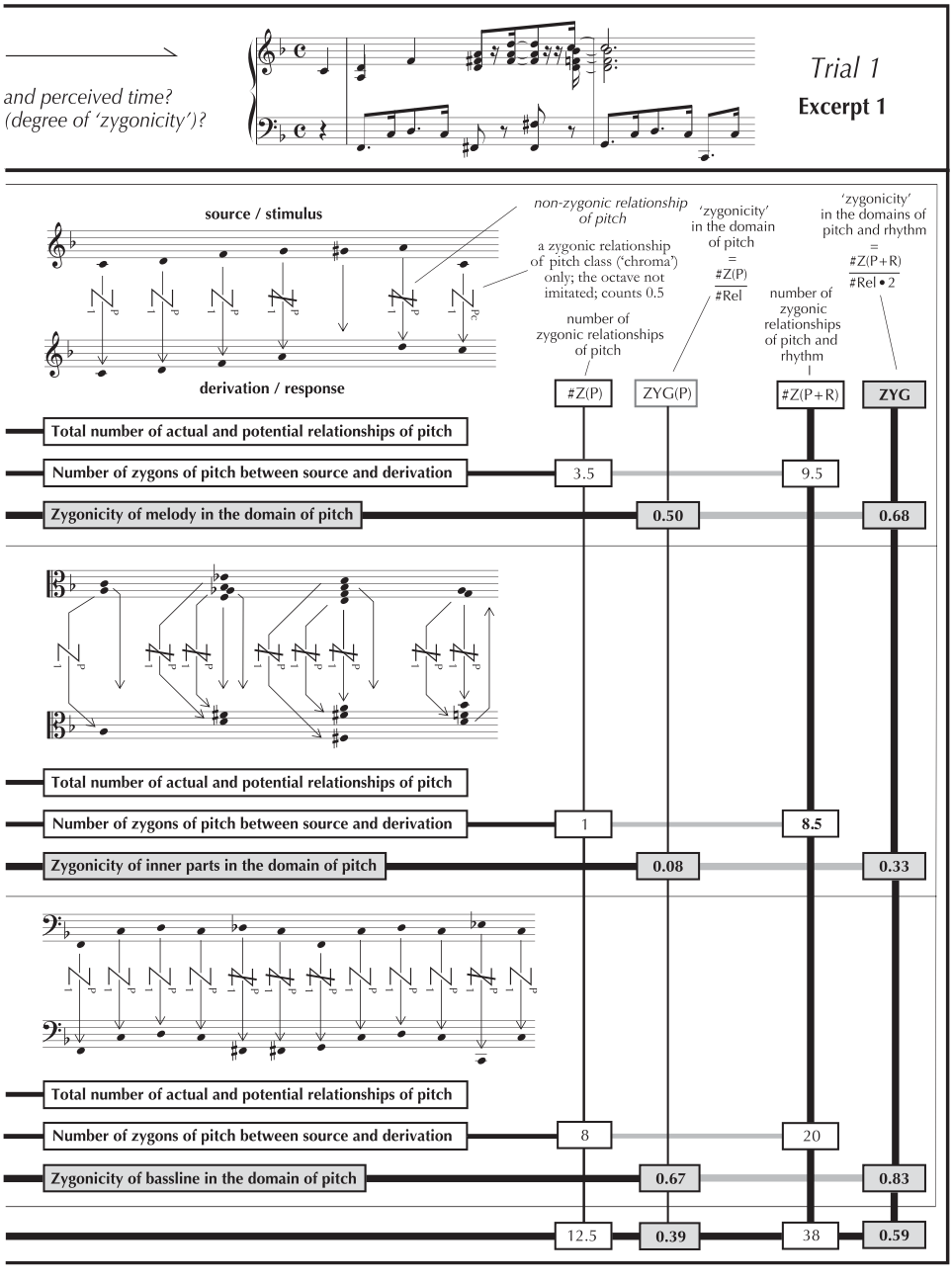


Fig. 7.10 (part ii) (continued).

Table 7.2 Derivation indices for Derek's Trial 1

	Excerpt 1						
	#Rel	**#Z(R)**	**ZYG(R)**	**#Z(P)**	**ZYG(P)**	**#Z(R+P)**	**ZYG**
Melody	7	6	0.86	3.5	0.50	9.5	0.68
Inner Parts	12	12	1.00	8	0.67	20	0.83
Bassline	13	7.5	0.58	1	0.08	8.5	0.33
Total / Average	**32**	**25.5**	**0.80**	**12.5**	**0.39**	**38**	**0.59**
	Excerpt 2						
Melody	11	4.5	0.41	1	0.09	5.5	0.25
Inner Parts	9	2	0.22	1.5	0.17	3.5	0.19
Bassline	22	3.5	0.16	5	0.23	8.5	0.19
Total / Average	**42**	**10**	**0.24**	**7.5**	**0.18**	**17.5**	**0.21**
	Excerpt 3						
Melody	7	6	0.86	3.5	0.50	9.5	0.68
Inner Parts	14	11	0.79	10	0.71	21	0.75
Bassline	14	6.5	0.46	2	0.14	8.5	0.30
Total / Average	**35**	**23.5**	**0.67**	**15.5**	**0.44**	**39**	**0.56**
	Excerpt 4						
Melody	11	4	0.36	1	0.09	5	0.23
Inner Parts	10	2.5	0.25	0	0.00	2.5	0.13
Bassline	20	5.5	0.28	0.5	0.03	6	0.15
Total / Average	**41**	**12**	**0.29**	**1.5**	**0.04**	**13.5**	**0.16**
	Excerpt 5						
Melody	17	8	0.47	4	0.24	12	0.35
Inner Parts	7	1	0.14	1	0.14	2	0.14
Bassline	25	0	0.00	2	0.08	2	0.04
Total / Average	**49**	**9**	**0.18**	**7**	**0.14**	**16**	**0.16**
	Averages / Totals						
Melody	53	28.5	0.54	13	0.25	41.5	0.39
Inner Parts	52	28.5	0.55	20.5	0.39	49	0.47
Bassline	94	23	0.24	10.5	0.11	33.5	0.18
Total / Average	**199**	**80**	**0.40**	**44**	**0.22**	**124**	**0.31**

through the discussion that follows. For now, we should note that, across the whole texture, 59% of the pitch and rhythmic material from the opening two bars was recalled, supporting Bartlett's assertion (his Clause 1) that accuracy of reproduction is the exception rather than the rule, and Predictions (i), (ii), and (iii), that some fragments and features would be recalled precisely and others approximately.

However, the 59% of material recalled leaves 41% that is unaccounted for in direct derivational terms. Where did it come from? Given that we expected Derek to produce music that "made sense," these additional elements would have to be compatible with the parts that he could remember. Our predictions (vii and viii) were that Derek would take material from elsewhere in *Chromatic Blues* or from other, stylistically congruent pieces (or a combination of the two). Moreover, since musical fragments and features usually have a multiplicity of roots (see Ockelford, 2005a, p. 114), those features of Trial 1 that had direct sequential equivalents in *Chromatic Blues* may additionally have been generated elsewhere.

The potential sources of additional musical ideas will now be explored in relation to Excerpt 1. The approach that will be adopted—zygonic analysis—seeks to identify relationships through which fragments of musical material can reasonably be deemed to have been derived from one another according to their similarity and salience. In undertaking this analysis, an indispensable factor is my detailed knowledge of Derek's repertoire, which informed the following account of the possible connections with other pieces. It goes without saying that this approach, which relies on the intuitive judgments of a musician who knows Derek well, potentially suffers from a lack of objectivity. However, it is important to acknowledge the ontological status of the analyses that follow: they are intended merely to be *indicative* of the type of musical relationships that appear to be present (and, therefore, of the kind of cognitive processes that created them). This is as much as can be attained through the zygonic approach (or any other music-analytical technique), which, despite its rigor, bears a degree of subjectivity. To reiterate, though, it is the principles that are illustrated that are more important than the verifiability of any particular aspect of them.[8]

We will consider first the material that Derek seems to have taken from elsewhere in *Chromatic Blues*. The first four bars appear to have provided him with a particularly rich vein of musical ideas to tap. Zygonic analysis suggests that a number of transformational techniques were adopted in relation to those fragments and features that Derek appropriated (in accordance with Prediction v), including the temporal reordering of material in the domain of pitch (see Fig. 7.11). For example, the contour of the *second* phrase (which begins in the same way as the first) was used at the *beginning* of his version. This has the effect of emphasizing the D major harmony that was particularly salient in the original, as it provided a stylistically unusual tonal goal for the second phrase of the melody. This ties in with Bartlett's observation (Clause 8) that outstanding detail tends to occur earlier in recall. Moreover, the ascent in the bassline from F to F♯ in bar 1 seems to echo the transition from C to D♭ in the original, effectively transforming a highly unusual move this early in proceedings into one that (as we shall see) is stylistically commonplace. Further reordering occurs as the descent to C4 that concludes the first phrase is moved to the end of the second in Derek's rendition.

In the domain of rhythm, Derek uses the opening phrase (without the acciaccatura) twice, creating a symmetry that is not found in the original *Chromatic Blues*. Hence, it appears that in

[8] This is methodologically comparable with the approach adopted, for example, by John Livingston Lowes (1951) in his detailed investigation into the sources of Samuel Taylor Coleridge's imagery; as Margaret Boden points out (2004, p. 127), "'evidence' and 'probably' are the best we can expect in investigations of this kind."

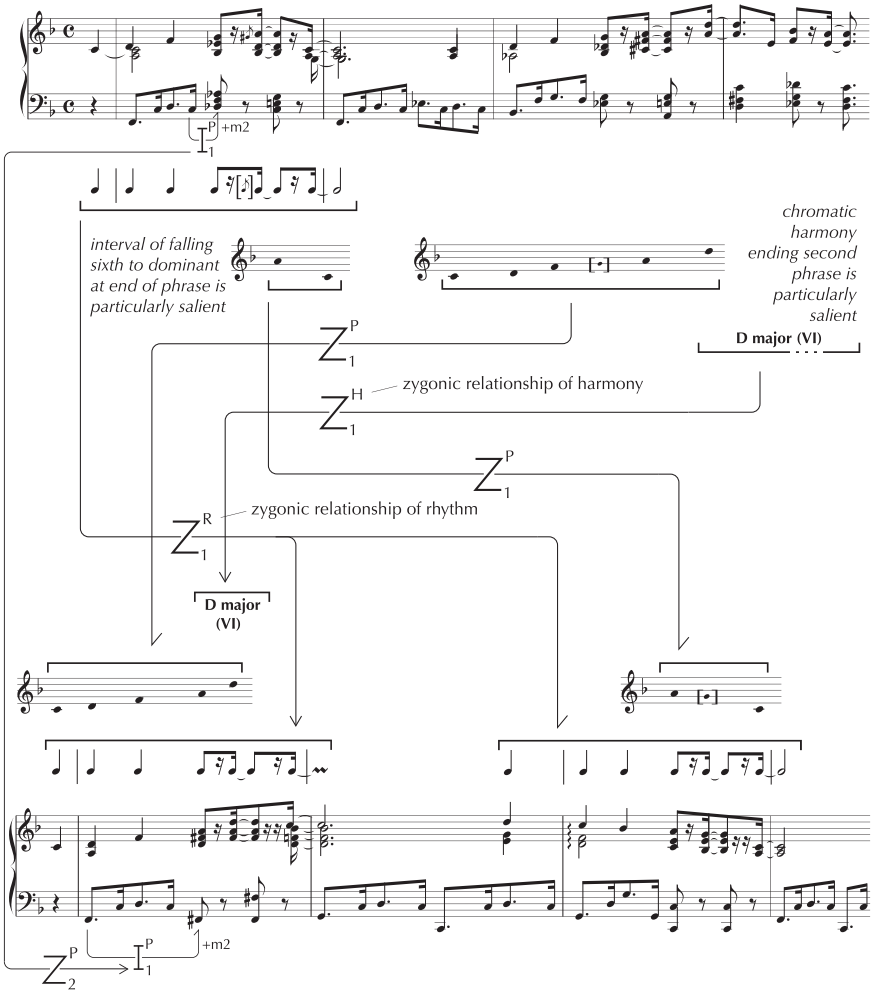


Fig. 7.11 Material that Derek is thought to derive from *Chromatic Blues*.

the process of generating his version, Derek separated elements of pitch and rhythm and then re-synthesized them to produce material that was closely related to the original, though distinct from it: a sophisticated form of transformation. Observe that while it is cross-culturally commonplace for rhythm to maintained against changing patterns of pitch (Ockelford, 2009b, p. 75) it is relatively unusual for pitch and rhythm to be uncoupled and then reassembled in different combinations.

As well as borrowing material from elsewhere in *Chromatic Blues* (Prediction vii) Derek seems to have taken ideas from other pieces too (Prediction viii), both generally (through stylistic features) and specifically (from individual works; a technique that is characteristic of traditional jazz—see, for example, Berliner, 1994, pp. 103ff.). Figure 7.12 shows three zygonic relationships originating in other pieces that may conceivably have played a part in the formulation of the opening bars of Derek's first rendition of *Chromatic Blues*. For instance, it is suggested that the first two bars of the bassline of Trial 1 may derive from a standard bass riff (exemplified here in an excerpt from

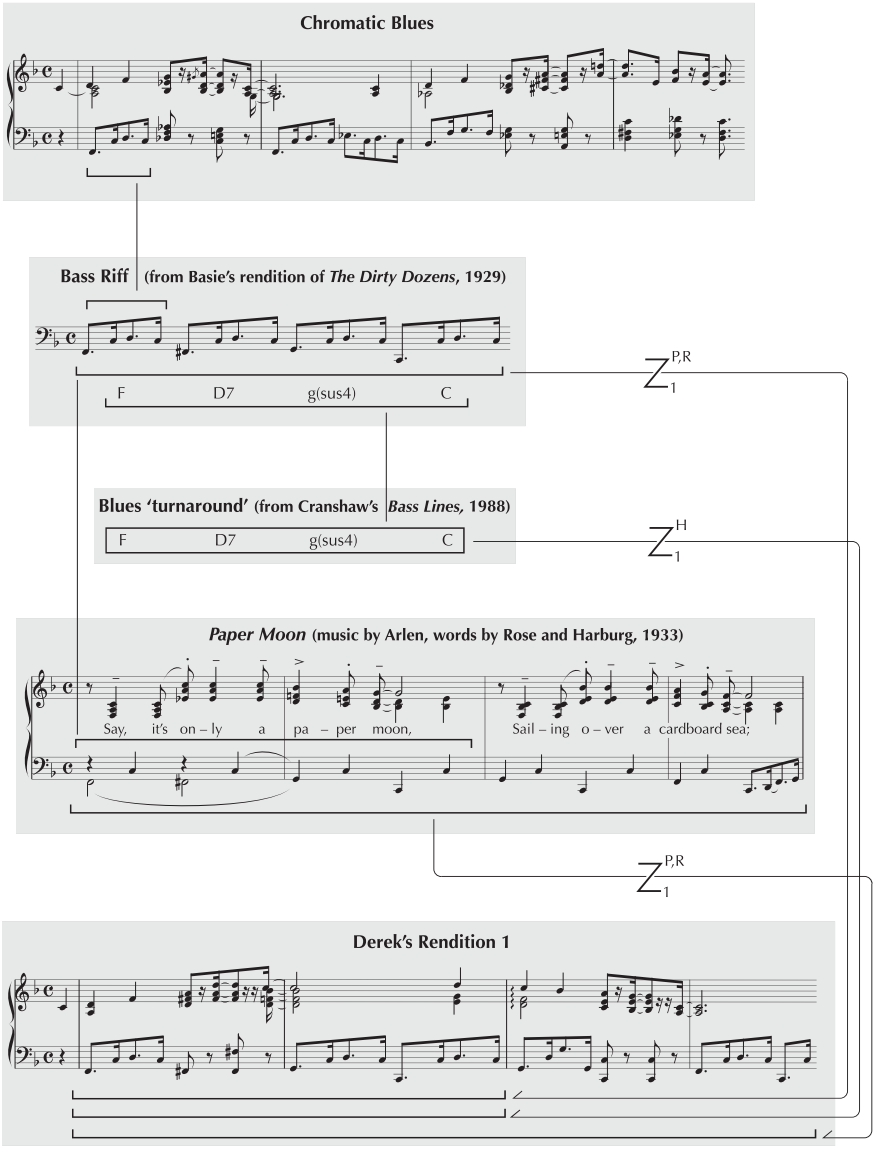


Fig. 7.12 Material that Derek is thought to derive from other pieces.

Count Basie's rendition of *The Dirty Dozens*, 1929), whose harmonic pattern also constitutes a popular blues "turnaround." Furthermore, the bassline and harmonies of the first four bars bear a close resemblance to those used in the chorus of *It's Only a Paper Moon* by Harold Arlen (1933). It is impossible to say the extent to which these pieces (with which Derek was very familiar), and others that could be identified, *actually* played a part in the formulation of his rendition—though, as we have seen, the probability of complex, integrated patterns of pitch and rhythm such as those identified resembling others by chance is statistically remote. In summary, then, Fig. 7.12

is intended to be illustrative: to offer an indicative and partial account, rather than one that is in some sense "absolute" or exhaustive.

How were differing materials such as these, taken from a diversity of sources, synthesized within a new, coherent musical whole? As we saw in Chapter 2, according to zygonic theory a necessary (though not sufficient) element in musical coherence is the ubiquitous presence of zygonic relationships. In relation to the first four bars of Trial 1, the position may be summarized as follows (see Fig. 7.13). The pitch contour of the melody traces the movement from C4 to C5, followed by a return to C4 via imperfect retrogression of the opening motif. These two gestures are also connected through repetition, whereby the last pair of notes of the initial figure are used to set the second in motion. This reiteration is mirrored in the bassline with the transition from G to C and the harmonic shift from ii to V, which together give the effect of picking up from where the first gesture left off and then taking it in a new direction. Rhythmically, the two halves are identical.

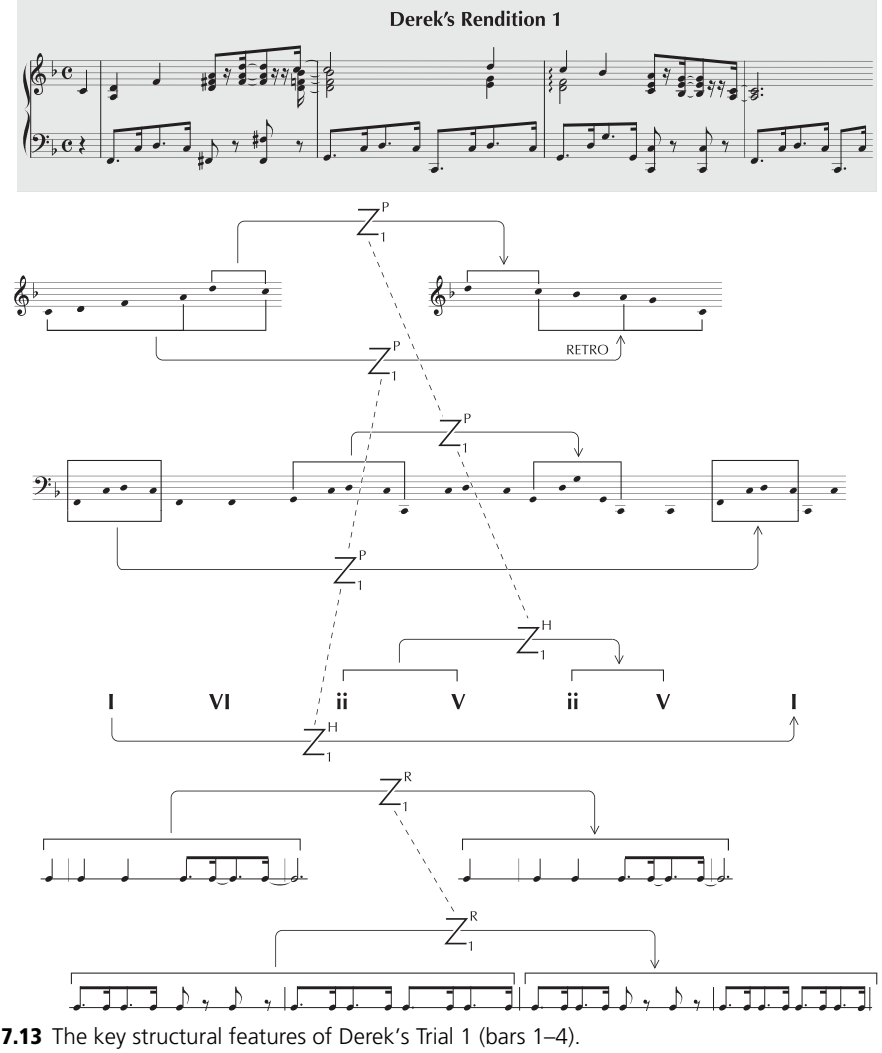


Fig. 7.13 The key structural features of Derek's Trial 1 (bars 1–4).

Zygonic theory contends that musical fragments from a variety of sources can be synthesized in this way because of the "chameleon" effect (Ockelford, 2005b, pp. 99ff.), whereby chunks of music can be modified without their identities being compromised. This enables them to coexist within a common framework of tonality, tempo, loudness, and timbre. Specifically, in the case of Trial 1, and in accordance with Predictions (ii) and (iv), Derek adopted a tempo of ♩ = 107 (slightly faster than the ♩ = 100 of the original *Chromatic Blues*), and used the same metrical framework (Common Time). Both *Chromatic Blues* and the music Derek created in Trial 1 utilize sets of context-specific transition probabilities in the domain of pitch that give rise to the sense of a major key (F major to those, such as Derek, with AP), and, in very broad terms, the feel of the blues.

The chameleon effect is one way in which the creation of the opening bars of Trial 1 balances the potentially conflicting forces of, on the one hand, Derek's deployment of extant materials and, on the other, the need for what he produces to make musical sense on a moment-to-moment basis. In his efforts to re-create music, it is the latter that almost invariably dominates, as the construction of the second melodic gesture (bars 3 and 4) illustrates. Having ascended an octave and reached the harmony G minor^{7}sus^{4} (from F major via D^{7}), the stylistically attuned ear strongly anticipates a balancing melodic descent and (with rather less certainty) a return to the tonic (F). Derek achieves both, by creating a new link—the D5–C5 taken from the end of the first phrase, setting in place a scalar motion which continues down to A4—before deploying a modified version of the ending of the first motif from *Chromatic Blues*, which permits a reiteration of the tonic chord.

The dominance of internal forces of coherence becomes even more apparent as Trial 1 proceeds (see Fig. 7.4). For example, in *Chromatic Blues*, following the opening four bars, there is a highly chromatic passage (labelled $B_{1.1}$ in the structural analysis shown in Fig. 7.3). This is linked to opening section ($A_{1.1}$) via the pivot note D5 in the melody, with serves successively as the root of the D major harmony with which the opening section ends (in bar 4) and the third of the B♭ major chord with which the chromatic sequence begins. However, in Trial 1 this link was not available to Derek, since his first section ended on C4. Hence, he was more or less compelled to take another tack (irrespective of whether he could remember what actually occurred at this point or not). What were his options?

Working within the constraint that he had to make the best use of whatever he could remember from *Chromatic Blues*, Derek chose to return to the opening for the source of his next swatch of material. However, given that he was also aiming to emulate the general shape of *Chromatic Blues* as far as possible (we may surmise), this left him with the structural difficulty of the need for contrast, including key change, at this juncture. Derek's solution was to re-harmonize the end of the first phrase in A minor, incorporating the stylistically unusual transition from D major (bars 5 and 6). He extended the A minor tonal region into the second phrase, at first through a simple re-harmonization (bars 6 and 7) but subsequently through the transposition and modification of the melodic descent first heard in bar 3, yielding a more assertive A minor cadence in bars 7 and 8. Unsurprisingly, then, Derek's Excerpt 2 is only weakly related to the original (Fig. 7.4), with an average zygonicity of 0.21. And even this low score is largely attributable to the rhythm of the melody (ZYG = 0.41), which, in *Chromatic Blues*, also borrows from the opening. The fact that melodic pitch replication is very low (ZYG = 0.09) suggests that it is these original internal similarities, rather than Derek's ability to recall the second phrase, that enable him to achieve even a modest average zygonicity score for this segment.

At this point (bar 8, beat 1), Derek's solution to the problem of tonal contrast presented him with a further challenge. Structurally, the model provided by *Chromatic Blues* requires a return

to the opening, both tonally and thematically. Hence, within a very short space of time (beats 2 and 3 of bar 8) Derek needed the music to modulate from A minor to prepare for a return to F major (through its dominant, C). This he achieved with a V–I sequence that continued into the reprise of the opening, logically binding the two sections together (through the series of harmonies D–G–C–F).

Next, Derek repeated his bars 1 to 4 (Excerpt 3) with only small changes in detail, again utilizing the structure of *Chromatic Blues* in preference to its content, and here the zygonicity is very similar to the identical Excerpt 1 (0.56 as opposed to 0.59), the main difference lying in the rhythm of the bassline, which Derek elaborates somewhat on its second appearance. It is interesting to reflect that he was presumably aware (at some level) that by repeating what he had first played in Trial 1 he was inevitably producing something that—once more—was different from the original. But we can also assume that he intuitively knew that musically it made more sense to repeat an "error" rather than to try for a more accurate recall of the opening theme at the second attempt.

Up to this point, then, Derek had produced a piece in the form $A_{1.1}$ $A_{1.2}$ $A_{2.1}$. If he were to continue to follow the *Chromatic Blues* model with regard to general structure—$A_{1.1}$ $B_{1.1}$ $A_{1.2}$ $B_{2.2}$ C—albeit approximately, then a further version of section A would be required, modified so as to produce an unambiguous sense of completion, with an authoritative perfect cadence in F major. And this is precisely what we get. The opening melody appears for a fourth time, but the feeling of forward motion engendered by the rocking motif in the bass is curtailed, replaced with arpeggiated chords. The impending sense of closure is reinforced by a move to the subdominant (B♭ major), which replaces the G minor harmony. In quantitative terms, with ZYG = 0.16, Excerpt 4 is even more remote from the original than Excerpt 2 (0.21)—a difference that largely pertains to pitch, and is largely attributable to the original transposition at this point, which Derek does not follow in his version of events.

Finally, within this four-bar section (functioning as $A_{1.3}$ in structural terms) Derek's rendition nods in the direction of the coda of *Chromatic Blues*, through an additional perfect cadence in the final bar in which eighth note triplets in the right hand (incorporating blues notes) extend upwards to F5, while the bass reaches down two octaves (to F1). These similarities with the original *Chromatic Blues* coda are sufficient at least to capture something of its spirit (although ZYG is low at 0.16), capping the piece off through the injection of a new rhythm and texture. Once more, the legacy of the preceding phrase meant that development, rather than replication, of the original material was inevitable.

In summary, it is evident that the requirement for musical coherence coupled with limited recall in Trial 1 caused Derek to utilize a range of improvisational strategies, some of which appear to have been hastily constructed in response to moment-to-moment needs (such as the move to A minor in bar 6, and the return to F major in bars 8 and 9), while others suggest a greater degree of structural anticipation, such as the reduction in the level of activity in the final phrase initiated at its outset through the chords in bar 13. With regard to the derivation of material from *Chromatic Blues*, there is, as we have seen, significant use of both its content and structure in section $A_{1.1}$ of Trial 1. In the following sections $A_{2.1}$ $A_{1.2}$ and $A_{1.3}$, however, only structural relationships are appropriated—although, inevitably, given the repetitive structure of *Chromatic Blues*, this results in some of the original content being replicated too (as in section $A_{2.1}$). It is only in the final bar, the coda, that a sense of derivation of musical content returns, although this is weak.

What, then, is the status of Trial 1 in musicological terms? While the foregoing analysis suggests that its opening is a patchwork of musical materials taken from other pieces and elsewhere in *Chromatic Blues*, it is evident from the first four bars alone that Derek had created what can reasonably be regarded as an original piece. The rising pitch contour of the opening gesture,

comprising intervals that increase arithmetically by semitones (a major 2nd, minor 3rd, major 3rd and perfect 4th),[9] is, as far as I am aware, shared by only one other piece in the "standard" Western repertoire (*Indian Love Call* from *Rose Marie* by Rudolf Friml, 1924), and here the rhythmic framework is very different.[10] That is to say, in the manner typical of many composers and improvisers, Derek fashioned something new by borrowing, transforming, and recombining materials with which he was familiar: in broad terms, within the framework of an act of recall, he used his imagination to forge an act of musical creativity.

What, if anything, can the zygonic analysis tell us about Derek's cognitive processing? What is it reasonable to infer? At the outset, we should acknowledge the methodological limitations inherent in this approach, in order to judge the potential validity of what follows. For example, while we can assume that the music Derek produced was closely related to his mental representations of *Chromatic Blues*, we should not presume that the mappings between model and product were exclusive or regular. For instance, it seems highly likely that there were traces of *Chromatic Blues* in Derek's memory that he did not realize in Trial 1. Partly, as we have surmised, this situation will have arisen due to Derek's (unwitting) aim of producing something that was musically coherent based on imperfect recall. Beyond this, it may also have been the case that the hand and finger movements required for his reproduction influenced what he played (through the use of purely kinesthetic schemata that may have been triggered) and, indeed, that these same routine motor patterns may have been the source of musical material that bore no direct auditory relationship to anything found in *Chromatic Blues*. Nonetheless, it seems reasonable to assert that the music Derek produced provides sufficient evidence for a number of plausible assumptions to be made about the cognitive processing that lay behind his efforts.

Let us begin by reaffirming the supposition, based on my extensive experience of working with Derek over a period of almost 30 years, that, since he was requested so to do, he would have tried to make his version of *Chromatic Blues* as faithful as to the original as he could. This leads to the conclusion that, because he did not reproduce the piece accurately, it must have lain beyond the limitations of his working memory. The transcription of Trial 1 in Fig. 7.4 shows us what he did remember and, by implication, what was beyond his capacity to recall. It is evident that what Derek did *not* do was to re-create *Chromatic Blues* sequentially up to a certain point and then stop (as a computer with a buffer of limited size would have done). As we observed above, Trial 1 was at once an act of creation and reconstruction, in which Derek utilized material from the beginning and end of *Chromatic Blues*, higher-level structural characteristics of the piece as a whole, and attributes, such as tempo and meter, that were present throughout (in accordance with Predictions i, ii, iii, and iv). That is to say, he appears to have built up and stored a bundle of musical fragments and features from various locations in the original piece, of varying lengths, types, and degrees of abstraction. With regard to the opening bars, for example (see Fig. 7.4), a *fragment* that was preserved in terms of both pitch and rhythm was the opening motif in the bassline. Subsequently (from the second half of the first bar) it was only the rhythm that was recalled accurately. A *feature* that was stored was the F major tonality.

As we shall see, Derek's *Chromatic Blues* memory bundle should not be conceived of as a collection of auditory traces and their abstractions laid down like rock strata, with no interaction, each layer consolidated at a certain point in time. Rather, it seems likely, and the accounts below of

[9] For psychomusicological considerations of this pattern, see Ockelford (1999, p. 517; 2002, p. 207) and Narmour (2000, p. 364).

[10] Subsequent enquiry revealed that this was a piece with which Derek was not familiar.

further renditions support this, that the system dynamically evolved as *Chromatic Blues* unfolded, and continued to develop during Trial 1 and in the period that followed.

These observations and hypotheses beg a number of questions. For example, why did certain items find their way into Derek's *Chromatic Blues* bundle and others (apparently) not? Under what conditions were the memories of items from other pieces stimulated? How did the process of "creative reconstruction" work?

First, we will consider the issue of the selection and storage of items in the bundle and their durability. The fact that *Chromatic Blues* apparently exceeded the capacity of Derek's working memory inevitably meant that there would have been competition among its elements, whereby some would be captured and retained while others were not. We may surmise that among the determining factors in this process were:

1 *salience*, including the immanent qualities of a particular item and how these related to the perceived attributes of surrounding stimuli in terms of similarities and differences (cf. Ockelford, 2005b, pp. 81ff.);
2 *structure*, including the degree of internal regularity of an item, which may have permitted its parsimonious encoding (Ockelford, 1999, pp. 115ff.);
3 *resilience*—the degree to which an item can retain its encoded identity among a welter of interference from rivals (again, a presumed function of the similarities and differences among them); and
4 *reinforcement*, brought about through the repetition of items (see Ockelford, 2004).

It seems that these factors frequently took effect in combination. Consider, for example, the opening rhythmic motif in the right-hand part of *Chromatic Blues*, which Derek reproduced accurately (though without the grace note)—indeed, it forms the basis of much of Trial 1, being used eight times. We can assume this motif had particular *salience*, being among the first things that Derek heard, and therefore suffering no pre-stimulus interference; *structurally*, it had moderate rhythmic regularity [for example, ZYG_1 (inter-onset interval) = 0.6][11] that proved to be *resilient* in the face of competing post-stimulus input; and it was heard twice in the course of *Chromatic Blues*—repetition which offered *reinforcement*.

Second, we consider the manner in which memories of elements from other pieces were stimulated. The indicative analysis shown in Fig. 7.12 suggests that memory traces were activated through the perception of new items with which they shared varying degrees of similarity. These were often incomplete, and comprised either direct perceptual features or the relationships between them (of varying degrees of abstraction; see Ockelford, 2002). Hence, we can conclude that the "pattern matching system" used had a broad degree of tolerance—a degree of fuzziness that arguably is a key feature of any act of creativity that operates within a probabilistic style-system. Some elements pertained to one piece and others to more than one, being in nature either "veridical" (relating to particular episodes) or "schematic" (relating to probability matrices in the domains of pitch or perceived time, or both, that derived from many such episodes: see Bharucha, 1987; Ockelford, 2006a). Evidently, one memory trace was able to stimulate another (in the case of the bass riff and *Paper Moon*, for example), resulting in only an indirect relationship between features of *Chromatic Blues* and Trial 1. For Derek, producing material at an average rate of seven

[11] That is to say, of all the possible relationships of inter-onset interval between the six notes in the series, 60% were potentially zygonic (see Ockelford, 2005a, p. 94).

events per second, the process of stimulation was evidently rapid and largely (if not entirely) unthinking.

Third, how did the process of "creative reconstruction" work? This can be understood using the analogy of a "music processing module" (MPM) in working memory (Ockelford, 2007b; see also Fodor, 1983; Peretz and Hyde, 2003; Peretz and Coltheart, 2003; Pring, Woolf and Tadic, 2008; Tillmann, Schulze and Foxton, 2009; Williamson, Mitchell, Hitch and Baddeley, 2010) whose primary input on this occasion was the auditory information deriving from the recording of *Chromatic Blues* and whose secondary input comprised Derek's memories of fragments and features from other pieces. The two outputs were the imagined auditory trace of Trial 1 and the necessary motor instructions to realize this on the keyboard. (Just how the motor output functioned, and how this and the auditory output interrelated are major topics in themselves, and beyond the scope of this book.) From Trial 1, we can surmise that the two guiding principles under which the music processing module operated were:

1 to produce something that made "musical sense";

2 to produce something that resembled, as far as possible, *Chromatic Blues*.

In the case of potential incompatibility, the evidence of Trial 1 indicates that (1) would take precedence over (2).

These general principles can be deconstructed to provide a more detailed understanding of the cognitive processes that we may hypothesize to have occurred. As we observed above, zygonic theory holds that a necessary condition for music to make sense is that every feature of each perceived sonic event should be related to another or others, such that each is felt to derive from or generate at least one other through imitation. Even this apparently stringent condition is not sufficient to guarantee immediate musical comprehensibility, however. For that, the relationships between simultaneous and successive events in the domains of pitch and perceived time and, in some instances, the relationships between these have also to be derived from other pieces and be capable of anticipation according to the probability of their past occurrence (see Chapter 8; see Huron, 2006; Ockelford, 2008b; Thorpe *et al*., 2012). My analysis of the first movement of Mozart's piano sonata in B♭ K. 333, summarized in Chapter 2, illustrates this principle in action in what can be taken to be a broadly representative piece from the "common practice" period of Western tonal classical music (Ockelford, 1999, pp. 704ff.). Here, it is shown that at any given point around 40 forms of zygonic structure are likely to be present, variously involving pitches, harmonies, and melodic and harmonic intervals; durations and inter-onset intervals; transition probabilities; tonal and metrical frameworks; etc. It is further postulated that this supersaturation with repetition is both typical and necessary for pieces to be readily comprehensible, implying that a similarly high level of "background" organization was a prerequisite for coherence in whatever music Derek improvised.

This suggests that the MPM, which is proposed to be central to musical imagination and creativity, must at its core be wired with neurological correlates of the fundamental zygonic process of derivation through imitation. Indeed, the universal predisposition of very young infants to replicate and transform their mothers' vocal patterns through the principle of "communicative musicality" (Malloch and Trevarthen, 2008) suggests that this aspect of brain architecture is fundamental to human musical design. For sure, the surface features (the musical "content") of what children produce may become increasingly culturally colored as they move through their early years [for example, the "potpourri" songs, comprising familiar musical fragments, that children spontaneously create around the age of 3—see Moog (1976) and Hargreaves (1986)—will inevitably vary according to their musical exposure], but the basic structural principles underlying

the music they create—the music that we *all* create—appear to be universal (Sloboda, 1985/2004, pp. 154, 259; Ockelford, 2012d).

In my view, what makes the *Chromatic Blues* study and other work with Derek of more than passing and idiosyncratic interest is the likelihood that his MPM is, in broad functional terms, the same as everybody else's. After all, what is his Trial 1, if not a sophisticated "pot pourri" song for keyboard? And the capacity to take fragments and features from whatever music is "in the air" and modify them so that they fit with the informal vocal improvisation of the moment seems to be commonplace. For example, Fig. 7.14 shows the transcription of a spontaneous attempt to sing "Happy Birthday" by my son, Tom, at the age of 3 years and 9 months. He misjudges the shape of the first phrase—overshooting the initial leap—but then modifies the second phrase with the same degree of "error" in order to maintain the rising pattern of pitch that leads the ear to the highest note of the piece, which occurs early in the third phrase.

So, just as Derek's musical mind must have calculated that, by starting the second phrase of his rendition with D5 and C5 (see Fig. 7.4), he was committing a surface "error" in order to maintain the deeper-level connection between the opening phrases, so Tom's hypothesized MPM must similarly have preferred to adhere to structure rather than content in modifying the second phrase of *Happy Birthday* to follow logically from the first. That is, what apparently makes Derek's MPM "different" is not the essence of what it enables him to do, but the fact that his exceptional perceptual abilities (see Chapter 6) potentially afford him more complex, multidimensional musical material to work with than most people are able to process. In addition, Derek's capacity to play the keyboard by ear means that he can subsequently realize in sound ideas that are more wide-ranging in pitch than the voice alone could manage (which is the only form of external melodic musical expression open to most people), including the production of harmonies. All these things mean that Derek's paths of creativity may be richer—more vivid—than those that most of us

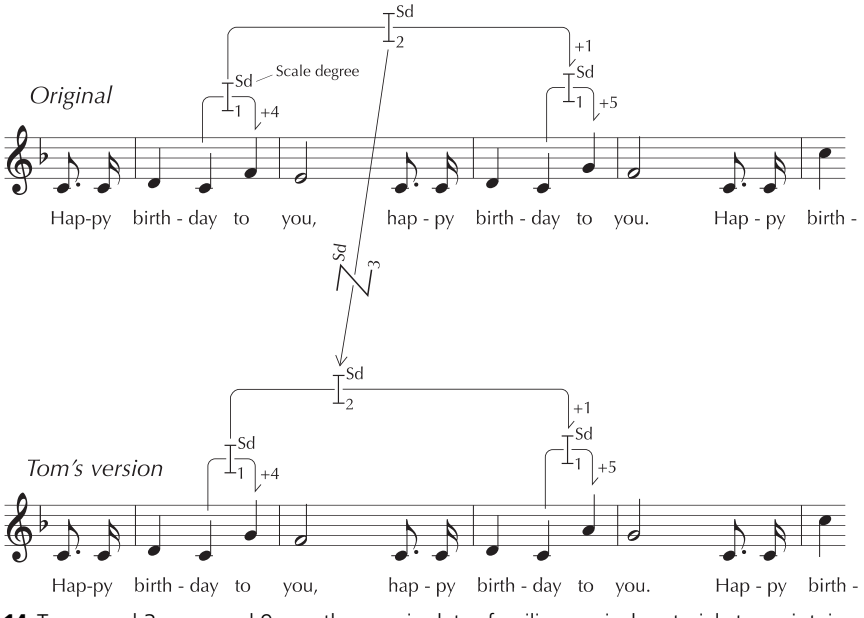


Fig. 7.14 Tom, aged 3 years and 9 months, manipulates familiar musical materials to maintain coherence in a vocal improvisation.

could tread, with the more limited auditory means at our disposal, but (to repeat the point made earlier) his perambulations in the musical landscape seem to be of a type that we can all typically make.

What, then, are the characteristics of an MPM? The evidence from the *Chromatic Blues* study suggests that the key functions include the capacity to do the following.

1 Acquire and store musical fragments and features of varying types in readiness for use—both from immediate perceptual input and from the memory traces that are stimulated by what is heard.
2 Establish (with varying degrees of potential sophistication) a multidimensional style system that is congruent with the features of new and remembered elements.
3 Select fragments or features from the available "bank" that would fit with each other—albeit with modification—within the evolving style system.
4 Transform these fragments and features as necessary, through the addition, deletion, or modification of material.
5 Synthesize the selected elements, integrating them "horizontally" (melodically) and, in the case of some instruments, "vertically" (harmonically) within the unfolding matrix of pitch and perceived time.
6 Potentially create new material within the style system, as required, to provide links between given material, to fill potential gaps and to ensure coherence.
7 [in the case of skilled improvisers] Track and direct the musical narrative simultaneously at different architectonic and hierarchical levels to ensure both short- and longer-term coherence.

Remarkably, this synthesis of schematic and veridical forces must all occur in "real time" as an improvisation proceeds, and, in Derek's case, it appears to have taken place quite unwittingly, with no conscious intervention; certainly, throughout the *Chromatic Blues* study, after each session Derek was unable to reflect upon what he had done (just as most people, unthinkingly whistling or humming a half-remembered tune, are unable to do).

A visual representation and summary of the MPM model imagined to operate in relation to Trial 1 is shown in Fig. 7.15. This also shows how the musicological (zygonic) analysis connects to assumptions in the psychological domain, an important conceptual feature of "applied musicology."

The second *Chromatic Blues* session took place 2 days after the first and began with Derek being asked to play the piece as well as he could, given what he could remember. What sources of material were potentially open to Derek to draw on at this point? As the color plate shows (Fig. 7.20), there were the two hearings of *Chromatic Blues* from the first session, the music from Derek's own Trial 1, and traces of other pieces that either of these may have stimulated. We had anticipated that Derek would produce something that resembled *Chromatic Blues* with a similar derivation index to Trial 1 (0.31). This expectation was only partly fulfilled, however. Derek's Trial 2 is shown in Fig. 7.5. It is constructed over a two-bar bass pattern that appears 15 times, followed somewhat abruptly by a coda of three bars, and giving prominence throughout to an ascending triplet figure in the right hand that appears first in bar 2 and on eight further occasions. Trial 2 has a derivation index from *Chromatic Blues* (based on the five excerpts shown in Fig. 7.3) of only 0.18: while the key of the original (F major), the meter (♪) and, in round terms, the tempo (♩ = 115 as opposed to the ♩ = 100 of the original) are reproduced, there is very little detailed resemblance to the original, with the exception of the dotted rhythm in the bassline and the concluding triplets.

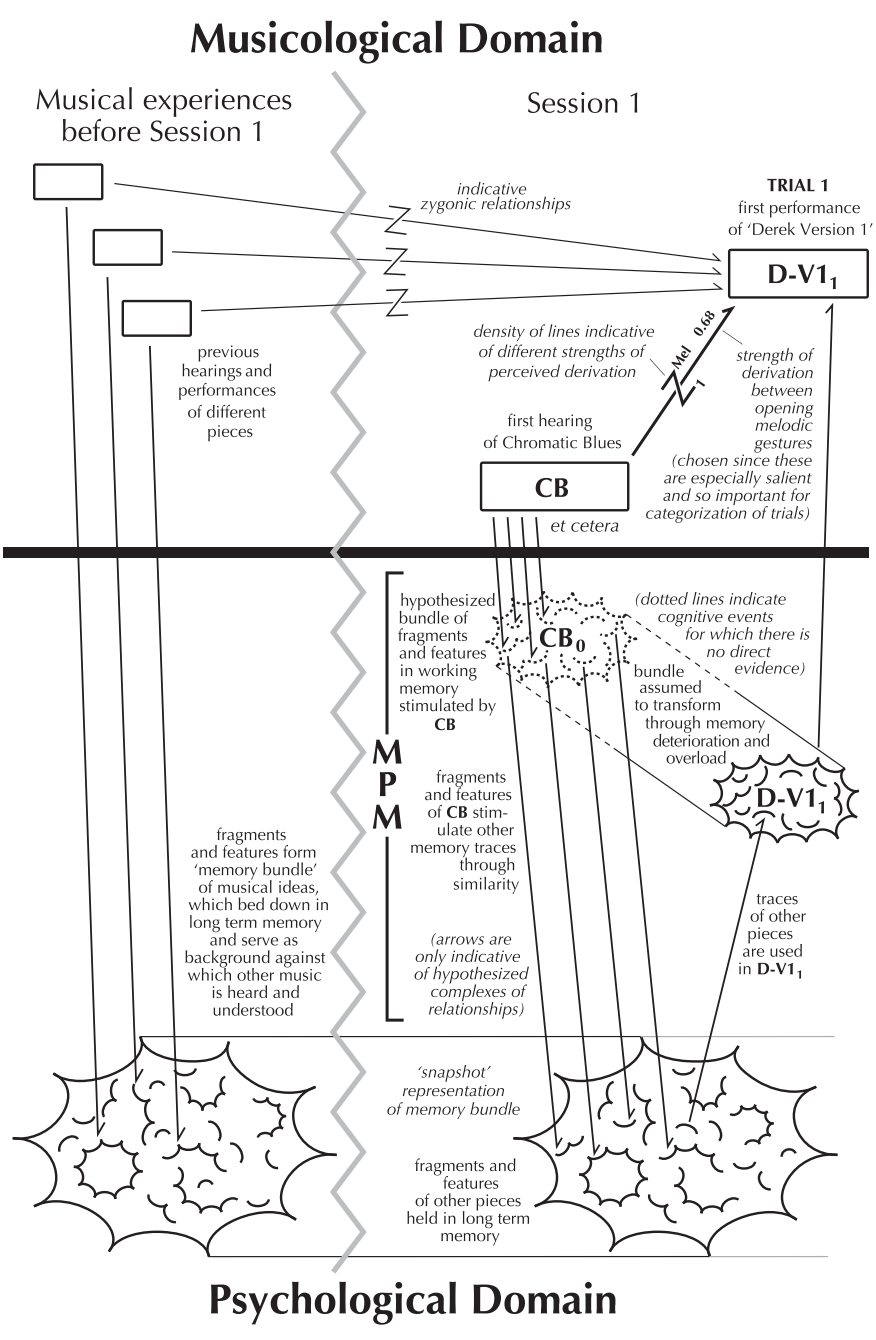


Fig. 7.15 Musicological analysis of Derek's Trial 1 leads to the psychological hypothesis of a "music processing module" ("MPM") in working memory.

An indicative zygonic analysis of the first two bars illustrates the potential derivation of material from the opening of *Chromatic Blues* and Trial 1, as well as possible borrowing from *Organ Grinder Blues* by Clarence Williams—a piece with which Derek was known to be very familiar. Specifically, in accordance with Prediction (viii), it is suggested that the initial bass motif in *Chromatic Blues* (and Trial 1) may have stimulated a memory trace of an almost identical figure that occurs at the beginning of *Organ Grinder Blues*, which in turn gave access to other features of the piece, notably an ascending triplet figure in the right hand which first occurs in bar 7 (see Fig. 7.16). This accords with Bartlett's observation (Clause 6) that, in long-term recall, there may be importation or invention.

Session 2 continued with Derek hearing *Chromatic Blues* once more, and again being asked to play what he could remember. His efforts (Trial 3), shown in Fig. 7.17, came as a considerable surprise, since we had anticipated that he would produce a piece that in derivational terms lay somewhere between Trial 2 and the original *Chromatic Blues*. In fact, Derek came up with something that most closely resembled Trial 1, taking the first phrase as a starting point and using it to create a four-section musical structure of the form $A_{1.1}$ $A_{1.2}$ $A_{1.3}$ $A_{1.4}$. Tonally, this trial has a single substantive modulation, to the subdominant (B♭ major), that occurs in $A_{1.3}$, emulating the same transition found towards the end of Trial 1. There is a hint too in bars 13–14 of the chromatic transition found in bar 8 of *Chromatic Blues*. These features notwithstanding, it is in the initial melodic gesture of each trial that the musical identity of Derek's renditions is principally vested, and the ZYG values relating these to the opening of *Chromatic Blues* are presented in Table 7.3.

The data in Table 7.3 show that the opening melody of Derek's Trial 1 is quite closely based on that of *Chromatic Blues* (ZYG = 0.68), while the equivalent connection with Trial 2 is far weaker (0.11). The comparable links between Trials 1 and 2, and between Trials 2 and 3 are also tenuous (0.17 and 0.14, respectively). However, the opening of Trial 3 is, again, quite strongly derived from that of *Chromatic Blues* (0.63), but to an even greater extent from the initial melody of Trial 1 (0.75). Hence it is reasonable to categorize these renditions as follows (see Fig. 7.5), where D-V1 and D-V2 stand for Derek's version 1 and Derek's version 2, respectively. That is to say, it appeared at this stage that Derek had two discrete "bundles" associated with *Chromatic Blues* in his long-term memory, either of which could input into his MPM. This impression was reinforced in Session 3 (5 days later), when Derek opened proceedings with a rendition (Trial 4), shown in Figure 7.18, whose opening bars derived from Trial 2 with ZYG = 0.95.

Figure 7.18 and the data shown in Table 7.4 suggest that, in the first four trials, the two memory bundles D-V1 and D-V2 were more potent forces in Derek's reproductions than the original *Chromatic Blues*, indicative of a high level interference (Prediction x). However, after hearing the piece for the fifth time, something remarkable happened (see Fig. 7.6). Derek began as though he were going to produce a further rendition of D-V1, with the melody rising up to D5, but after three beats, there is—very unusually for him—an audible hesitation in his playing as he switches to a different version of the tune that closely resembles the opening of *Chromatic Blues*, which sinks back to C4. For the first time in this study, it seems that Derek's desire for accurate recall overwhelmed his inclination to produce music that made sense, and we can hypothesize that, as, in his mind, he crossed the threshold between one memory bundle pertaining to *Chromatic Blues* and another, his MPM was unable to paper over the crack that opened up in the musical narrative as a result. Ironically, it is this very failure in musical syntax that sheds particular light on Derek's mental processing, enabling us to surmise two features of his cognitive activity in relation to the *Chromatic Blues* study.

First, it appears that that an "authentic" version of *Chromatic Blues*, D-CB, was evolving tacitly in Derek's mind prior to Trial 5, in which it appeared for the first time, spontaneously, in more or

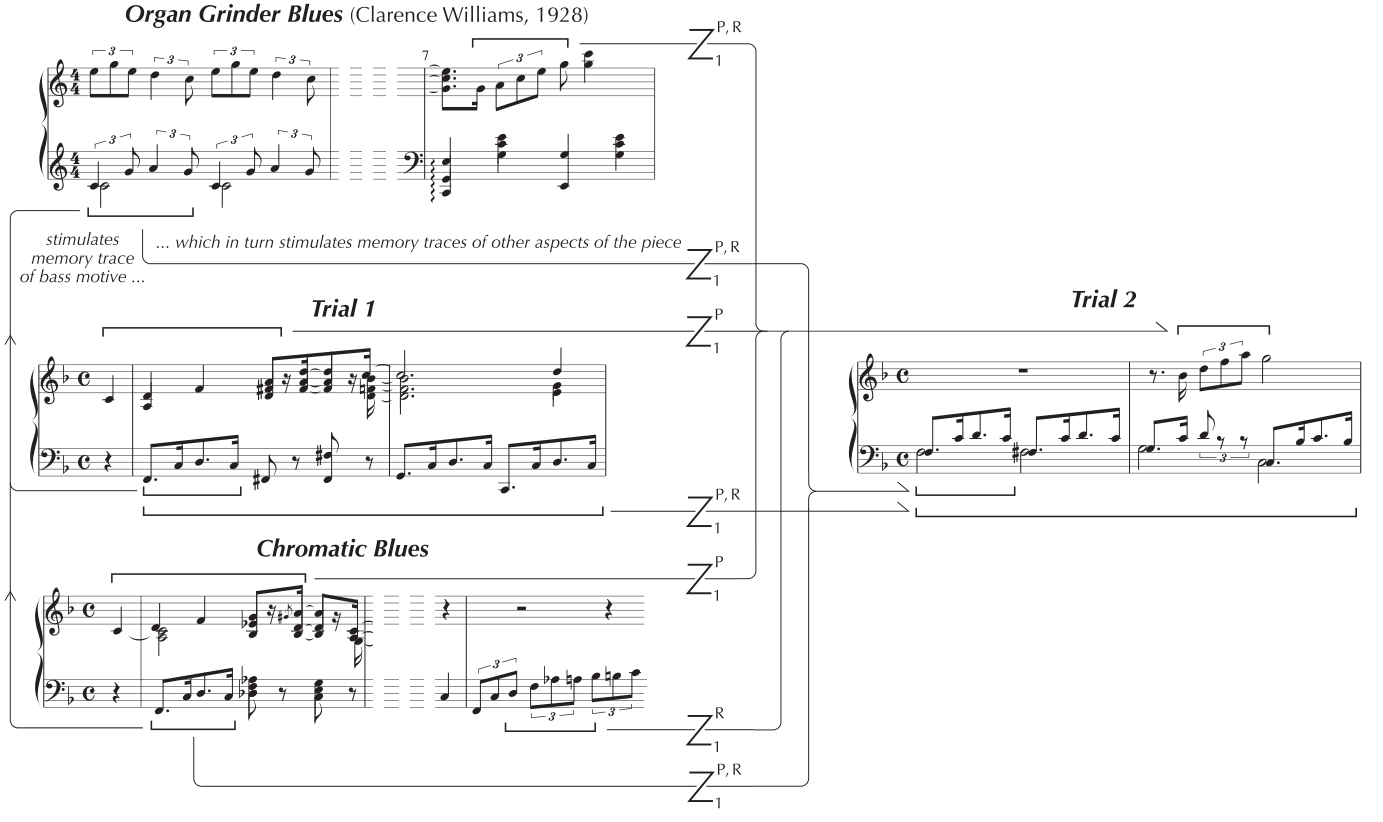


Fig. 7.16 The putative derivation of material in Trial 2 from a motif in *Organ Grinder Blues*.

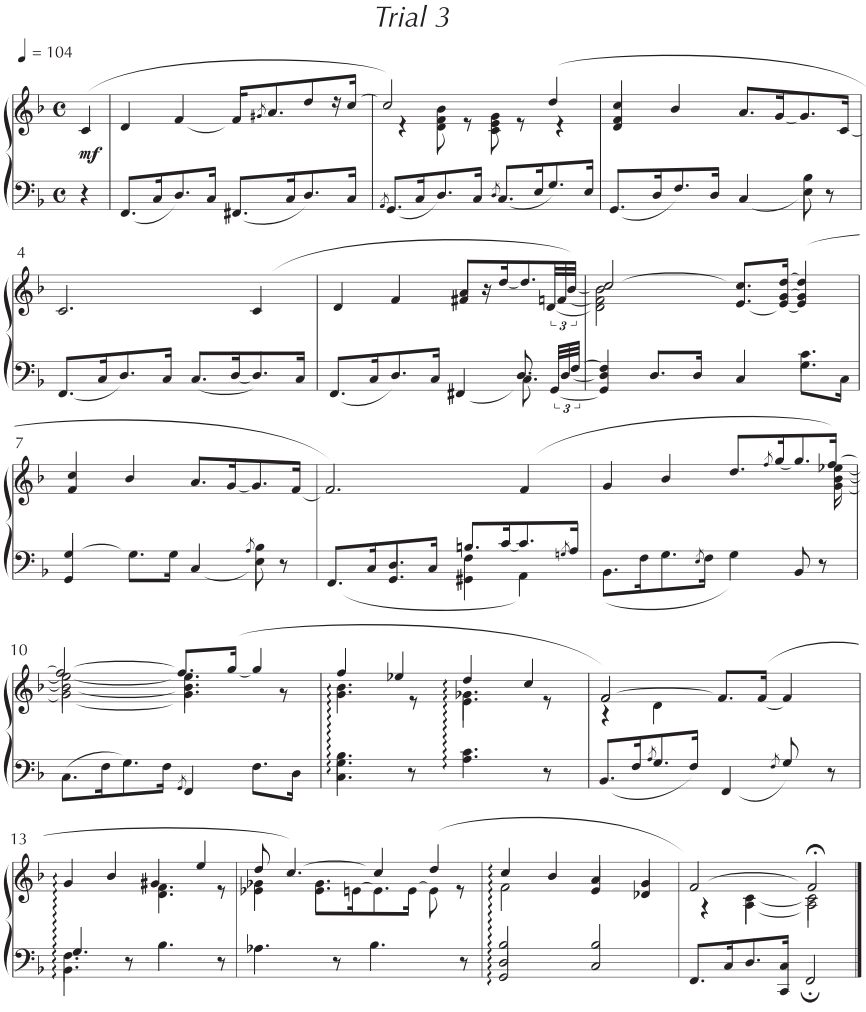



Fig. 7.17 Derek's 3rd rendition of *Chromatic Blues*.

Table 7.3 ZYG values pertaining to the opening melody of Derek's Trials 1, 2, and 3 of *Chromatic Blues*

		ZYG values of . . .		
		Trial 1	**Trial 2**	**Trial 3**
from . . .	*Chromatic Blues*	0.68	0.11	0.63
	Trial 1	–	0.17	0.75
	Trial 2	–	–	0.14

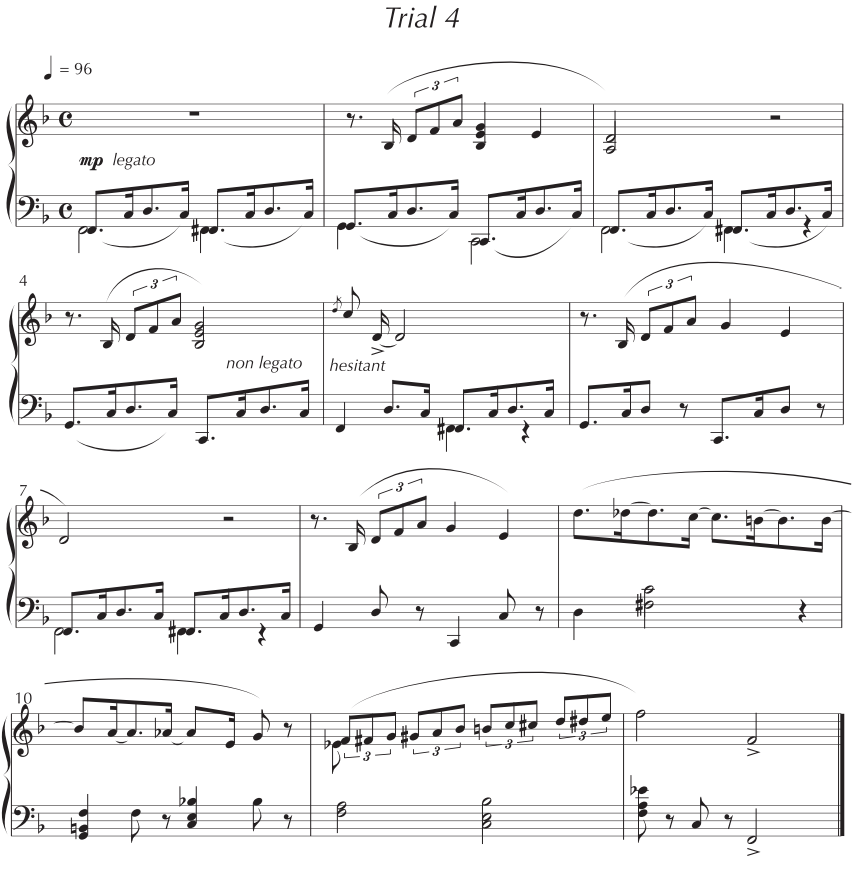



Fig. 7.18 Derek's 4th rendition of *Chromatic Blues*.

Table 7.4 Derek's two versions of *Chromatic Blues* as they appeared in Trials 1 and 2

	Version 1	**Version 2**
Trial 1	D-V1$_1$	–
Trial 2	–	D-V2$_1$
Trial 3	D-V1$_2$	–

less complete form (ZYG = 0.41). This compares with ZYG scores of 0.18, 0.18, and 0.19 for the previous three attempts. Second, we can surmise that D-V1 continued to exist in his memory after Trial 5 as a discrete bundle of ideas (though for how long we do not know, since Derek never chose to access it again). But what of D-V2? This next appeared in Trial 7, in the second part of Session 4. The preceding Trial 6 had been straightforward enough: a further version of D-CB with a derivation index of 0.49 (see Fig. 7.19). But Trial 7 was extraordinary. The initial four bars are virtually identical to those that open Trial 4 (Fig. 7.18), and so constitute a third appearance of D–V2; yet the music breaks off prematurely and, in retrospect, is heard to function merely as an introduction to what is by far the most accurate rendition of D-CB to date (ZYG = 0.69)—an improvement of over 40%. This accords with Prediction (xii), that improvement would sometimes occur in

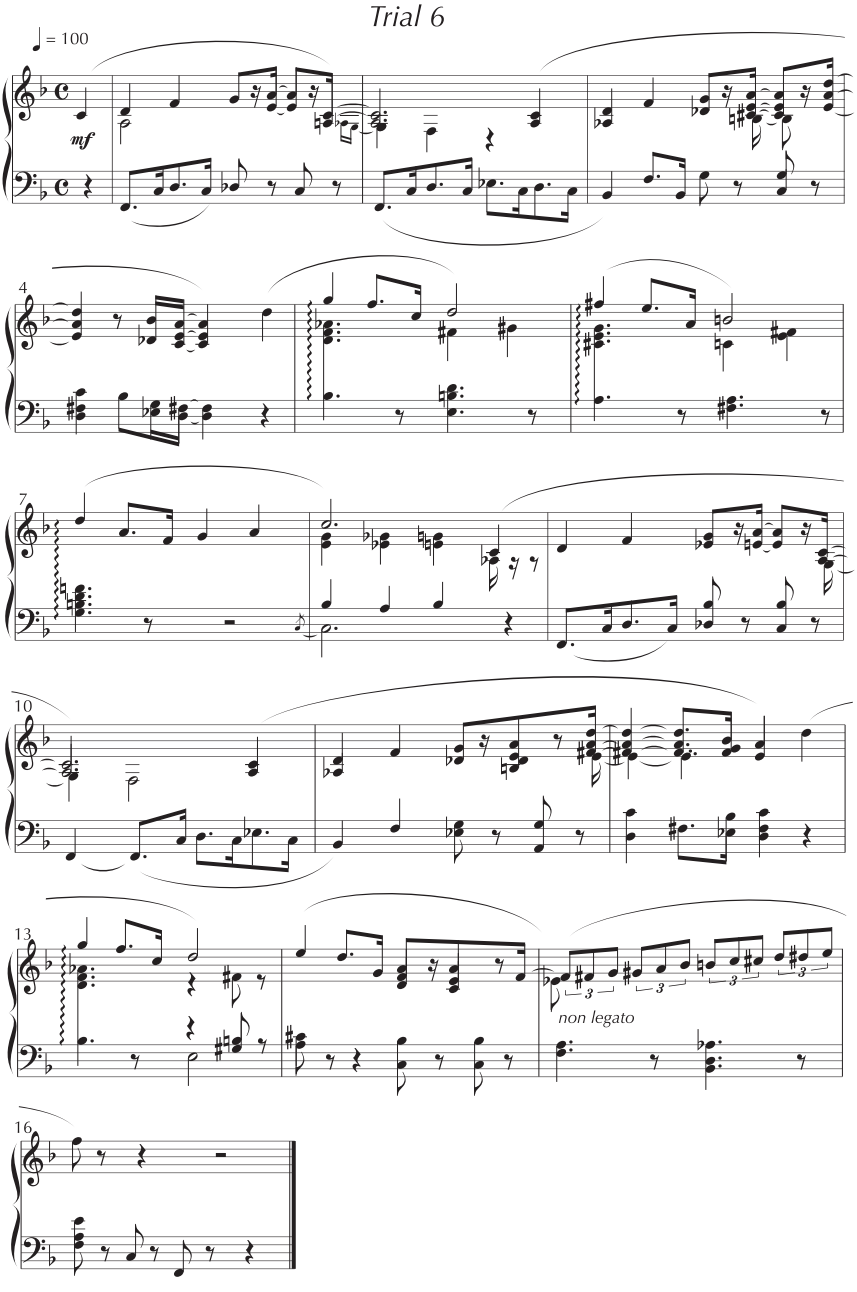



Fig. 7.19 Derek's 6th rendition of *Chromatic Blues*.

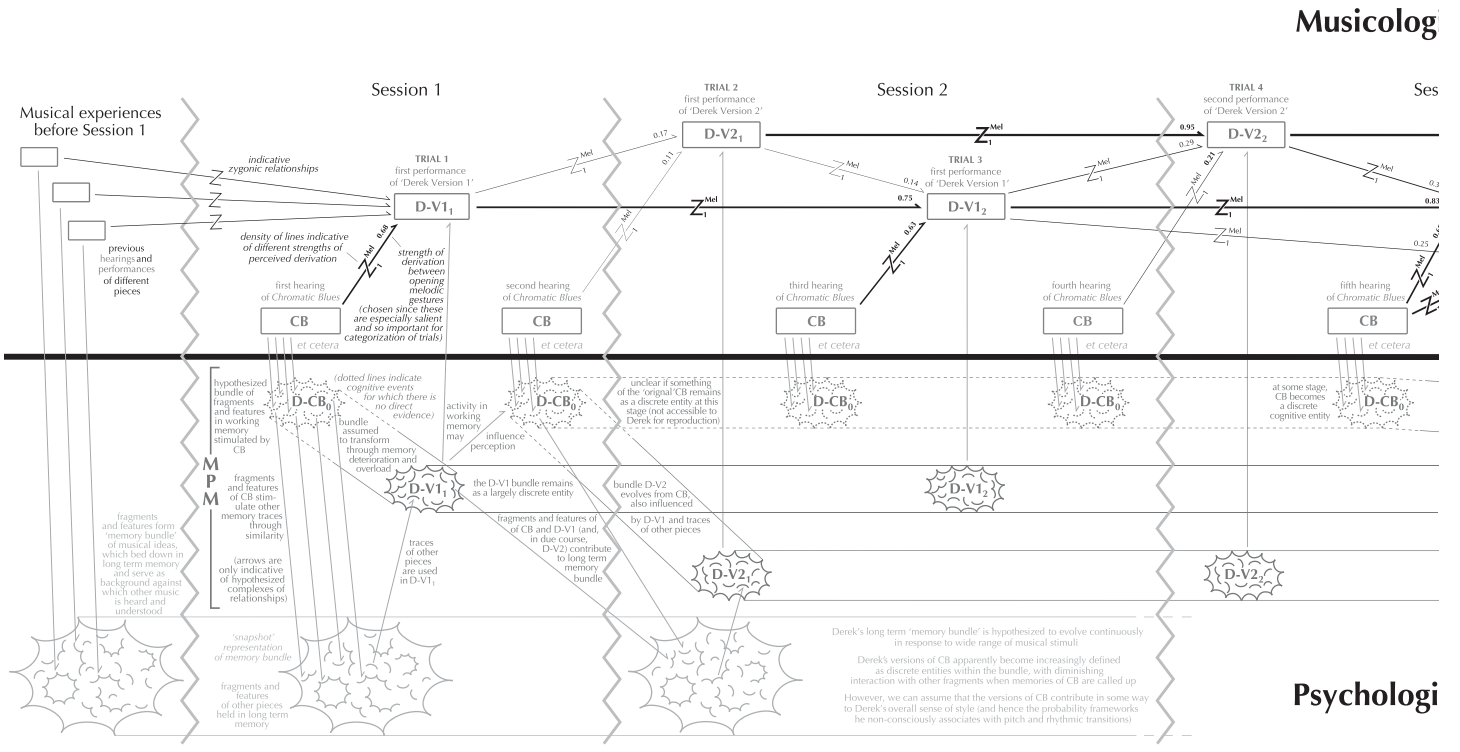


Fig. 7.20 Sessions 1–6 modeled in the musicological and psychological domains. See colour plate section for larger full colour image.

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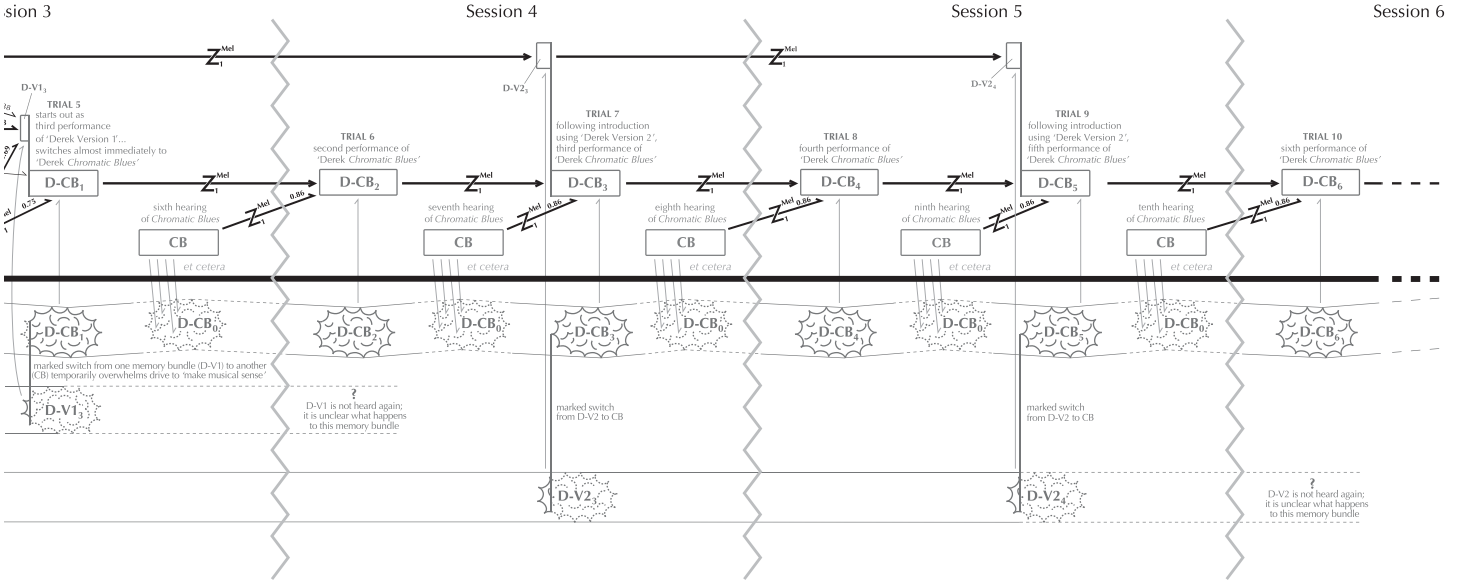

cal Domain

Fig. 7.20 (part ii) (continued).

discrete steps as substantial chunks of music that were incorrect were replaced with authentic material. Overall, the impression one gets is of Derek enjoying himself, unable to resist playing with the materials at his disposal, turning them over in his mind, and reconfiguring them in a way that at once sheds new light on the relationship between D-V2 and *Chromatic Blues* and creates a new entity, musically convincing in its own right (see Fig. 7.7).

These examples illustrate just how complex learning music by ear can be, and how a key function of creativity in this context, at least as far as Derek is concerned, appears to be to serve as the metaphorical glue to fix the imperfect (and sometimes concealed) shards of memory together in ways that make sense. As one with advanced improvisational skills, Derek has evidently taken a further step, and is able to manipulate his "creative glue" in order to assemble musical fragments in novel ways—purely, it seems, for his own and others' amusement.[12]

Trials 8 and 9 (in Session 5) are similar to 6 and 7, both quantitatively, as gauged by the ZYG function (0.64 and 0.69, respectively), and qualitatively, in that Trial 8 is a more or less straightforward rendition of *Chromatic Blues* in terms of content and structure, whereas Trial 9 re-establishes the introduction that Derek used in Trial 7, despite having just heard *Chromatic Blues*. Following this session, there was a break of a month, and the introduction was never heard again.

Using these qualitative accounts and the ZYG values pertaining to the opening melodic motifs as proxy indicators of the identities of the renditions as a whole, it is possible to extend the model shown in Fig. 7.15 to illustrate how zygonic analyses undertaken in the musicological domain can underpin hypothesis-building in the psychological domain over the first five sessions of the *Chromatic Blues* study (see Fig. 7.20). There are two points to note here in relation to Bartlett's observations. First, with regard to his Clause 2, Derek's versions, D-V1 and D-V2, do show a remarkable resilience, as he persists with them despite hearing *Chromatic Blues* in its original form 10 times before they finally disappear completely. Second, with respect to Clause 4, there is remarkable stability between different presentations of the same version, which display an apparent inertia to change. In summary, the biggest improvements that occur are *between* versions rather than *within* them. An account of how the relationships between trials compare with patterns of derivation that exist between trials and the original *Chromatic Blues* over all 14 sessions is given later in this chapter.

When we set up the *Chromatic Blues* study we had anticipated that Sessions 1 to 10 would constitute the main learning period for Derek and that the sessions thereafter, at periods of 3, 6, 12, and 24 months, would largely test long-term recall. In the first trial of each of these later sessions (when Derek would not have heard *Chromatic Blues* or attempted to play it for some time), we thought, in accordance with Bartlett's Clause 5, that there may well be some omission of detail or simplification of events and structure. However, as the data presented in Fig. 7.21 show, this not what happened.

Following 1 month's break, in Trial 10 Derek produced his most accurate rendition up to that point (ZYG = 0.74), an improvement of over 7% on his previous highest score (ZYG = 0.69). The increase was largely attributable to the pitch content of the inner parts of Excerpt 3, where there was an advance of over 30% (from ZYG(P) = 0.54 to ZYG(P) = 0.71), and progress in almost all elements of Excerpt 4, from ZYG = 0.66 to ZYG = 0.81, a rise of almost 23%. So, in the 25 days in which Derek had not attempted to play *Chromatic Blues*, or even consciously thought about it as far as we are aware (by all accounts, it was not a topic of conversation), consolidation of his memory of the piece was apparently occurring in the cognitive "background." The changes,

[12] Derek always plays *for* whoever is listening (in this case, Katherine Woolf, the research assistant and me), often seeking their approbation after playing a piece.

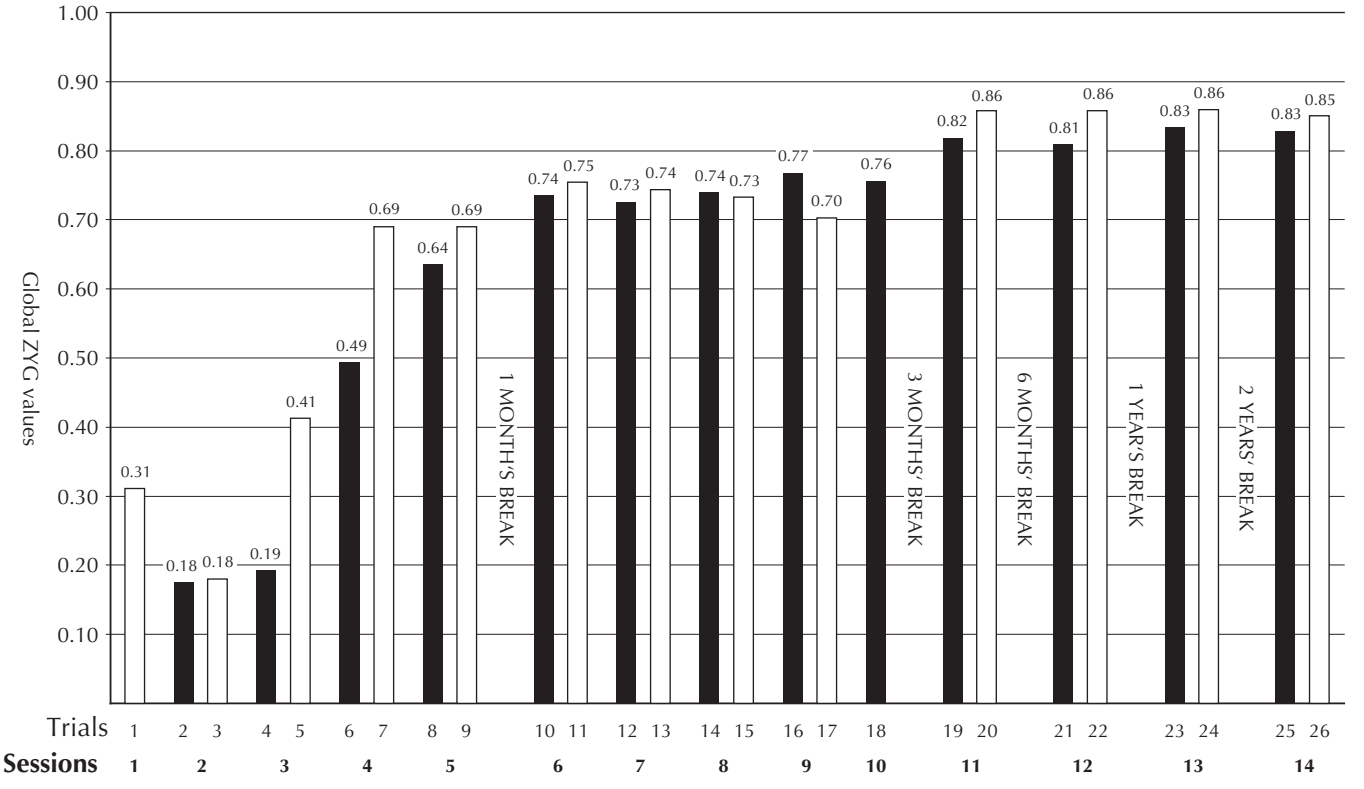

Fig. 7.21 Global ZYG values pertaining to all of Derek's attempts to remember and play *Chromatic Blues*.

although marked, were of the incremental variety anticipated in Prediction (xi): the content and structure of Trials 9 and 10 were in essence the "same thing", but those pertaining to the latter were refined somewhat to become more faithful to the original *Chromatic Blues* material.

Trial 10, with the following eight trials (11–18), which occurred over the following 2 weeks (Sessions 6–10), produced consistent global derivation results ($M = 0.74$, $SD = 0.02$), with no tendency to change. There then followed an extended break of 96 days (around 3 months), and, in Trial 19, a further pronounced shift occurred, from ZYG = 0.76 to 0.82, an improvement of around 8%. Again, this appears to mark a non-conscious consolidation, away from the keyboard, of memories of *Chromatic Blues* on Derek's part. The main factor in the rise is a movement from ZYG = 0.51 to 0.79 (a 55% increase) in Excerpt 5, with change in ZYG(R) from 0.62 to 0.84 (35%) and a surge in ZYG(P) from 0.41 to 0.75 (a growth of 83%).

What are we to make of these findings? Are they reflective of a form of cognitive processing that is peculiar to Derek, or to musical savants, or to musicians with AP in general, for example? Or are the results due to the particular nature of the memorization task or specific to the design of *Chromatic Blues*? Some evidence that the latter might *not* be the case is presented in relation to S's data discussed later. With regard to the former, there is little in the music-psychological literature that offers clarification. A small body of research on "mental rehearsal"—defined by Christopher Connolly and Aaron Williamon (2004, p. 224) and Harald Jørgensen (2004, p. 92) as the "cognitive or imaginary rehearsal of a physical skill without overt muscular movement"—dates back to Grace Rubin-Rabson's studies in memorizing piano music (for example, Rubin-Rabson, 1941) and extends to more recent work by Stewart Ross (1985) and Don Coffman (1990). Although the findings across the literature as a whole are inconsistent with regard to the benefits of "silent practice," the three studies cited provide support for the notion that combining physical and mental rehearsal can have a positive impact on musical learning. However, Derek's position is rather different, in that he was not, as far as we are able to tell, consciously attempting to rehearse between sessions. Moreover, unlike the subjects of the mental rehearsal research that has been undertaken, he did not have access to a visual stimulus (the score) to help him. All he had were his apparently imperfect memories whose manifestation in performance somehow improved by themselves, without overt practice, over time.

A similar phenomenon was observed by Géza Révész (1924/1971, p. 94) in relation to the prodigy Erwin Nyíregyházi, who had AP (and was alluded to earlier in relation to chordal disaggregation; see p. 186):

> It has been observed that a series of impressions are better and more firmly retained in the memory after a certain period has elapsed than directly after their assimilation. In the case of Erwin, I frequently had occasion to observe that a day or two after having learnt a certain musical piece he was able to reproduce it with greater exactitude than on the day on which he learned it.

What does this account, and the *Chromatic Blues* data pertaining to Derek, tell us about musical memory? It appears that he (Derek) and Erwin had captured the information needed to produce more accurate representations of a piece than they had physically managed to realize. Was it that separate memory traces, processed initially by the MPM, became integrated over time in long-term memory, and therefore came to be accessible *en bloc*? Or was it the case that potential conflicts with extant fingering schemata and (in Derek's case) a new auditory stimulus became resolved through non-conscious "mental rehearsal"? Clearly, further research is required to shed more light on these issues, and this is under way by my postgraduate students Annamaria Mazzeschi and Ruth Peskett.

Trials 21, 23, and 25 occurred after intervals of 6 months, 1 year, and 2 years, respectively, which together with Trial 19, and Derek's attempts directly following re-hearings of *Chromatic Blues*

(Trials 20, 22, 24, and 26), have global ZYG values that are remarkably consistent ($M = 0.84$, $SD = 0.02$). Again, this challenges Bartlett's Clause 5, which suggests that, over time, there is likely to be loss of detail, or even the metamorphosis of material into more generic (archetypal) forms. For sure, Bartlett's subjects did not attempt to learn their stimulus (a short story) with complete fidelity; and Derek (unlike Bartlett's research participants, who only had the opportunity to read their passage through twice) had fresh access to *Chromatic Blues* in the course of sessions following each of his initial attempts. However, the improvements between Derek's "pre-hearing" and "post-hearing" trials tended to be small, particularly after the initial learning phase in which three different versions of the piece appeared in rotation (mean ZYG = 0.01)—indeed, there are even cases where Derek's performance is *worse* following a re-hearing (Trials 15 and 17)—suggesting that being exposed to the material again had little, if any, positive impact.

One could argue, of course, that, as far as advanced pianists working in the Western classical, jazz, and popular traditions are concerned, Derek's memory skills represent the norm rather than the exception, since, when working as soloists, all tend to perform from memory, with some reputed to have large repertoires available at short notice (for example, Arthur Rubinstein; see Sachs, 1995, pp. 67, 68). It is not clear, however, how many advanced (though more "typical") pianists would be willing to perform a piece after a break of 2 years with no access to a score, and, if they did, how accurate their renditions would be. The small amount of research that has been undertaken in this area to date (for example, by Jane Ginsborg and Roger Chaffin, p. 244) suggests, like Bartlett (Clause 5), that, over time omissions, simplifications and mutations to material that is more stylistically typical will occur. For instance, in reporting her own recall of *Ricercar I*, "The maidens came," for solo soprano and ensemble from Stravinsky's *Cantata* (1952), Ginsborg states that her efforts to write out the soprano part, which she had memorized for performance, declined in accuracy from 97.1 to 66.4% some 4 years later. The main errors were the omission of whole sections and rhythmic transformation.

In summary, then (see Fig. 7.21), Derek's recall of *Chromatic Blues* can be understood to exist in five "phases" (Table 7.5). As well as offering a perspective on Derek's global pattern of recall, the ZYG measure enables us to probe the trends within and differences between elements of *Chromatic Blues*: "horizontal" strands in the texture (comprising top, inner, and bottom parts), "vertical" chunks (in the form of Excerpts 1–5), and the two pervasive features, pitch and rhythm. The complete data set appears in Appendix 1; here we will summarize some of the key findings.

Table 7.6 sets out the data pertaining to Derek's recall of *Chromatic Blues* at the highest level, integrating 8914 judgments pertaining to relationships between the stimulus and Derek's 26 attempts to replicate it, of which 5739 (64%) were deemed to function zygonically.

Table 7.5 General trends in Derek's recall of *Chromatic Blues*

Phase	Sessions	Trials	Description	Mean ZYG	*SD*
1	1	1	Initial attempt	0.31	0.00
2	2 and 3	2–4	Multiple versions	0.18	0.01
3	3–5	5–9	Rapid improvement	0.58	0.13
Consolidation					
4	6–10	10–18	Plateau 1	0.74	0.02
Consolidation					
5	11–14	19–26	Plateau 2	0.84	0.02

Table 7.6 Summary of Derek's recall of *Chromatic Blues*

Description	**Total number of potential relationships**	**Total number of zygons of rhythm**	**Zygonicity of rhythm**	**Total number of zygons of pitch**	**Zygonicity of pitch**	**Total number of zygonic relationships**	**Global zygonicity**
Formula	#Rel(R or P)	#Z(R)	$ZYG(R) = \frac{\#Z(R)}{\#Rel(R)}$	#Z(P)	$ZYG(P) = \frac{\#Z(P)}{\#Rel(P)}$	#Z(Rel) = #Z(R) + #Z(P)	$ZYG = \frac{\#Z(Rel)}{\#Rel \times 2}$
Melody	1304	1054	0.81	914.5	0.70	1968.5	0.75
Inner parts	1992	998.5	0.50	1113	0.56	2111.5	0.53
Bassline	1161	821.5	0.71	837.5	0.72	1659	0.71
Sums/averages	4457	2874	0.64	2865	0.64	5739	0.64

Pitch and rhythm

It is striking that, across the 130 excerpts and three textural strands that were analyzed, rhythm and pitch have identical global scores. It is difficult to get a sense from the literature of just how typical of savants this may be, since accounts of their perceptual abilities have tended to focus on the tonal rather than temporal, in line with music psychology's more general bias (noted as long ago as 1978 by John Booth Davies, p. 176). However, Derek's consistency of accomplishment in Western music's two principal dimensions does not accord with Blanche Minogue's (1923, p. 351) description of a 23-year-old male savant whose pitch discrimination was "remarkable" and his tonal memory "unusually good" while his sense of rhythm was "more variable," nor with Thomas O'Connell's report of a hyperactive 8-year-old autistic boy with absolute pitch but limited rhythmic ability (O'Connell, 1974, p. 227). In his extensive study of musical savants mentioned earlier, Leon Miller (1989, p. 109) concludes that they

> do extremely well when the task requires retention of harmonic information. On tasks involving tonal material presented sequentially, "melody like" information, they also do quite well, though their performance does not seem so exceptional. Finally, when the task omits any tonal element, the savant appears to do no better or worse than other musicians.

Why the difference from Derek? One can point to dissimilarities in the way that Miller's experiments and the *Chromatic Blues* study were conducted. For example, the former pertained to short-term memory only, and the stimuli were realized on a single pitch. The latter was a combined exercise in working and long-term memory, and used a stimulus that was rich in tonal information. However, in Derek's first attempt to reproduce the piece (Trial 1), when he was entirely reliant on working memory, rhythm was reproduced 82% more accurately than pitch in all five excerpts (mean ZYG(R) = 0.40 as opposed to 0.22)—indicative of a superiority in the perceived temporal domain that persisted (albeit less markedly) until Trial 7. Thereafter, with one exception (Trial 22), pitches were replicated more precisely (see Fig. 7.22).

There is insufficient information to say whether this early inclination towards rhythm in learning *Chromatic Blues* and Derek's subsequent proclivity for pitch is a feature of his cognitive style, or—Miller's findings notwithstanding—of musical savants in general, or of other groups of musicians more widely (cf. p. 318). We would expect the nature of the materials used for testing to be an important factor too, and analysis of Derek's performance over the 26 sessions does indeed reveal differential performance by segment: rhythmic recall was superior in Excerpts 1, 3, and 5 [mean ZYG(R) = 0.71, $SD = 0.22$; mean ZYG(P) = 0.66, $SD = 0.25$, $t(77) = 5.05$, $P < 0.0001$], while pitch was better in Excerpts 2 and 4 [mean ZYG(R) = 0.61, $SD = 0.22$; mean ZYG(P) = 0.69, $SD = 0.31$, $t(51) = 4.14$, $P = 0.0001$].

Moreover, we can speculate that the savants may have performed relatively poorly on Miller's rhythmic task (compared with percussion students) because of the artificial nature of the stimuli. Far from omitting *any* tonal element (as Miller asserts), these comprised pitches repeated on a synthesizer, which may have failed musically to engage the savants, accustomed as they would have been to the variety in pitch that keyboards offer. There is a certain artificiality, too, in conceiving pitch in isolation from rhythm, since all series of pitches necessarily have a temporal component, and, according to Hébert and Peretz (1997), who had listeners try to recognize familiar melodic stimuli whose pitches and rhythms were interchanged, optimal access to long-term memory for music resides in a combination of the two. That is, we should expect the *interaction* of pitch and rhythm in *Chromatic Blues* to impact on the way that both were encoded, and examination of the accuracy with which pitch and rhythm were reproduced over the whole 26 sessions reveals

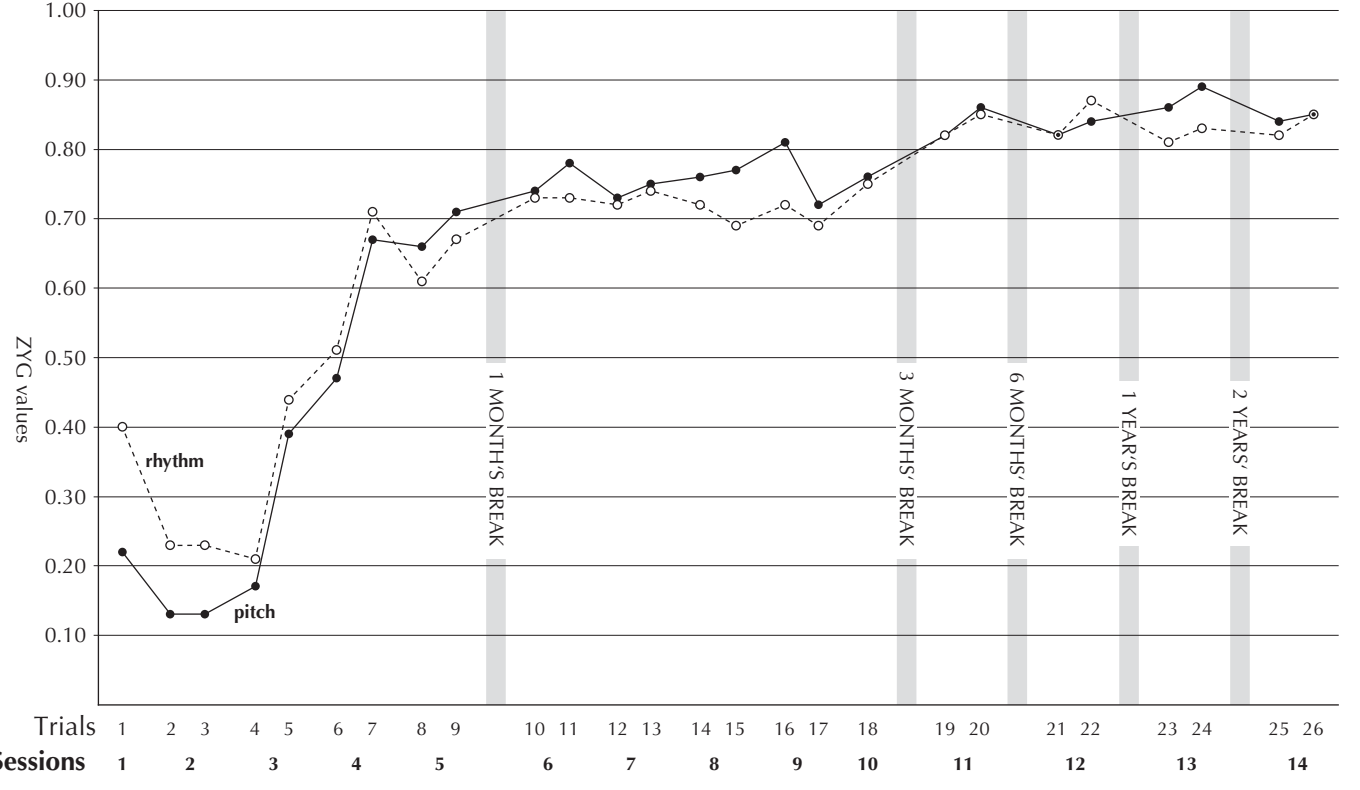

Fig. 7.22 Derek's recall of the pitch and rhythm pertaining to *Chromatic Blues* over the 26 sessions.

an extremely high correlation between the two, $R = 0.98$, $P < 0.0001$ (see Fig. 7.22). Further observations on this topic are made in relation to S's performance later.

Excerpt by excerpt

A somewhat different perspective on Derek's *Chromatic Blues* data can be obtained by considering the global ZYG values excerpt by excerpt. A within-trial one-way analysis of variance (ANOVA) shows that the variation among the segments is significant: $F(4,25) = 28.11$, $P < 0.0001$. Tukey post-hoc comparisons indicate that there is no significant difference in the accuracy with which Derek recalled Excerpts 1 and 3 (which are musically identical) or Excerpts 2 and 4 (which are transpositionally equivalent, comprising the same pattern of intervals starting at a different absolute pitch). However, the difference between all other pairs is significant, $P < 0.001$ (see Fig. 7.23).

How do we explain these differences? There are two factors that we should take into account: serial position, and the musical content and structure of the excerpts (Mishra, 2010). Dealing first with serial position, previous studies have indicated that memory for music, like verbal memory (Crowder and Greene, 2000), is influenced by serial position, with material at the beginning of a sequence (the "primacy" effect) and the end (the "recency" effect) being remembered, ceteris paribus, most accurately. For example, primacy and recency effects were found for randomized

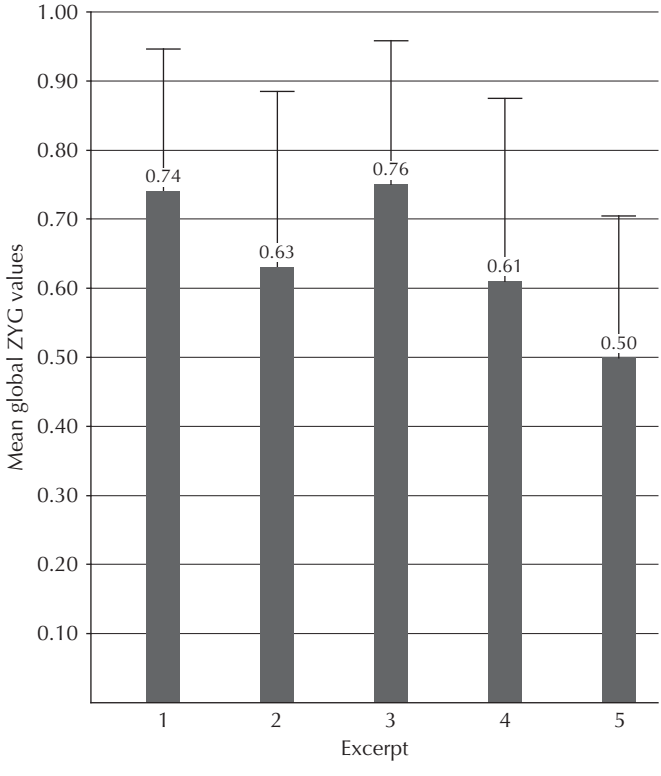

Fig. 7.23 Mean ZYG values and standard deviations for Excerpts 1–5 of Derek's attempts to recall *Chromatic Blues*.

sequences of eight pitches by Greene and Samuel (1986) and for six or seven by Williamson *et al.* (2006) (though not for shorter series). Finney and Palmer (2003) obtained a comparable result using authentic two-voice musical stimuli of 23 notes. Maylor (2002), employing complete pieces of music stored in long-term memory (hymns), showed a serial position effect in that subjects presented with the verses of a hymn in random order were able to place first and last stanzas correctly more often than middle ones. Finally, Mishra (2010) had her subjects learn a 36-bar exercise, comprising a four-bar introduction, followed by two distinct sections of 16 bars each. Participants took, on average, a little over half an hour to learn the sequence. There followed a 25-minute retention interval (involving a musical distracter task), and then the recall phase. Results showed a separate primacy and recency effect for each of the two main sections of the melody.

Clearly, Derek's position is somewhat different from all of these, in that his task involved learning and attempting to reproduce a piece of music of moderate length and considerable complexity over many months, using a protocol that involved both working and long-term memory. His global recall data, excerpt by excerpt (Fig. 7.24) could be taken to show a primacy effect, or, at least, a lack of recency effect, if Excerpts 3 and 4 (which echo Excerpts 1 and 2) are taken to "restart the structural clock."

Examining the data in relation to the five phases identified in Table 7.5 reveals a more complex position, however, in which Excerpt 5 shows an almost linear trend of improvement ($R^2 = 0.96$) in contrast to the more fluctuating paths of Excerpts 1–4, which were adversely affected by the multiple versions of *Chromatic Blues* that Derek produced in Phase 2, and afterwards improved rapidly (in Phrase 3) and then more gradually (in Phases 4 and 5). That is, the relative fidelity with which different excerpts were reproduced varied at different points in Derek's journey of learning and recall. Nonetheless, with the exception of Phase 2, the scores of pairs of Excerpts 1 and 3, and

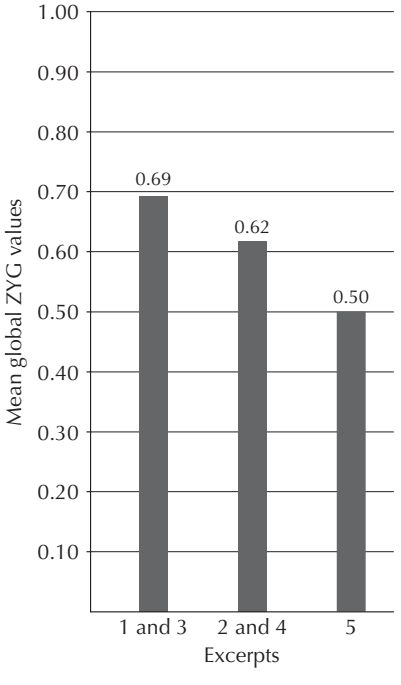

Fig. 7.24 Primacy (or lack of recency) effect in Derek's attempts to recall *Chromatic Blues*.

Table 7.7 Mean global ZYG scores by excerpt and phase

Phase	Excerpts 1 and 3	Excerpts 2 and 4	Excerpt 5
1	0.58	0.19	0.16
2	0.26	0.09	0.26
3	0.69	0.60	0.40
Consolidation			
4	0.85	0.76	0.51
Consolidation			
5	0.90	0.81	0.77

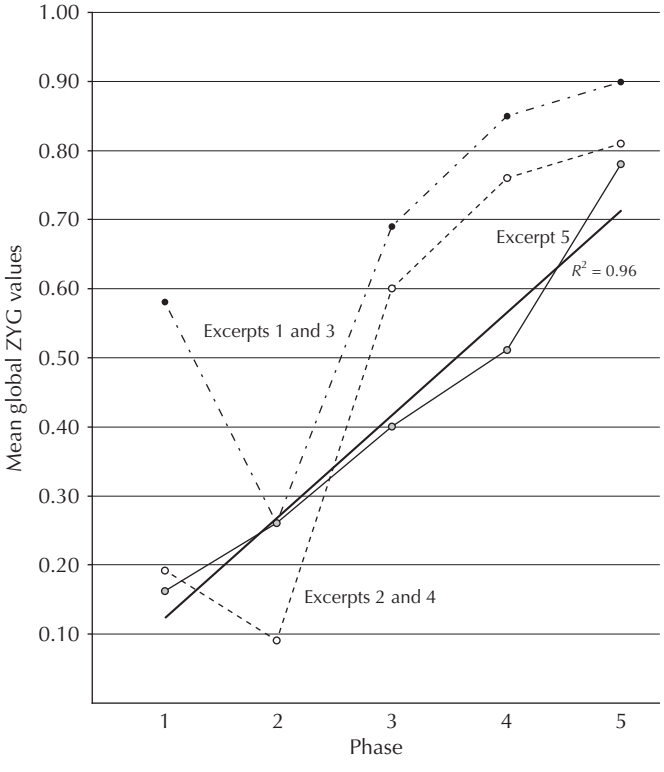

Fig. 7.25 Graphical representation of Table 7.7.

2 and 4, and Excerpt 5 retain the same ranks throughout (see Table 7.7 and Fig. 7.25). We will probe these consistent differentials by examining issues of musical content and structure, excerpt by excerpt.

Why should some excerpts be more difficult to remember than others? A number of factors may potentially play a part: internally, their size and complexity (which is related to the parsimony with which they can be encoded); and externally, their affinity (or lack of congruence)

Table 7.8 Differences in the excerpts pertaining to four features

Excerpt	1 and 3	2 and 4	5
Size (no. of notes)	30	33	27
Length (beats)	8	9	8
Average chordal density	4.13	4.56	2.38
Chromatic/diatonic ratio	0.17	0.30	0.22

with familiar material, and their salience in the contexts in which they appear (cf. Ockelford, 2009b, pp. 83, 84). As we shall see in Chapter 9, complexity is a many-faceted thing and equates, in zygonic terms, to content/structure (which, in terms of information theory, is equivalent to information/redundancy). Here, a few descriptive measures (see Table 7.8) are sufficient to show that Excerpts 2 and 4 are the longest, the most dense (in terms of simultaneous notes per beat), and have the highest ratio of "chromatic" notes (that lie outside the diatonic key framework). Excerpt 5, in contrast, comprises the fewest events, has a low chordal density (comprising, for the most part, an unaccompanied melodic line), and is moderately chromatic. Hence we could reasonably anticipate that this would be the easiest to encode and recall, while Excerpts 2 and 4 would present the greatest challenge.

So why was Derek's recall of Excerpt 5 the least successful? Perhaps Miller was right in suggesting that savants do less well in retaining melodic rather than harmonic information. Or maybe the fact that Excerpt 3 is an exact repeat of Excerpt 1 (enabling Derek to hear precisely the same musical information twice), and Excerpt 4 is a transposed version of Excerpt 2 (which meant that Derek heard the same rhythm and *intervallic* pattern twice), while Excerpt 5 stands alone, accounts for the descending difference in their ZYG scores. Clearly, this is an area where more research is needed.

Finally, in relation to excerpts, we consider the *order* in which they were presented and recalled, which is not as straightforward an issue as one may think. For example, we do not know whether Derek stored Excerpts 1 and 3 separately in his mind (a possibility, given that they fulfill two distinct musical functions within *Chromatic Blues*) or encoded them as a single memory trace that was tagged to occur at certain points in the piece. The fact that there is no significant difference between their global ZYG scores (see Fig. 7.23) offers one indication that Derek may have been using a solitary cache for both Excerpts 1 and 3, which he accessed twice in the course of each rendition. Further evidence is to be found in the early stages of the experiment, when Excerpts 1 and 3 are consistently similar *within* trials (despite their content varying considerably *between* them) (Fig. 7.26). Here the ZYG function is used *within* a realization to show the strength of derivation of one excerpt from another, as a proxy for the affinity of the hypothesized memory traces (which, as we have seen, may either have comprised a single bundle of information that varied over time, or two discrete bundles) pertaining to each.

Now, had Derek been using two discrete caches for Excerpts 1 and 3, we could arguably have expected that his memories of each would mutate, to a greater or lesser extent, in different ways, leading to noticeably different musical correlates. But this appears not to be the case. In Trials 1–5, the pairs of excerpts sound remarkably similar, with differences in detail only, which one would expect in the context of improvisation. In the course of the experiment as a whole—26 trials—a greater similarity exists *between* Excerpts 1 and 3 in each rendition than between these and the original versions in *Chromatic Blues* on 90% of occasions (see Fig. 7.27).
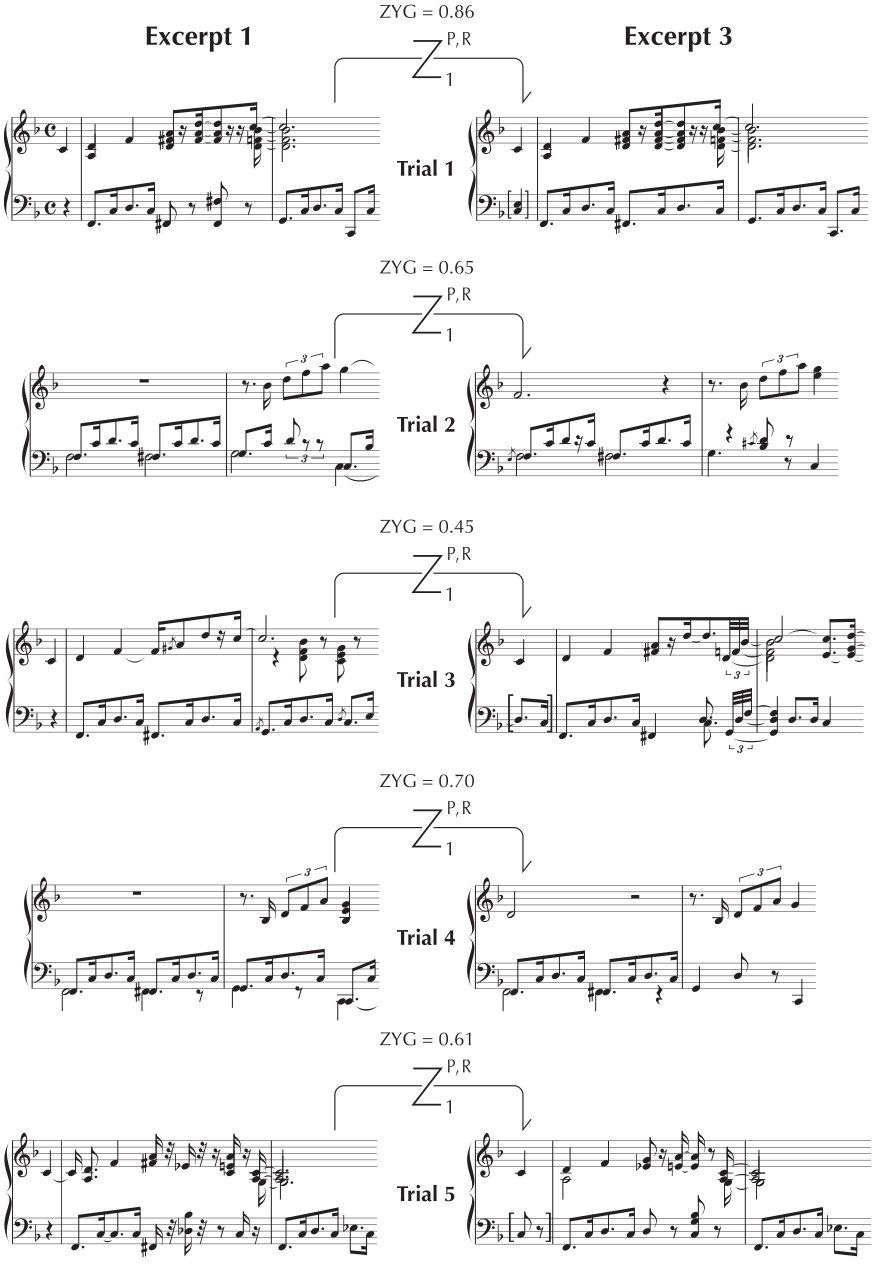
Fig. 7.26 Global ZYG values for Excerpts 1 and 3 from Trials 1–5 of Derek's attempts to play *Chromatic Blues*.

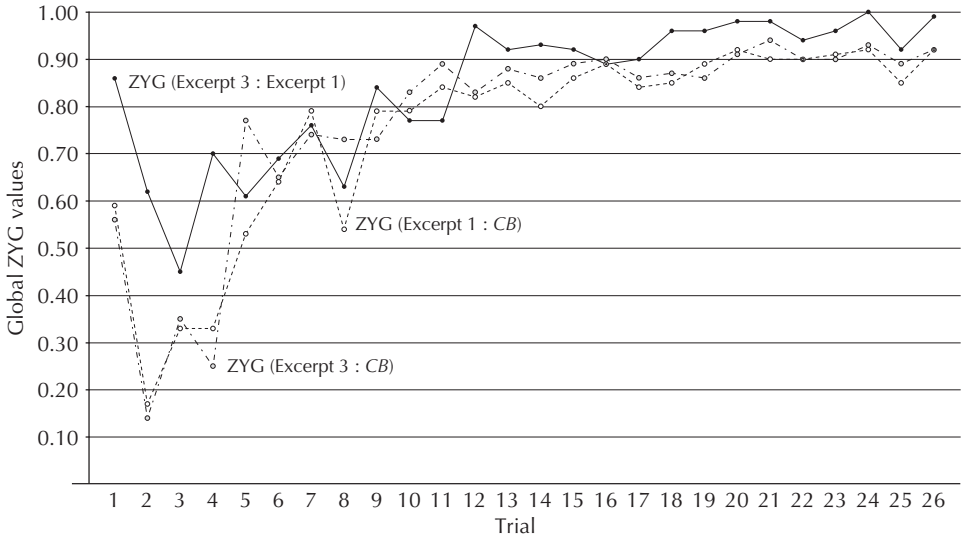

Fig. 7.27 ZYG values for Excerpts 1 and 3 and *Chromatic Blues* (*CB*) across the course of the 26 trials.

An ANOVA indicates that the variation between the three data series is significant: $F(2,25) = 10.35$, $P = 0.0002$, while Tukey post-hoc tests indicate that the significant differences lie between ZYG (Excerpt 3: Excerpt 1) and ZYG (Excerpt 1: *CB*[13]), $P < 0.001$; and between ZYG (Excerpt 3: Excerpt 1) and ZYG (Excerpt 3: *CB*), $P < 0.01$. The ZYG (Excerpt 1: *CB*) and ZYG (Excerpt 3: *CB*) data series are very highly correlated, $R = 0.95$, $P < 0.0001$. The consistent similarity in Derek's production of Excerpts 1 and 3, and the increasingly uniform differences between these and the original extracts in *Chromatic Blues*, again point to a single memory trace, with appropriate "tags" to indicate how these relate sequentially to other material (see Ockelford, 2007b, p. 29).

Derek's efforts at recalling Excerpts 2 and 4 tell an even more intriguing story. Like Excerpts 1 and 3, it is possible that they may have been stored as two memory traces, or, conceivably, a single one, whose pitches were encoded at the level of *intervals* rather than absolute values. As we observed in Chapter 6, despite his refined sense of AP, this would not have presented a problem for Derek, whose unusually advanced transpositional abilities (which give him instant access to all his considerable repertoire in any key) strongly suggest that he must store melodic and harmonic information relatively as well as absolutely (cf. Fig. 5.23). What do the quantitative data tell us? The ZYG scores between Excerpts 2 and 4, and between these and the original *Chromatic Blues*, are illustrated graphically in Fig. 7.28.

The results show that, in Phases 1 and 2 of Derek's responses, there is not the resemblance of material that characterized the relationship between Excerpts 1 and 3 (although Excerpts 2 and 4 were more similar to each other than to the equivalent passages in *Chromatic Blues* nonetheless). It seems that Derek did not immediately pick up on the structural connection between Excerpts 2 and 4 in the same way that he did with 1 and 3, where, despite the content being variable, the

[13] That is, the original version of *Chromatic Blues*.

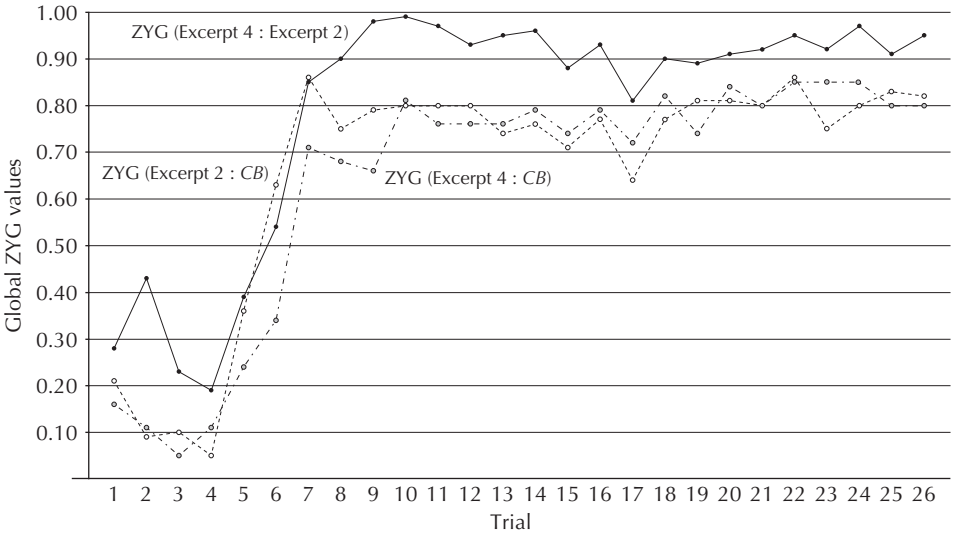

Fig. 7.28 ZYG values for Excerpts 2 and 4 and *Chromatic Blues* (*CB*) across the course of the 26 trials.

repetition of phrases was nonetheless recognized: there is no sense of Excerpt 4 being a transposition of Excerpt 2 in these early stages. During Phase 3, however, there is a dramatic change, and ZYG (Excerpt 4: Excerpt 2) rises from 0.19 in Trial 4 to 0.99 in Trial 10, a fivefold increase in derivational strength. The original motif from *Chromatic Blues* starts to emerge in Trial 5, but here, both Excerpt 2 and Excerpt 4—embryonic as they are—appear at the same pitch level. In Fig. 7.29 one can see how the motif is refined over the next two trials: observe that it is often *incorrect* notes or intervallic patterns that are common between the excerpts. As the ZYG (Excerpt 2: *CB*) and (Excerpt 4: *CB*) scores increase, so does ZYG (Excerpt 4: Excerpt 2) (see Fig. 7.28). This pattern of errors and corrections, and the common pitch level of the excerpts (overriding the original tonal structure), both hint at Derek holding a single memory trace rather than two distinct ones.

It is only in Trial 10, after a break of a month, that Excerpt 4 finally appears at the correct pitch. Is this a sign that a previously single memory trace divided into two during the intervening period? Evidence that this may be the case is to be found in the general decline over the nine sessions of Phase 4 of around ZYG = 0.10 from Trial 10, in which the excerpts are (in terms of rhythm and relative pitch) to all intents and purposes identical (ZYG = 0.99). That is, it may be that having become represented in two separate traces, Excerpts 2 and 4 drift apart somewhat. However, in Trial 17, a hint of confusion appears, in that Derek starts by playing the opening of Excerpt 4 before correcting himself (see Fig. 7.30). Then in Trial 19 (after 3 months' break), the mistake becomes, as it were, fully fledged, and the order of the excerpts is reversed. In Trial 21, the pause on the pivot note D at the beginning of what should be Excerpt 2 (see Fig. 7.8) suggests that Derek is taking time to think things through (though arriving at the wrong conclusion). The sequential error persists until Trial 24, when the correct order is reinstated. In Trial 25 Derek produces two Excerpt 4s before finally, in Trial 26, reversing the order once more.

What does this tell us about Derek's memory processes? One explanation is that Derek maintained a single trace of Excerpts 2 and 4 that had two tags informing him (1) of the excerpts' positions in the global *Chromatic Blues* sequence and (2) the absolute pitches at which the two appearances had to be realized—and that these labels became confused. Another possibility is

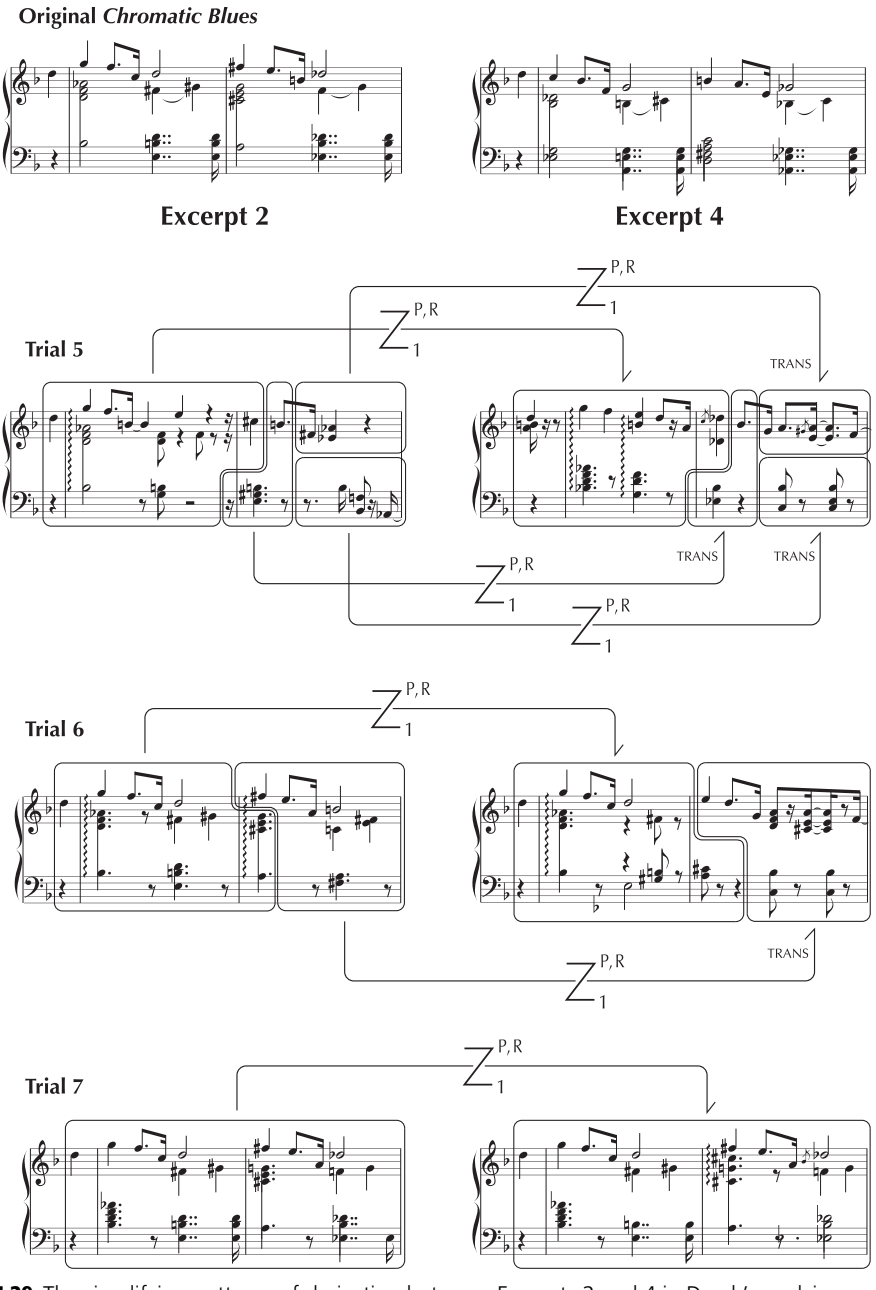

Fig. 7.29 The simplifying patterns of derivation between Excerpts 2 and 4 in Derek's evolving recall of *Chromatic Blues* suggests the consolidation of a single memory trace.

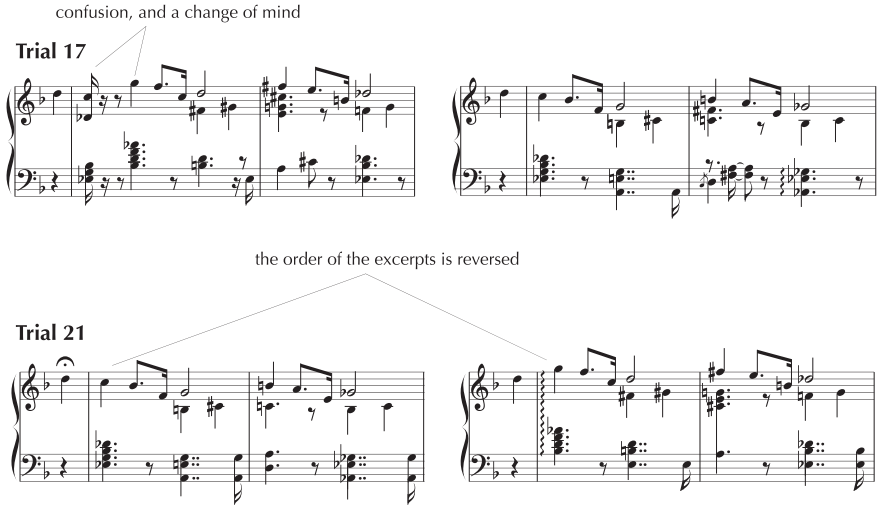

Fig. 7.30 Derek's differing realizations of Excerpts 2 and 4 some time into the *Chromatic Blues* experiment shows that his memory traces of the music were still evolving.

that two memory traces evolved, which were activated by the same pivot note, D5 (a structural ambiguity that was consciously built in to *Chromatic Blues*), and Derek became confused as to which route he should take, despite hearing the original piece repeatedly between trials. It is at times like this that we would expect a neurotypical pianist to fall back on explicit, conceptual memories rather than implicit, perceptual impressions. For example, Roger Chaffin and Gabriela Imreh's account (1997) of the second author's attempt to learn the last movement of Bach's *Italian Concerto* shows that both practice and recall data were organized by her recognition of the formal structure of the music. Chaffin and Imreh (1997, p. 324) note:

> similar passages can save memory work, but are also a potential source of interference . . . . The identification of different repetitions of the same theme became critical in session 17, when the pianist began to work on playing without the score. She spent the first half hour of the session comparing the differences between the various repetitions of the A and B themes. She began by comparing the A themes at the beginning and end of the piece. "The difference . . . has to be drilled in".

Such metacognitive strategies—or, indeed, access to a score—were, of course, not open to Derek, who had to rely purely on his intuitive grasp of the music. And it could be that "deeper" structural issues—the large-scale "road maps" of pieces, first drawn so compellingly by Heinrich Schenker (1932)—were either not accessible to Derek or were simply not regarded by him as being as important as the surface detail. This points us again in the direction of "weak central coherence," a cognitive style characteristic of those with autism (Happé, 1999; Heaton, 2003), in which the processing of local features is favored at the expense of a more global, context-dependent focus (see p. 186). This issue is discussed below in the light of S's efforts to learn and recall *Chromatic Blues*.

Top, inner, and bottom parts

On a global level (see Table 7.6), Derek is most successful at reproducing melodies (ZYG = 0.75), followed by basslines (ZYG = 0.71), and then inner parts (ZYG = 0.53). An ANOVA indicates that the variation between the three data series that yield these figures is significant: $F(2,25) = 99.89$,

$P < 0.0001$, while Tukey post-hoc tests indicate that significant differences lie between the inner parts and the outer parts, in each case $P < 0.001$. The tendency for the melody and bassline to be more accurate than the interior notes in the texture is found consistently across the 26 trials, although the three strands converge increasingly as time goes on and the inner parts continue their steady improvement (see Fig. 7.31).

These findings are in line with those of Bruno Repp (1996), who, in a somewhat different context, had 10 graduate student pianists perform pieces by Schumann, Chopin, Grieg, and Debussy three times from the score after a brief rehearsal. Repp found that all three types of error that were identified (substitutions, omissions, or intrusions) occurred almost exclusively in "non-melody" (subsidiary) voices, especially in the inner parts of chords (Repp, 1996, p. 176). Similarly, Gabriela Imreh's initial accuracy of recall after 27 months of the first 32 bars of the last movement of Bach's *Italian Concerto*, which varies between two-, three- and four-part textures, was 79% for the right hand and 52% for the left, suggesting the (topmost) melody was relatively well preserved compared with lower parts (see Chaffin and Imreh, 1997, p. 330). As Derek was working entirely by ear, it is also worth noting that his pattern of errors corresponds to Palmer and Holleran's (1994) discovery that listeners are least able to detect pitch changes in the middle voice of three-part musical textures (Palmer and Holleran, 1994, pp. 305, 307).

In contrast to this compatibility with previous studies, Derek's data may, at the first blush, seem to be out of kilter with those from the chordal disaggregation study (Chapter 6), which suggested that that his success at replication decreased as a function of relative pitch height. However, more detailed examination of the figures (Table 7.6) reveals that rhythm is largely responsible for the Derek's relative success in recalling the top line: ZYG(R, Melody) = 0.81, ZYG (R, Bassline) = 0.71 and ZYG (R, Inner Parts) = 0.50. In the dimension of pitch, the bottom part is reproduced with greatest accuracy: ZYG (P, Bassline) = 0.72, ZYG (P, Melody) = 0.70, and ZYG (P, Inner Parts) = 0.56.

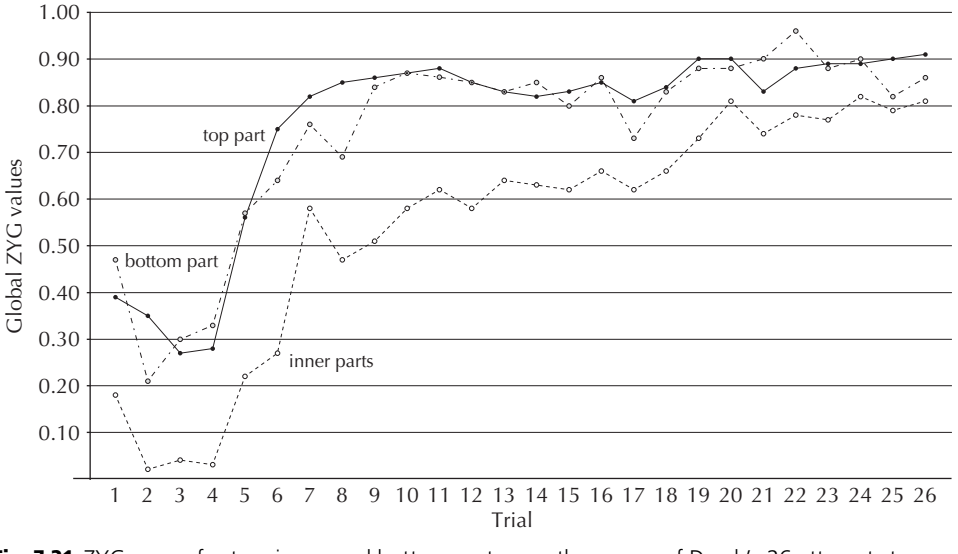

Fig. 7.31 ZYG scores for top, inner, and bottom parts over the course of Derek's 26 attempts to recall *Chromatic Blues*.

Table 7.9 ZYG scores by excerpt for top, inner, and bottom parts of Derek's attempts to recall *Chromatic Blues*

	Strand	Rhythm	Pitch	Mean
Excerpt 1 + Excerpt 3	Melody	0.78	**0.79**	0.78
	Inner parts	**0.64**	0.56	0.60
	Bassline	0.87	**0.88**	0.88
Excerpt 2 + Excerpt 4	Melody	**0.81**	0.75	0.78
	Inner parts	0.48	**0.64**	0.56
	Bassline	0.55	**0.58**	0.56
Excerpt 5	Melody	**0.83**	0.57	0.70
	Inner parts	0.29	**0.33**	0.31
	Bassline	0.38	**0.39**	0.38

Note: the higher figure of pitch or rhythm is in bold type.

As we would expect, the *nature* of the stimulus is important too, as an examination of the data, excerpt by excerpt, shows (Table 7.9). In Excerpts 1 and 3, the bassline is, by some margin, reproduced the most accurately with respect to both pitch and rhythm, which are virtually identical. In Excerpts 2 and 4, and Excerpt 5, the melody is recalled most faithfully. The inner parts are invariably the least precise. In terms of the differences between rhythm and pitch, in the bassline, these are never significant; in relation to the melody and the inner parts, the differences vary by excerpt.

How Derek's renditions compare with each other as opposed to the original *Chromatic Blues*

We noted earlier that Derek seemed to hold three distinct versions of *Chromatic Blues* in his head over the first few sessions, that were only finally resolved following Trial 9. We also observed that, within each rendition, Derek's recollections of excerpts that were repeated (1 and 3) or of those which were transposed (2 and 4) were sometimes more similar to each other than to the originals. We now take this analysis a stage further and compare Derek's renditions following Trial 9 (when *Chromatic Blues* proper first appeared without additional or alternative material) in each case with the one that appeared immediately before (see Fig. 7.32).

These two data series are highly correlated ($R = 0.86$); the difference between them (ZYG = 0.1) remains more or less constant throughout; and the two means of the series, mean ZYG (Trials 9–16, *Chromatic Blues*) = 0.79 and mean ZYG (Trial n, Trial $n-1$) = 0.88, are significantly different: $t(16) = 13.50$, $P < 0.0001$. That is to say, there is a strong and consistent tendency for Derek's renditions to become more internally coherent (through repeated sections being the same and transposed sections being transformed isomorphically) as they become more faithful to the original *Chromatic Blues*. While this may seem unsurprising (since in *Chromatic Blues* the repetition and transposition of sections is exact) it would have been conceivable, as Derek's early efforts showed, for him to produce versions that were increasingly internally coherent but which bore less and less resemblance to the original.

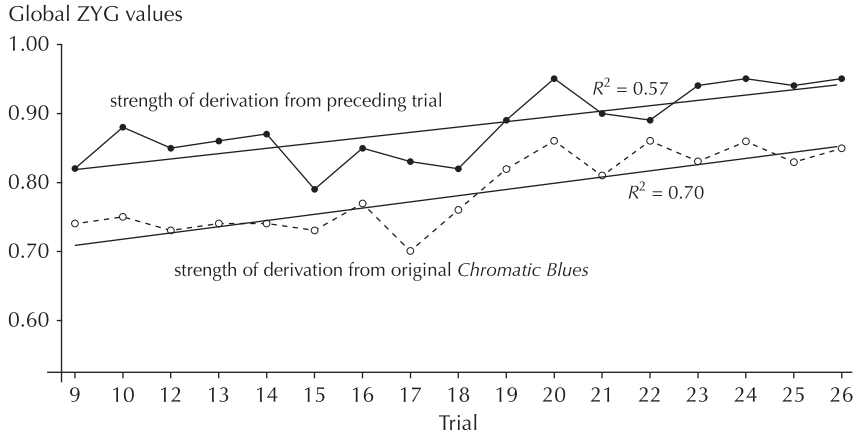

Fig. 7.32 Comparison of ZYG scores for Trials 9–26, derived from the original *Chromatic Blues* and the previous rendition in each case.

Indeed, comparing the results of trials from around the beginning and the end of the period shown in Fig. 7.32 shows just how resilient Derek's own, internalized version of *Chromatic Blues*, which he had assembled over a few hearings, was. Take, for example, Trial 10 (which occurred immediately after the first month's break) and Trial 25 (which happened almost 4 years—15 trials—later), and imagine that the latter was derived directly from the former.[14] This yields the somewhat sobering statistic (from a pedagogical point of view) that ZYG (Trial 25: Trial 10) = 0.81 (see Table 7.10) is almost identical to ZYG (Trial 25: *CB*) = 0.83 (see Fig. 7.21). That is, Trial 25 is almost as strongly derived from memories that reach back to the first few weeks of the experiment as they are from Derek's learning of *Chromatic Blues* that is assumed to have occurred in the intervening period.

We can further analyze how Trials 10 and 25 of *Chromatic Blues* relate by considering their ZYG scores in terms of three intersecting sets (see Fig. 7.33). This yields seven distinct regions:

(a) material in *Chromatic Blues* not emulated in Trials 10 or 25
(b) material unique to Trial 10
(c) material unique to Trial 25
(d) material shared by *Chromatic Blues* and Trial 10 but not Trial 25
(e) material shared by *Chromatic Blues* and Trial 25 but not Trial 10
(f) material shared by Trials 10 and 25 but not *Chromatic Blues*
(g) material common to *Chromatic Blues*, Trial 10 and Trial 25

We can populate these regions with data since we know from Fig. 7.21 that ZYG (*CB*: Trial 10) = 0.74, and from Table 7.10 that ZYG (Trial 25: Trial 10) = 0.81 and ZYG (Trial 25: *CB*) = 0.83. Hence:

[14] In reality, of course, the relationship is likely to be *indirect*, through a shared general memory, rather than the specific recall of a particular trial.

Table 7.10 ZYG (Trial 25 : Trial 10)

	#Rel(R or P)	#Z(R)	$ZYG(R) = \frac{\#Z(R)}{\#Rel(R)}$	#Z(P)	$ZYG(P) = \frac{\#Z(P)}{\#Rel(P)}$	#Z(Rel) = #Z(R) + #Z(P)	$ZYG = \frac{\#Z(Rel)}{\#Rel \times 2}$
Excerpt 1							
Melody	6	5.5	0.92	6	1.00	11.5	0.96
Inner parts	14	8	0.57	10	0.71	18	0.64
Bassline	12	11	0.92	12	1.00	23	0.96
Sums/averages	32	24.5	0.77	28	0.88	52.5	0.82
Excerpt 2							
Melody	6	6	1.00	6	1.00	12	1.00
Inner parts	12	10	0.83	11	0.92	21	0.88
Bassline	10	8.5	0.85	9	0.90	17.5	0.88
Sums/averages	28	24.5	0.88	26	0.93	50.5	0.90
Excerpt 3							
Melody	9	9	1.00	8.5	0.94	17.5	0.97
Inner parts	6	5	0.83	5.5	0.92	10.5	0.88
Bassline	16	9	0.56	14.5	0.91	23.5	0.73
Sums/averages	31	23	0.74	28.5	0.92	51.5	0.83

Table 7.10 (continued) ZYG (Trial 25: Trial 10)

	#Rel(R or P)	#Z(R)	$\text{ZYG(R)} = \frac{\#Z(R)}{\#Rel(R)}$	#Z(P)	$\text{ZYG(P)} = \frac{\#Z(P)}{\#Rel(P)}$	#Z(Rel) = #Z(R) + #Z(P)	$\text{ZYG} = \frac{\#Z(Rel)}{\#Rel \times 2}$
Excerpt 4							
Melody	9	9	1.00	9	1.00	18	1.00
Inner parts	6	5	0.83	6	1.00	11	0.92
Bassline	16	12	0.75	13	0.81	25	0.78
Sums/averages	31	26	0.84	28	0.90	54	0.87
Excerpt 5							
Melody	16	15	0.94	6	0.38	21	0.66
Inner parts	6	2.5	0.42	2.5	0.42	5	0.42
Bassline	10	6	0.60	8	0.80	14	0.70
Sums/averages	32	23.5	0.73	16.5	0.52	40	0.63
Sums/averages							
Melody	46	44.5	0.97	35.5	0.77	80	0.87
Inner parts	42	33.5	0.80	37	0.88	70.5	0.84
Bassline	66	43.5	0.66	54.5	0.83	98	0.74
Sums/averages	154	121.5	0.79	127	0.82	248.5	0.81

$$(d) + (g) = 0.74 \tag{7.8}$$
$$(f) + (g) = 0.81 \tag{7.9}$$
$$(e) + (g) = 0.83. \tag{7.10}$$

Moreover, since

$$(a) + (d) + (e) + (g) = 1 \tag{7.11}$$
$$(b) + (d) + (f) + (g) = 1 \tag{7.12}$$
$$(c) + (e) + (f) + (g) = 1 \tag{7.13}$$

this implies that

$$(a) + (e) = (f) + (g) = 1 - 0.74 = 0.26 \tag{7.14}$$
$$(a) + (d) = (c) + (f) = 1 - 0.83 = 0.17 \tag{7.15}$$
$$(b) + (d) = (c) + (e) = 1 - 0.81 = 0.19. \tag{7.16}$$

Since

$$(d) + (g) = 0.74 \tag{7.17}$$

and

$$(d) \geq 0 \tag{7.18}$$

then

$$(g) \leq 0.74. \tag{7.19}$$

Similarly, since

$$(e) + (g) = 0.83 \tag{7.20}$$
$$(f) + (g) = 0.81 \tag{7.21}$$
$$(c) + (e) + (f) + (g) = 1 \tag{7.22}$$
$$(c) \geq 0 \tag{7.23}$$

then

$$(e) + (f) + 2(g) = 1.64 \tag{7.24}$$
$$(e) + (f) + (g) \leq 1 \tag{7.25}$$
$$(g) \geq 0.64. \tag{7.26}$$

Hence

$$0.64 \leq (g) \leq 0.74. \tag{7.27}$$

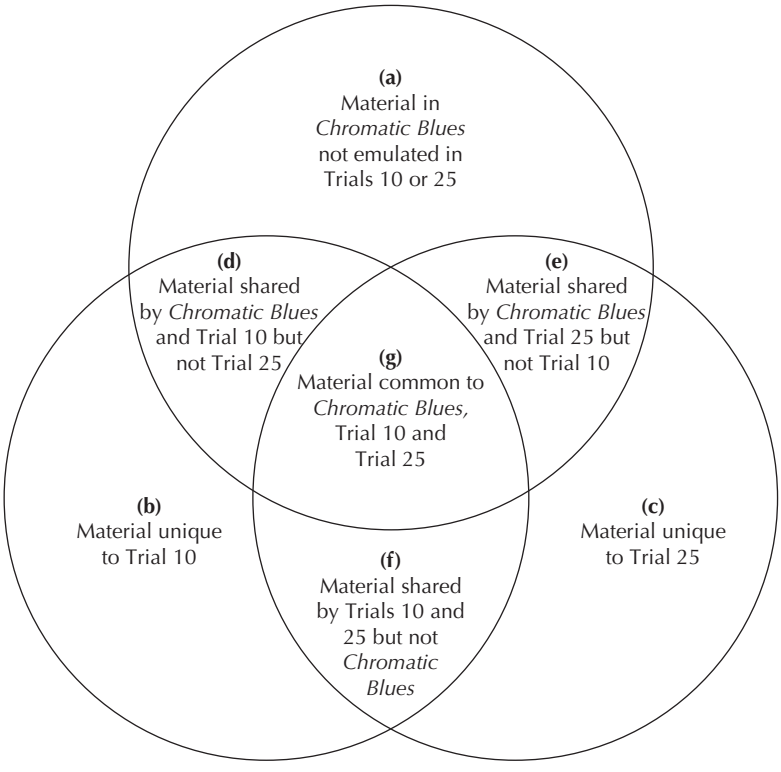

Fig. 7.33 Schematic presentation of the possible derivation of material pertaining to Trials 10 and 25 and from the original *Chromatic Blues*.

And it follows that

$$0.07 \leq (\text{a}) \leq 0.17 \tag{7.28}$$

$$0.09 \leq (\text{b}) \leq 0.19 \tag{7.29}$$

$$0.00 \leq (\text{c}) \leq 0.10 \tag{7.30}$$

$$0.00 \leq (\text{d}) \leq 0.10 \tag{7.31}$$

$$0.09 \leq (\text{e}) \leq 0.19 \tag{7.32}$$

$$0.07 \leq (\text{f}) \leq 0.17. \tag{7.33}$$

Fig. 7.34 illustrates these data: how the proportion of material from *Chromatic Blues* that is not recalled by Derek in Trial 10 or Trial 25 is between 0.07 and 0.17; the fraction of Trial 10 that is unique lies between 0.09 and 0.19; and the portion of Trial 25 that is distinct is in the range 0 to 0.1. This suggests, as one would expect, that there is a movement away from the introduction of novel material—from creativity—as we reach a later point in the process of learning, where consolidation is more the order of the day. However, it appears that virtually the same amount of material (0.7 to 0.17) was taken other than from *Chromatic Blues* as from this stimulus (0.09 to 0.19).

Analysis such as this is valuable both for the light it potentially sheds on the psychological processes of learning and recall, as well as to those seeking to learn music by ear (and those teaching

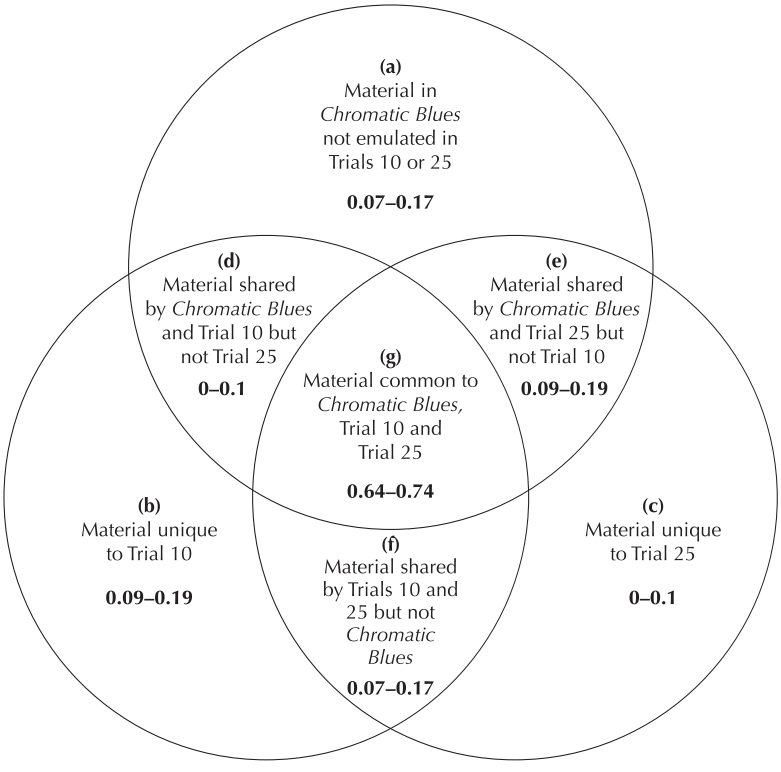

Fig. 7.34 Set analysis of the possible derivation of material pertaining to Trials 10 and 25 and from the original *Chromatic Blues*.

aurally). Clearly, the interference effects of early—premature, one might say—attempts at reproduction can, in Derek's case, at least, be considerable, and continue to exert an effect months and even years into the future. And there comes a point in proceedings, earlier than one might expect, when continued exposure to a stimulus does relatively little to improve accuracy of recall—to shift previously acquired idiosyncrasies. Counterintuitively, as we have seen, the absence of the original stimulus and a period without trying to recall it may have a beneficial effect.

Analysis of S's attempts to learn *Chromatic Blues*, and comparison with Derek's results

In setting up the *Chromatic Blues* study, it was our intention that S should seek to learn and recall the piece in conditions that were as similar as possible to those that Derek experienced. In the event, the main difference was in the schedule: S managed to complete an initial run of nine sessions (17 trials) within 4 weeks (whereas Derek had a month's break between Sessions 5 and 6), followed by intervals of 3 months and then 6 months, after which the experiment was terminated with S, as he moved away from the UK. Hence he completed 11 sessions (21 trials) in total (see Table 7.11) compared with Derek's 26 trials over 14 sessions (Table 7.1). Nonetheless, as we shall see, there are enough corresponding data to enable comparisons to be drawn.

Table 7.11 S's schedule of *Chromatic Blues* sessions

Session number	Trials	Days since previous session	Time period
1	1	–	
2	2 and 3	6	
3	4 and 5	1	
4	6 and 7	5	
5	8 and 9	2	≈ 1 month
6	10 and 11	4	
7	12 and 13	3	
8	14 and 15	1	
9	16 and 17	3	
10	18 and 19	87	≈ 3 months
11	20 and 21	192	≈ 6 months

We assumed, as we had with Derek, that *Chromatic Blues* would be too difficult for S to learn immediately, and so we predicted that in the first session, like Derek, he would recall only a limited number of fragments and features, and that these would be adapted and combined with other material to ensure that what he produced made musical sense. In subsequent sessions, once again, we expected to hear an improvement in S's performances that was at times incremental, as some elements were refined, and on other occasions comprised step changes, as chunks of music that were invented or borrowed from elsewhere were replaced with authentic material. As was the case with Derek, we anticipated that what S produced would interfere with memories of *Chromatic Blues* proper.

In order to get a sense of how S's attempts evolved, we show transcriptions of his Trials 1–5 and 21 (Figs. 7.34–7.39, respectively). These are versions of the scores that were produced automatically in *Finale* that have been "cleaned up" with respect to rhythm. It is interesting to compare these with Derek's equivalent attempts, which are shown in Figs. 7.4, 7.5, 7.17, 7.18, 7.6, and 7.8, respectively. Again, to limit the number of quantitative data to be analyzed, we will focus on the five excerpts set out in Fig. 7.3.

S's Trial 1

S's Trial 1 is shown in Fig. 7.35. The ZYG values for S's Trial 1 are shown in Table 7.12.

In Excerpt 1, ZYG(P + R) = 0.52, similar to Derek's value of 0.59 (see Table 7.2). S's recall of pitch, ZYG(P) = 0.39, is identical in quantitative terms to Derek's; it is his rhythm that is weaker, with ZYG(R) = 0.65 as opposed to 0.80. With regard to texture, both subjects scored most highly on their recall of the bassline, where ZYG = 0.70 (S) and 0.83 (Derek), followed by the melody, ZYG = 0.64 (S) and 0.68 (Derek), and then the inner parts, ZYG = 0.25 (S) and 0.33 (Derek). Considering pitch and rhythm separately by textural strand, the only area where S scored more highly than Derek was in the pitch of the inner parts: ZYG = 0.17 (S) and 0.08 (Derek). Hence, in purely quantitative terms, both men performed at a similar level, with Derek's recall being slightly more accurate overall.
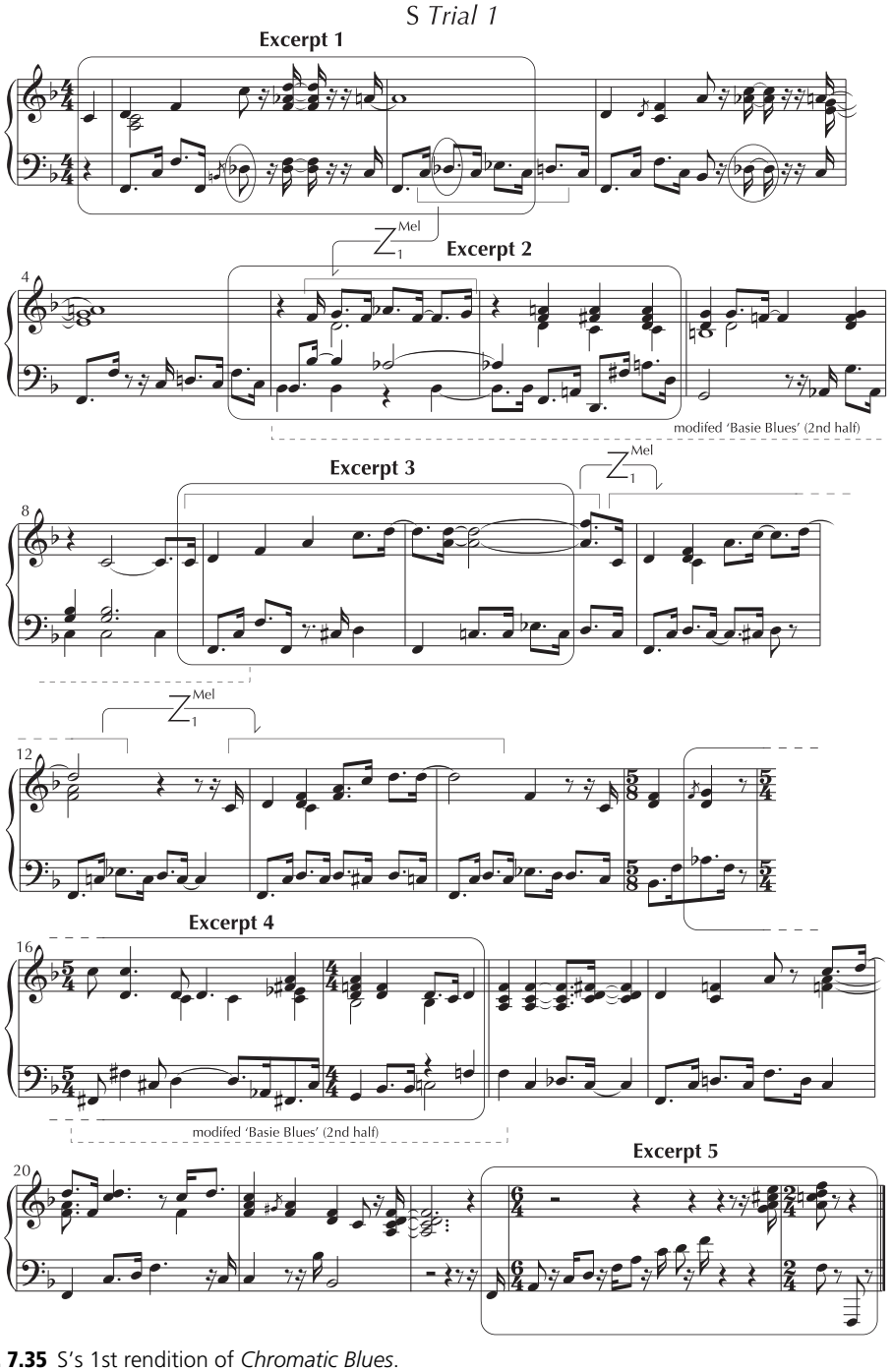
Fig. 7.35 S's 1st rendition of *Chromatic Blues*.

Table 7.12 Derivation indices for S's Trial 1

	Excerpt 1						
	#Rel	**#Z(R)**	**ZYG(R)**	**#Z(P)**	**ZYG(P)**	**#Z(R+P)**	**ZYG**
Melody	7	6	0.86	3	0.43	9	0.64
Inner Parts	12	4	0.33	2	0.17	6	0.25
Bassline	14	11.5	0.82	8	0.57	19.5	0.70
Total / Average	**33**	**21.5**	**0.65**	**13**	**0.39**	**34.5**	**0.52**
	Excerpt 2						
Melody	13	2.5	0.19	0	0	2.5	0.10
Inner Parts	18	2	0.11	1	0.06	3	0.08
Bassline	12	2	0.17	2	0.17	4	0.17
Total / Average	**43**	**6.5**	**0.15**	**3**	**0.07**	**9.5**	**0.11**
	Excerpt 3						
Melody	7	3	0.43	3	0.43	6	0.43
Inner Parts	12	0	0	0	0	0	0
Bassline	12	9	0.75	8	0.67	17	0.71
Total / Average	**31**	**12**	**0.39**	**11**	**0.35**	**23**	**0.37**
	Excerpt 4						
Melody	13	3	0.23	1	0.08	4	0.15
Inner Parts	24	6	0.25	1	0.04	7.5	0.15
Bassline	13	3.5	0.27	3	0.23	6	0.25
Total / Average	**50**	**12.5**	**0.25**	**5**	**0.10**	**17.5**	**0.18**
	Excerpt 5						
Melody	16	2.5	0.16	9	0.56	11.5	0.36
Inner Parts	8	1.5	0.19	2	0.25	3.5	0.22
Bassline	3	0.5	0.17	2	0.67	2.5	0.42
Total / Average	**27**	**4.5**	**0.17**	**13**	**0.48**	**17.5**	**0.32**
	Averages / Totals						
Melody	56	17	0.30	16	0.29	33	0.29
Inner Parts	74	13.5	0.18	6	0.08	19.5	0.13
Bassline	54	26.5	0.49	23	0.43	49.5	0.46
Total / Average	**184**	**57**	**0.31**	**45**	**0.24**	**102**	**0.28**

Qualitatively, though, their responses differ markedly. The first two bars of Derek's Trial 1 are entirely coherent musically, whereas S's are not. Stylistically, the most unusual feature of the opening of the original *Chromatic Blues* is the move to the flattened submediant—D♭ major (with added 9th, sharpened 11th and 13th)—on beat 3 of bar 1, and this evidently made an impression on S, since he incorporated the root of the chord (D♭3) into his bassline three times during the course of Excerpt 1 (see Fig. 7.35). One has the sense that he was repeatedly trying to make the note fit, since none of its appearances is musically persuasive—the first two, in particular, forming strident discords with the melody notes (C5 and D5) that sound unambiguously "wrong" in the implied style.

As we saw in Fig. 7.4, Derek, however, makes no attempt to incorporate a D♭ into his rendition: rather, his attention seems to have been taken by the next stylistically unorthodox event to occur in the stimulus—the D major harmony at the end of the second phrase (see Fig. 7.2). This proves rather easier to assimilate than the D♭, and Derek's Trial 1, with no stylistic solecisms, sounds musically convincing. So as well as being more similar to the opening of *Chromatic Blues* than S's first attempt, Derek's version also has its own, distinct musical identity, which, as we observed above, proved sufficiently resilient to survive in the face of repeated hearings of the original stimulus. In contrast, S attempted to use the D♭ again in the bassline of Excerpt 1 on only one occasion in the next 20 trials (when the note appears fleetingly in the opening phrase of Trial 5). It is as though, having initially failed to make the D♭ work, S non-consciously became averse to trying to use it again.

S's second phrase (bars 2 and 3) more or less repeats the first, and includes a final attempt to press the D♭ into meaningful musical service (which, again, fails). Derek at this point also uses rhythmic repetition to link phrases one and two—perhaps the simplest means of all of ensuring coherence between groups (see p. 138)—but in combination with melodic inversion. The result is that S's second phrase is more like the original than Derek's (which uses melodic repetition too), but S's use of the tonic chord at the end (echoing the conclusion of the first phrase) results in the same problem that Derek had to face: even had he remembered it, S would have been unable to use the pivot note (D5) that in *Chromatic Blues* leads into Phrase 3, since its introduction would make no harmonic sense at this juncture. Formally, following the *Chromatic Blues* model, there should be a change at this point. Derek achieved this through the somewhat unconventional expedient of modulating to A minor, while S took the more authentic route in 12-bar blues of moving to the subdominant (B♭ major^7). Melodically, he adapts the material from the standard bass riff (heard in bar 2). In the traditional 12-bar pattern, the subdominant harmony would be repeated at this stage, followed by a return to the tonic. However, the form of *Chromatic Blues* demands a modulating sequence leading to the dominant (C) to presage the recapitulation of the opening theme. S fulfills these structural requirements (without the original content) by introducing bars 8–10 of the Basie blues, which moves round the circle of fifths, VI–II–V (see Scott, 2003, p. 73). However, the transition to this sequence (beat 2, bar 6) from the preceding chord IV is awkward musically and unconvincing stylistically. In quantitative terms, only 11% of the material from this passage (Excerpt 2) is derived from *Chromatic Blues*. This compares with Derek's ZYG = 0.21. The main differences are in the rhythm of the melody, where ZYG(R) = 0.41 (Derek) and 0.19 (S), and the pitch of the inner parts, where ZYG(P) = 0.23 (Derek) and 0.06 (S).

The recapitulation of the opening theme duly occurs in bar 9, with some modifications: the ill-fitting D♭, for example, is now entirely absent. Quantitatively, ZYG = 0.56 (Derek) and 0.37 (S). S's second phrase begins, once again, like the first, but instead of the expected concluding descent, the original contour is repeated (which is stylistically improbable), and then played for a third time (stylistically unthinkable), and one gets the sense that S is circling, pending a decision

as to which direction to move off in next. In the event, he chooses the familiar blues subdominant (B♭ major^7) as before. But what was awkward the first time now becomes a musical crisis, and S hesitates before playing C5—the pitch that originally functioned as the first harmonized note (following the pivot) in Excerpt 4. Here, however, it serves as the seventh of the first of the three Basie chords (VI–II–V) that are reiterated, albeit in a somewhat ungainly way, with a loss of meter and several pitch errors. So again, S nods in the direction of the *Chromatic Blues* structure, by repeating the harmonies he used for Excerpt 2 (observe that following the model more precisely by transposing the chords down a perfect fifth would have led the music to the subdominant). In quantitative terms, the strength of derivation from of Excerpt 4 from *Chromatic Blues* is, in the case of both subjects, very weak, with ZYG = 0.16 (Derek) and 0.18 (S).

A perfect cadence spans bars 17 and 18, followed by another moment of musical indecision, when the first Basie chord (D major^7) is briefly heard again. The sequence breaks off prematurely, however, and the opening theme returns once more, for a further reprise that is not found in *Chromatic Blues*. S appears to sense the need to wind things up, and in bar 21 he inverts the initial motif for the first time, producing a descent that suggests closure [most melodies end by falling (see Huron, 2006, pp. 85–8) and here the contrast with what has gone before makes the effect all the more telling]. This is precisely the technique that Derek used early on in his Trial 1 (bar 2), though to rather different musical ends, producing an arch contour that characterized subsequent phrases. In S's case, the music comes to a halt in bar 22, before starting up again in a fair reproduction of a coda that was a distinctive component of the original piece, thereby creating a more convincing ending than Derek's efforts in this respect, which resulted in little more than a cadential ornament. Quantitatively, ZYG = 0.32 (S) and 0.16 (Derek).

Taking Trial 1 as a whole, quantitative analysis shows that Derek and S derive pitch from *Chromatic Blues* to much the same degree: ZYG(P) = 0.24 (Derek) and 0.22 (S). It is rhythm where the main difference lies: ZYG(R) = 0.40 (Derek) and 0.31 (S). In terms of texture, basslines are most strongly derived from the original, and are virtually identical, with ZYG = 0.47 (Derek) and 0.46 (S); melodies are next, and show a marked difference, with ZYG = 0.39 (Derek) and 0.29 (S); while both the scores for inner parts are markedly lower, with ZYG = 0.18 (Derek) and 0.13 (S).

In the chordal disaggregation experiment, a key difference between Derek's and S's responses lay in their *size* relative to the stimuli: a function of the additions and omissions that were made (see Table 6.8). In Derek's case, 29 notes were omitted from the stimulus set of 780, and 67 were added, giving a response size of 818, and a stimulus: response ratio of 1.05. In contrast, S omitted 226 pitches and added 195, producing a response of 749 events, and a stimulus: response ratio of 0.96. That is to say, Derek utilized 9% more pitches than S. The *Chromatic Blues* experiment produced comparable results, with Derek using 160 notes in the five excerpts and S 126, against an original figure of 153. Hence Derek's stimulus: response ratio was again 1.05, and S's was 0.82. The biggest difference was in the inner parts: in Trial 1 (and, as we shall see, in subsequent trials), S tended to produce a sparser texture than Derek, perhaps intuitively following the dictum "when in doubt, leave it out" (since wrong notes in chords tend to be more noticeable than omissions; see Repp, 1996, p. 177). In contrast, Derek's approach seemed to be "when in doubt, play a few more notes," a strategy of enrichment that, I believe, was key to his producing material—even when he was struggling with limited recall—that had a stronger musical identity.

Weighing all this evidence up, it is clear that S's Trial 1 provides further, powerful evidence of the existence of a MPM, capable of retrieving fragments of material from working and long-term memory, adapting them as necessary, and (re)assembling within familiar tonal and rhythmic frameworks in accordance with a given formal structure—but this time found in a neurotypical

jazz pianist. Functionally, S's MPM seems to have the same attributes and capacities as Derek's. Indeed, some motivic transformations, such as the inversion of the opening melodic phrase, were produced by both, as we have seen. Generally speaking, however, we should not be surprised that the MPM outputs differed on a moment to moment basis (even given the same input, *Chromatic Blues*), since we can surmise that these would have depended on: the volatilities of attention (such as S's focus on the D♭ major harmony rather than the D major that attracted Derek); the numerous potential associations of each fragment or feature with others through idiosyncratic networks of memories (S's adoption of Basie blues progression as opposed to Derek's appropriation of the harmonies of *Paper Moon*, for instance); and the virtually limitless possibilities for reconfiguring and recombining motifs (including S's adaptation of the bass riff from bar 2 to form the melody at bar 5 in contrast to Derek's modification of the descending second phrase to form the final cadence that spans bars 15 and 16). All these complex decisions were made non-consciously (we assume) within a fraction of a second.

Listening to the two men's responses, however, they do sound subjectively quite different. As we noted above, Derek's Trial 1 makes musical sense throughout and has its own credible musical identity as well as sharing some key features with *Chromatic Blues* (ZYG = 0.31). In contrast, S's attempt has points where the musical logic breaks down, where pieces in the musical jigsaw have been laid side-by-side that do not quite fit together, such as the melody and the bassline in second half of bar 1, and the move in bar 15 from the subdominant chord to the Basie blues progression. As a consequence, as we observed, the trial as a whole has a weaker identity: it does not sound distinct from *Chromatic Blues*, but strikes the listener in the way one would expect—as an attempt to remember a short, though complex, piece, in which over 70% of the notes were incorrect (ZYG = 0.28).

The two renditions seem to place a different *emphasis* on "getting it right" (i.e. producing a faithful rendition) or "making musical sense." Derek intuitively opts for the latter (although in doing so, he is reasonably successful in the former). S, in contrast, seems to have leant more towards "getting it right," partly as a result, no doubt, of his heeding the instructions that he was given more faithfully than Derek did, who simply could not resist following his musical instincts once his performance was under way. Indeed, one can speculate that in musicians who are better able than Derek to conceptualize what they are doing, the parameters within which the MPM works—its "settings"—can be tweaked to effect different outcomes according to the requirements of the occasion.

Personal experience bears this out. As a teenager, I took a number of part-time jobs, including playing for a children's ballet class on Saturdays. Sometimes I would use the sheet music that was provided, but on other occasions, the instructor would ask me to improvise music for the girls to dance to (a "slow 4," for example, or a waltz). Here the critical thing was not to produce a coherent melody, but an unswerving rhythmic pattern within a regular hypermetrical framework (typically a succession of four bar phrases). From time to time, finding myself heading towards a musical cul-de-sac I would instinctively relinquish melodic felicity for the sake of rhythmic continuity. On Sundays, however, things were different: the temporal was replaced by the spiritual, the répétiteur's piano by the church organ. Here, improvisation was required for other reasons: largely to heighten the sense of devotion at key moments (such as the Eucharist and shortly afterwards) when otherwise there would have been silence. But obtrusive rhythms would have been wholly inappropriate: here, slow-moving harmonies (usually borrowed from the preceding Communion hymn) were the order of the day, played *sotto voce*, producing an ambient sonic stillness. Here, the tables were turned, and I would unthinkingly sacrifice rhythmic precision on the altar of serene harmonic flow. One can imagine that these different improvisational priorities were achieved by

my intuitively "tweaking the MPM controls," such that, where potential conflicts arose, either rhythm or harmony would take priority. As we shall see, a comparable difference of emphasis came to characterize Derek's and S's attempts to re-create *Chromatic Blues* more and more as the early trials progressed.

S's Trial 2

S's second session occurred 6 days after his first. As he made his second attempt to play *Chromatic Blues*, S had heard the piece twice and tried to re-create it once before (see Fig. 7.36).

To remind ourselves: Derek at this stage produced a response formed on an ostinato that was derived from the first two bars of his Trial 1 (Fig. 7.5). In Trial 2, the material appeared 16 times, and incorporated elements from other pieces such as *Organ Grinder Blues* (see Fig. 7.16). The effect was of something new, musically confident and assertive, that bore some general similarity to *Chromatic Blues* (ZYG = 0.18). The closest resemblance was in Excerpt 5 (the coda), where ZYG = 0.40. The scores pertaining to other excerpts were as low as ZYG = 0.09.

Faced with the same problem of limited recall, S chose a similar solution to the one that Derek adopted: he too fixed on an ostinato culled from bar 2 of the bassline of his Trial 1, which is very similar to the original material that appears in *Chromatic Blues*. S's right-hand part is predominantly chordal, although a short melodic motif, derived from the left hand (as it was in Trial 1) is a recurrent feature too. The result is a thematic paucity that prevents the music from generating a strong identity of its own. However, S introduces more harmonic variety than Derek did, with regular moves to the subdominant (for example, in bar 4) that were found in S's Trial 1 (and are characteristic of the blues) and, less predictably, the unorthodox use on two occasions of D♭ major harmonies. From their structural locations, these seem to hint at the chromaticism found in Excerpts 2 and 4 of *Chromatic Blues*, but maybe also reflect memories of the chord of D♭ originally heard on beat 3 of bar 1, which S could not resolve satisfactorily in Trial 1. Overall, one has the sense that S, like Derek, is improvising on one or two key fragments of *Chromatic Blues* that he can remember—a combination of the stylistically humdrum and the abnormal—and quantitatively, the result is very much the same, with ZYG = 0.20 (S) as opposed to 0.18 (Derek). Here, both subjects' MPMs seem to be functioning in a remarkably similar fashion, and we can speculate that, as far as S is concerned, after a 6-day break, the memory of *Chromatic Blues* was so weak that there could be no serious attempt at reproduction of the piece as a whole. Hence there is no conflict with the moment-to-moment demands of improvisation, and the hesitations and slips that characterized S's Trial 1 are absent. S does retain the global structure of *Chromatic Blues*, however, whereas Derek does not, which suggests that this may have been a conscious act on S's part—a difference in approach that becomes more significant as the trials progress.

S's Trial 3

Recall that Trial 3 was the first occasion in the *Chromatic Blues* experiment with Derek when something totally unexpected happened. Having just heard the piece for the third time, he responded with music that was internally coherent, but quite unlike the original piece (ZYG = 0.18). What Derek produced bore a closer resemblance to Trial 1 (that had occurred 2 days before), suggesting that this had formed a discrete bundle of musical ideas in his memory that was more vivid than the stimulus he had just heard.

In contrast, S's response was much more along the lines of what we had anticipated would occur: the opening theme and its repetition now traced the appropriate melodic contour,
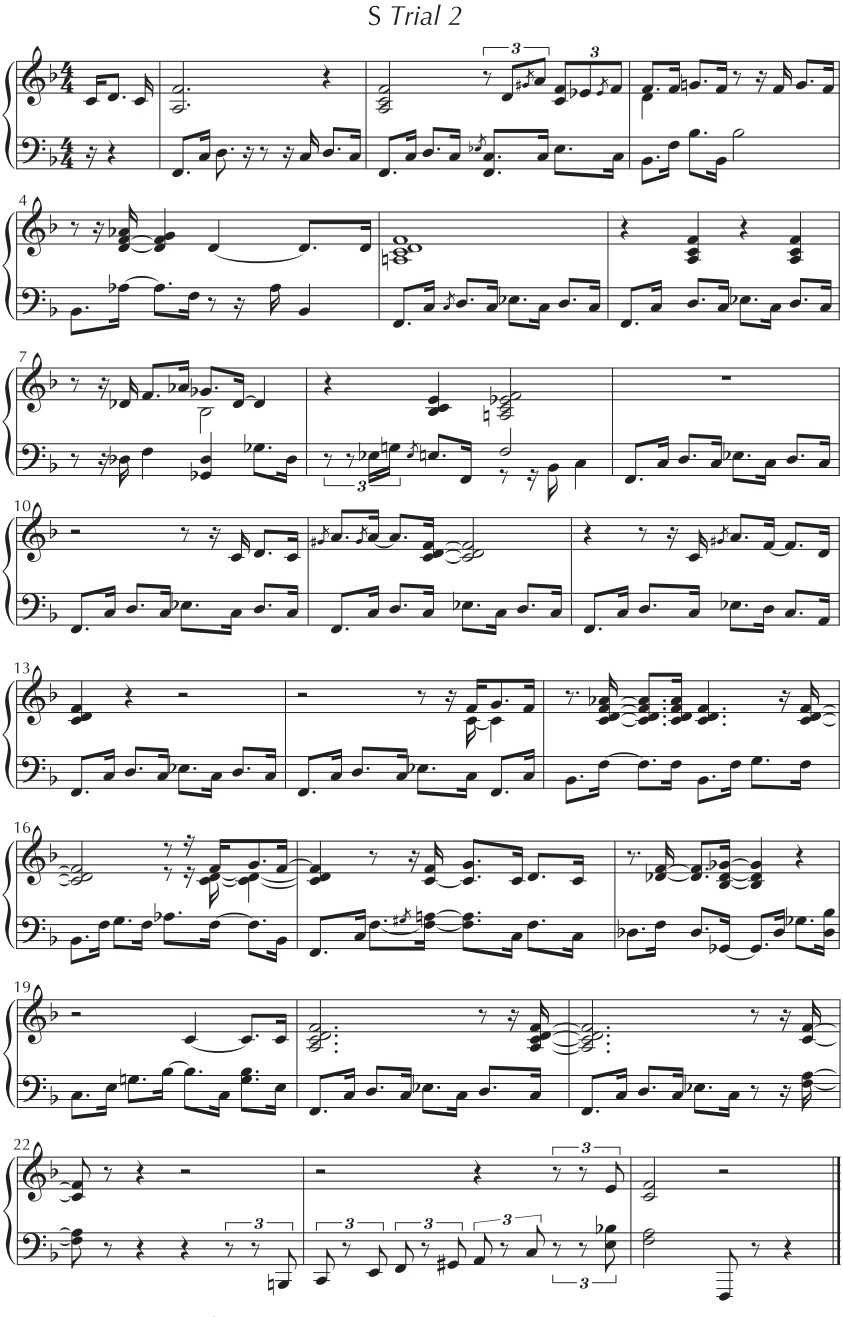
Fig. 7.36 S's 2nd rendition of *Chromatic Blues*.
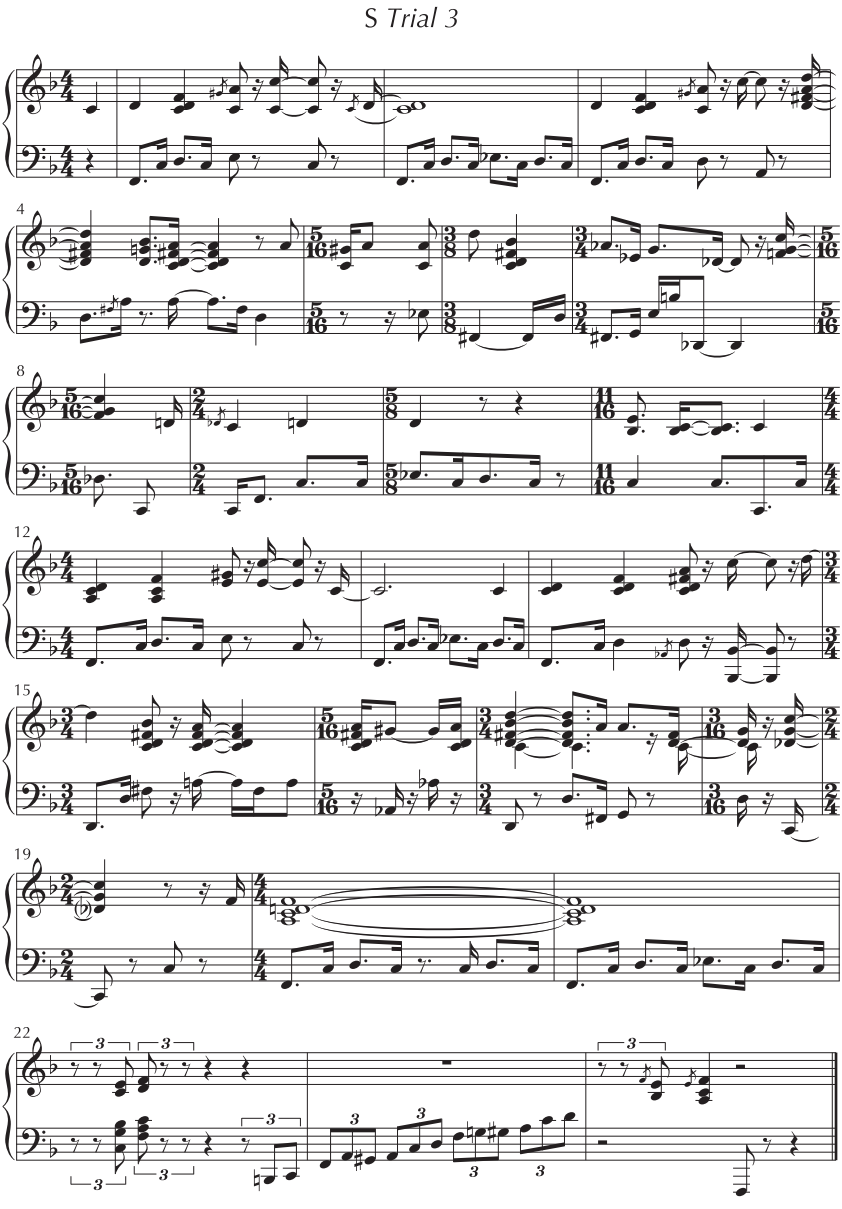
Fig. 7.37 S's 3rd rendition of *Chromatic Blues*.

supported by a harmonic outline that was by and large correct (reflected in global ZYG scores of 0.54 for Excerpt 1 and 0.58 for Excerpt 3) (see Fig. 7.37 and Appendix 2).

The effect is moderately musically persuasive, with two chords in particular sounding stylistically anomalous—unconvincing substitutions for the D♭ major harmony that caused S problems in Trial 1 (replaced in bar 1, beat 3 with iiic, and in bar 15, beat 3 with vi♯). Rhythmically there

are no hesitations, however, and one gets the sense that S's MPM is managing to balance effectively the needs of musical continuity with patchy recall. In Excerpts 2 and 4, however, things break down melodically, harmonically, and rhythmically, and neither recall nor improvisation seem to be functioning at all well: the effect is of a series of disjointed notes, evinced by global ZYG scores that are exceptionally low (0.07 for Excerpt 2 and 0.06 for Excerpt 4). In the coda (Excerpt 5), S mounts something of a recovery: ZYG = 0.47. S's score over the whole trial is ZYG = 0.34.

Here, then, one gets the sense of two MPMs working in very different ways—but, given the similarities in Trial 2, we can speculate that this may be less a matter of capacity and more to do with the way that the parameters within which music was produced (or reproduced) were set (non-consciously in Derek's case, and with a probable combination of deliberate and intuitive control in S's).

S's Trial 4

Trial 4 sees a further incremental improvement in S's recall, with the overall ZYG rising from 0.34 to 0.39 (see Fig. 7.38 and Appendix 2). Particularly notable is the transformation in Excerpt 2, where, for the first time, the initial leap from D5 to G5 is present (although the underlying harmonies are incorrect and the music buckles immediately afterwards; ZYG = 0.22). As we observed in relation to Derek's renditions, this is a critical point in the piece, since both Excerpts 2 and 4 begin with the same pivot note (D5), but then move off in different directions. An error at either of these junctures would lead to structural problems down the line, as the results of Derek's later trials show. At this stage (Trial 4), Derek produces material that clearly derives from his second attempt, and has little in common with the original *Chromatic Blues* (ZYG = 0.19).

So, once more, it seems that the men's MPMs are functioning with very different ends in mind—and, accordingly, produce dissimilar outputs. With S, in Trials 1 to 4, one has the sense of a series of reproductions of *Chromatic Blues* in which the underlying tonal and thematic structure quite rapidly fall into place, and which increasingly become populated with more detail that is faithful to the original (rather as an artist would typically draw a face, for example, by first sketching the general physiognomy and then working on the surface features, all the time referring back to the subject). In S's efforts at musical recall, errors, discontinuities, and attempted corrections appear to be integral to the process of refinement. Not so for Derek, though, who sketched confidently, and in detail, from the beginning—rather as savant artists, such as Stephen Wiltshire, often do. Here, the structure seems to emerge implicitly from the surface, rather than the other way round. However, by Trial 4, Derek was by all accounts paying a heavy price for the musical coherence of his earlier attempts (which was produced at the expense of fidelity to the stimulus). He seemed unable to erase the first two trials from his musical "auditory sketchpad," whose presence apparently prevented him from moving towards a more accurate rendition (unlike S, where the very uncertainty of his first efforts did not block subsequent change). However, as we know, this was not the full story of what was occurring in Derek's MPM, as the results of Trial 5 were to show. Nonetheless, it is interesting to reflect that, were we to have terminated the experiment at Trial 4, S would have been regarded as the more successful at musical recall by a margin of some 20%.

S's Trial 5

At this stage, the form of *Chromatic Blues* is firmly established, including the correct movement of the pivot note D5 to C5, which opens Excerpt 4, in bars 12 and 13 (see Fig. 7.39). This is something that Derek did not achieve until Trial 10, and even after that, as we have seen, he was
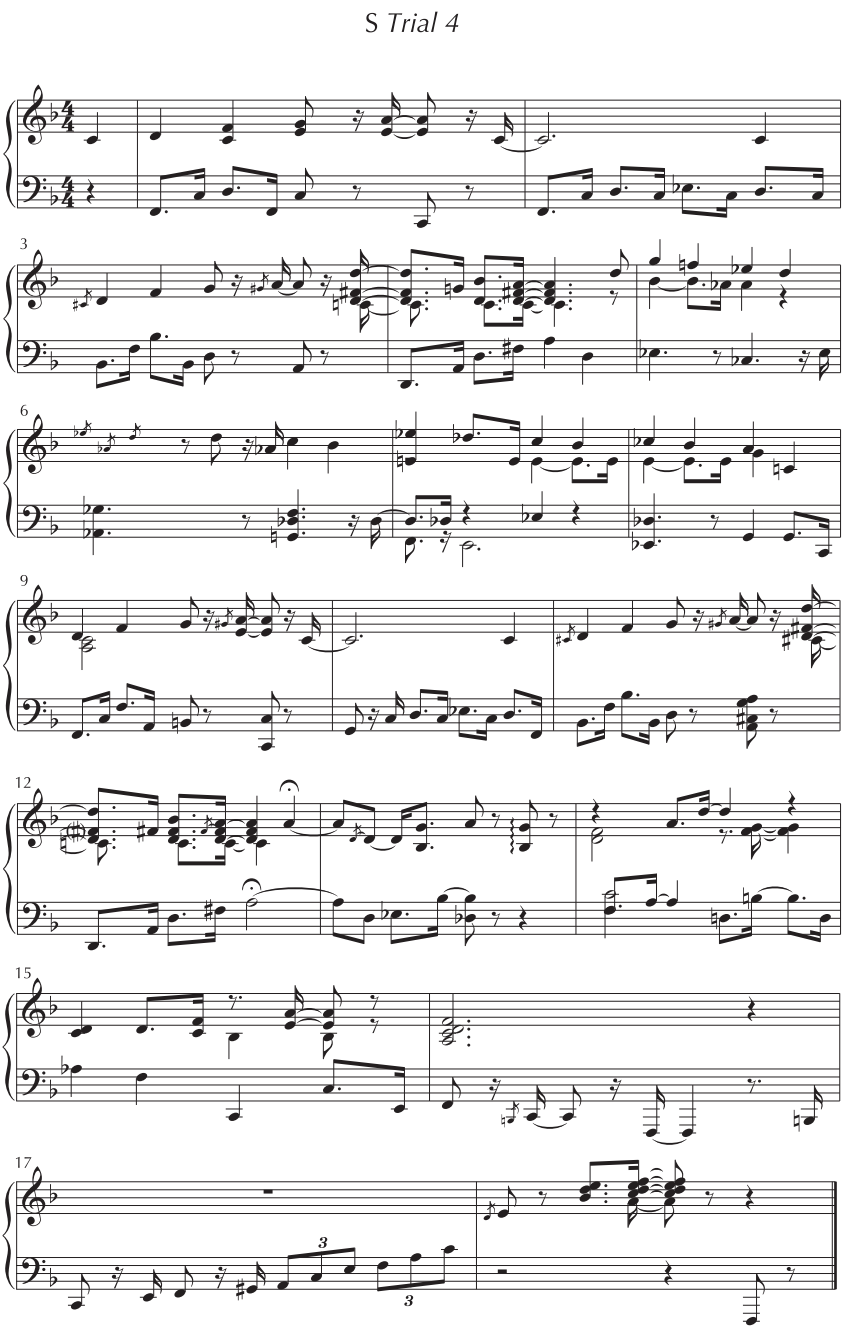
Fig. 7.38 S's 4th rendition of *Chromatic Blues*.
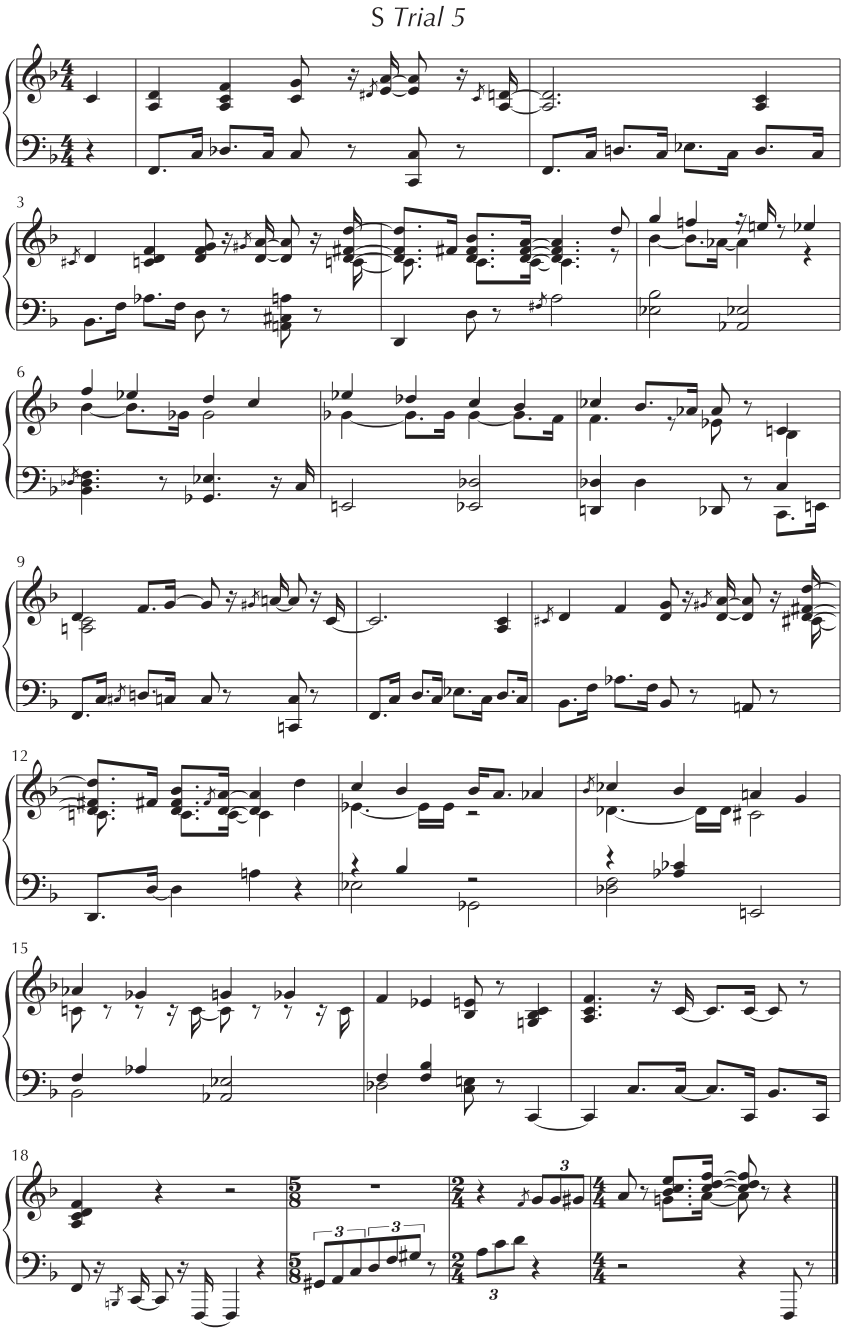
Fig. 7.39 S's 5th rendition of *Chromatic Blues*.

inconsistent. However, Trial 5 was the point at which he did suddenly produce a recognizable version of *Chromatic Blues*, which was distinctly different from his earlier efforts. But was it the case that the kind of processes S had been rehearsing through Trials 1–4 had been going on tacitly in Derek's MPM and that we were only now privy to the results?

The overall ZYG scores offer support for this notion (see Appendix 2), since they are very similar (S, ZYG = 0.43; Derek, ZYG = 0.41). Strand by strand, too, the results bear close comparison (melody: S, ZYG = 0.59 and Derek, 0.56; inner parts, S, ZYG = 0.64 and Derek, 0.56; bassline, S, ZYG = 0.18, and Derek, 0.22, Derek), and with regard to pitch (S, ZYG = 0.37 and Derek, 0.39) and rhythm (S, ZYG = 0.48 and Derek, 0.44). However, comparing the trials excerpt by excerpt tells a very different story. S outperforms Derek on Excerpt 1 (ZYG = 0.61 as opposed to 0.53), but this hardly surprising as it is here that Derek makes the switch to recalling *Chromatic Blues* proper (rather than an earlier rendition). With the identical Excerpt 3, S's score falls back to ZYG = 0.54, whereas Derek achieves ZYG = 0.77 (higher than S ever obtains in relation to this or any other excerpt). The main difference is in Derek's recall of the D♭ major chord (bar 1, beat 3), which S initially struggled with and then abandoned. Derek outperforms S in Excerpt 2 (where ZYG = 0.36 as opposed to 0.20) and Excerpt 4 (ZYG = 0.24 and 0.21, respectively), and here the difference between the two trials is most audible, with S producing a litany of errors as he strives but fails to recall the chromatic harmonies. Derek, on the other hand, manages to combine a partial recall of the chords (particularly at the beginning of the sequence) with enough improvisational skill to enable the music to flow with reasonable coherence. It is in Excerpt 5 that the largest quantitative disparity is found, with ZYG = 0.26 (Derek) and 0.58 (S). Derek does not move beyond the simple chromatic scale, supported with tonic and dominant chords (that are not present in *Chromatic Blues*), which served him adequately in Trials 2 and 4 (and which persist until Trial 19, following the 3 months' break). S's version of Excerpt 5, on the other hand, has all the main elements in place.

Hence, there is an uneven picture of recall across the piece as a whole, and it seems unlikely that S's earlier output could reasonably be judged to offer much of an insight into the recall and organization of the material from *Chromatic Blues* that was presumably taking place in Derek's MPM during Trials 1–4. This would require further research (of the type that is currently under way by Mazzeschi and Peskett).

The remaining trials

Trials 6–10 paint a picture of gradual improvement in S's ZYG scores, from 0.46 to 0.59, with a slight dip in Trial 9 (see Appendix 2). Advancements are generally made both within sessions and between them. Trial 8 marks an important stage in the evolution of S's recall of *Chromatic Blues*, when the basslines of Excerpts 2 and 4 emerge in their correct form for the first time. In subsequent trials the inner parts are increasingly sketched in too, though they never appear in their entirety. S's scores plateau after Trial 10 (mean ZYG = 0.60, $SD = 0.03$). There is a marked diminishment in accuracy between Trials 19 and 20, the second of which occurred after a month's break, from ZYG = 0.64 to 0.56. As we noted above, Derek's learning trajectory is quite different. His renditions improve markedly in accuracy over Trials 6–10, from ZYG = 0.49 to 0.74. This includes a gap of a month between Trials 9 and 10 over which time, as we have observed, certain entrenched inaccuracies, particularly in Excerpts 2 and 4, disappear. Then, as we saw in Table 7.5, Derek's ZYG scores plateau initially between Trials 11 and 18 (mean ZYG = 0.74, $SD = 0.02$) and again, at a higher level, between Trials 19 and 26 (mean ZYG = 0.84, $SD = 0.02$), which includes interruptions of up to 2 years. Although we did not continue to collect data from S beyond Trial 21
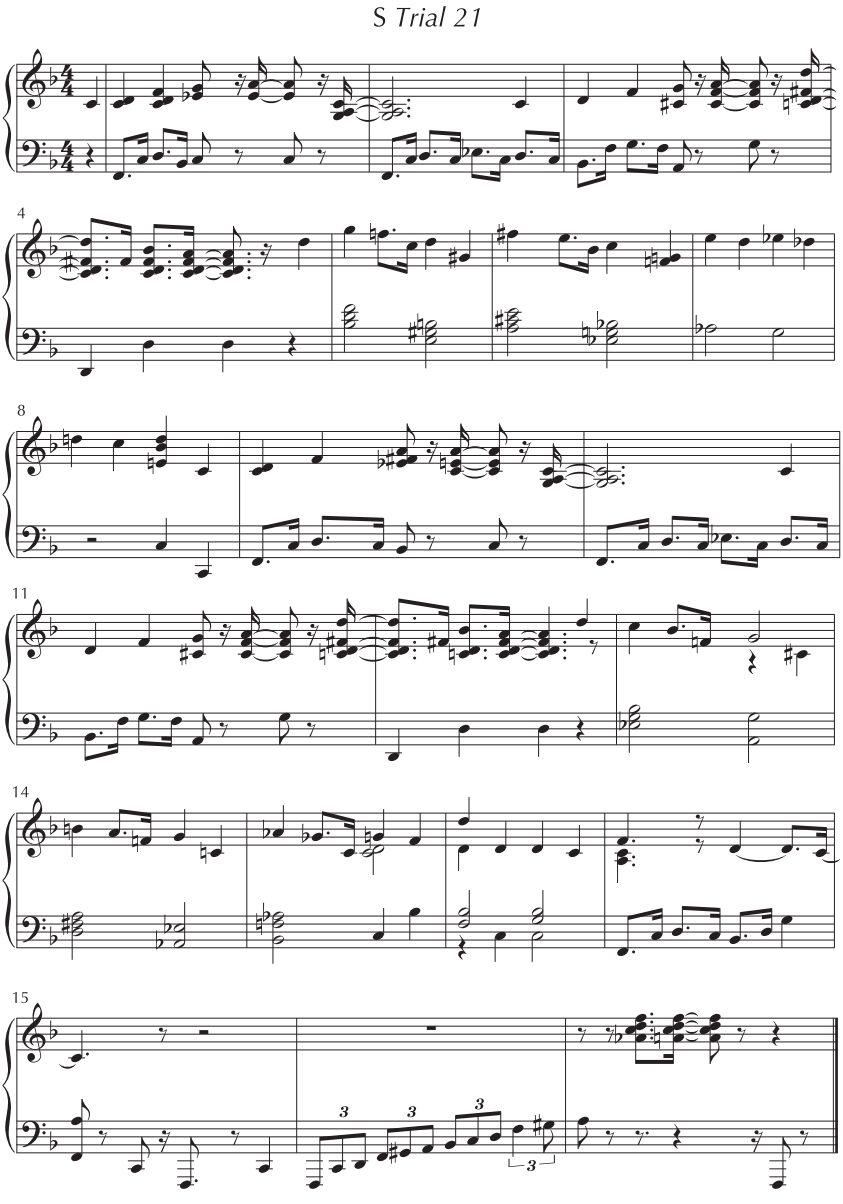
Fig. 7.40 S's 21st rendition of *Chromatic Blues*.

(see Fig. 7.40), his drop in performance following Trial 19 suggests that it is unlikely he would have continued to improve, as Derek did, with further, longer breaks (see Fig. 7.41).

This does seem to represent a fundamental disparity in the operation of the men's MPMs, though to what extent this can be ascribed to differences in them as individuals and how more broadly representative it may be of a potential distinction between neurotypical and savant musicians, only further research could reveal.

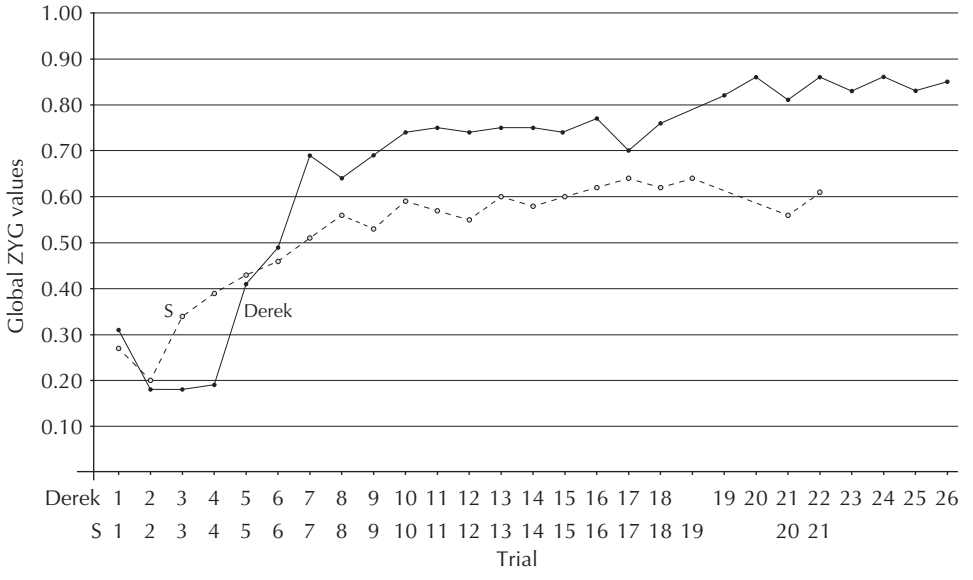

Fig. 7.41 Derek and S's differing learning trajectories of *Chromatic Blues* indicated by their global ZYG scores by trial.

The ZYG data for all S's trials, set out in Appendix 2, enable us to draw comparisons between his results and Derek's over the experiment as a whole. At the highest global level, taking into account pitch and rhythm, the three strands in the texture (melodies, inner parts, and basslines), and all five excerpts, over the 47 trials undertaken by the two men, Derek clearly outperforms S (ZYG = 0.64 and 0.51, respectively): $t(62) = 3.43$, $P = 0.001$. However, deconstructing the bigger picture indicates that the difference between them is by no means straightforward (as we should anticipate from their very different learning styles described above). It is in the realm of pitch where Derek shows the greater advantage [ZYG(P) = 0.64 as opposed to 0.47 for S], particularly (though not exclusively) in the inner parts [ZYG(P) = 0.56 as opposed to 0.25 for S]. With regard to the basslines, Derek's ZYG(P) = 0.72 and S's is 0.65. This corresponds to the differentiated performance across harmonic textures exhibited by Derek and S in the chordal disaggregation experiment (p. 229) (see Table 7.13).

The difference in rhythm is not as marked [ZYG(R) = 0.64, Derek, and 0.55, S], though it is still statistically significant $t(45) = 2.05$, $P = 0.05$. Again, it is in the middle parts where Derek dominates most [ZYG(R) = 0.50 as opposed to ZYG(R) = 0.30 for S], though melodically too Derek is superior [ZYG(R) = 0.81 for Derek and 0.76 for S]. With regard to basslines the scores are virtually identical [ZYG(R) = 0.72 for Derek and 0.71 for S].

An examination of the global ZYG scores, excerpt by excerpt (see Appendices 1 and 2), shows that Derek's recall of Excerpts 1–4 is superior, particularly in relation to Excerpts 2 and 4 (average ZYG difference = 0.24). Again, this most evident in relation to the pitches of the inner parts, which S never mastered. However, S achieves a higher level of recall than Derek in Excerpt 5 (ZYG = 0.60 as opposed to 0.50 for Derek). This could be due to a recency effect that did not have an impact on Derek's performance, or the fact that S fared better with a simpler texture (largely a single line), which, as we have seen, Derek consistently harmonized up to Trial 19.

Table 7.13 Summary of S's and Derek's efforts at recalling *Chromatic Blues*

	Total number of potential relationships		**Total number of zygons of rhythm**		**Zygonicity of rhythm**		**Total number of zygons of pitch**		**Zygonicity of pitch**		**Total number of zygonic relationships**		**Global zygonicity**	
Formula	#Rel(R or P)		#Z(R)		$ZYG(R) = \frac{\#Z(R)}{\#Rel(R)}$		#Z(P)		$ZYG(P) = \frac{\#Z(P)}{\#Rel(P)}$		#Z(Rel) = #Z(R) + #Z(P)		$ZYG = \frac{\#Z(Rel)}{\#Rel \times 2}$	
Subject	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Melody	1304	1066	1054	814.9	0.81	0.76	914.5	665	0.70	0.62	1968.5	1480	0.75	0.69
Inner parts	1992	1492	998.5	442	0.50	0.30	1113	379	0.56	0.25	2111.5	821	0.53	0.28
Bassline	1161	889	821.5	644	0.71	0.72	837.5	576.5	0.72	0.65	1659	1221	0.71	0.69
Sums/averages	4457	3447	2874	1901	0.64	0.55	2865	1620.5	0.64	0.47	5739	3521	0.64	0.51

Conclusion

This chapter uses a study involving a musical savant, Derek Paravicini, and a neurotypical jazz pianist with absolute pitch, S, to show learning, memory, recall, and creativity in action through zygonic analysis. Although Derek has exceptional musical abilities, which, among other things (through his capacity to play by ear), offer researchers a window onto his musical mind, it is posited that the essence of what he does when improvising—taking fragments and features of familiar material and reconstituting them—is typical, as the universal "pot pourri" songs of young children attest. It is hypothesized that the "pot pourri" capacity arises from the operation of a "music processing module" (MPM) in working memory, with can draw on data from both working and long-term memory, and manipulate these to form more or less original combinations and permutations of musical elements within an evolving style system. S demonstrates this too, although the parameters guiding the functioning of his MPM—including the capacity for the conscious control of certain elements—are probably different from the intuitive constraints under which Derek operates.

In summary:

- S's trend in learning *Chromatic Blues* is one of gradual improvement, in which more and more detail is gradually "sketched in" to a larger form that is grasped quickly; initially his efforts at reproduction are not musically persuasive.
- Derek, in contrast, produces a detailed and convincing musical "surface" from the beginning; though as much of what he creates initially does not correspond to the material in the original *Chromatic Blues*, this brings about a far more irregular learning journey in the early stages. Moreover, the global form of the piece is never entirely secure.
- In the long term, Derek is more successful than S in reproducing the piece, with marked improvements away from the piano over long periods of time, and extraordinarily accurate perseverance of memory over several years; S's performance in contrast diminishes with a long break.

Part IV

Applying zygonic theory to probe music-structural cognition

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Chapter 8

Why knowing what's going to happen next makes anticipation in music all the sweeter

Introduction

Expectation is key to human understanding and survival. As David Huron (2006, p. 3) puts it: "A cook expects a broth to taste in a certain way. A pedestrian expects traffic to move when the light turns green. A poker player expects an opponent to bluff. A pregnant woman expects to give birth." The ability to make judgments about the future based on memories from the past and present experiences is wired deep in our neural architecture (Kveraga *et al.*, 2007). We should not be surprised, therefore, that the importance of expectation has been recognized by researchers working in many areas of cognitive science: for example in visual perception (Engel *et al.*, 2001; Summerfield and Egner, 2009), attention (Hogarth *et al.*, 2008), memory (Whittlesea *et al.*, 2005), language processing (Otten *et al.*, 2007), and behavior (Olson *et al.*, 1996).

The notion of expectation lies at the heart of a good deal of current music theory too (Schmuckler, 1989, p. 111), often extending the paths pioneered by Leonard Meyer (1956, 1967). Meyer's ideas, rooted in *Gestalt* perception and information theory, were developed by Eugene Narmour in his "implication-realization" model (Narmour, 1977, 1990, 1992, 1996). This subsequently found some support in empirical studies (Schellenberg, 1996, 1997; Thompson and Stainton, 1996), which showed that simplification leads to little diminution in its predictive power. Moreover, von Hippel and Huron's (2000) cross-cultural analysis of melodies indicated that Narmour's key principle of "registral return" could be explained as an artifact of constraints on range. Nevertheless, the broad thrust of his theory retains its relevance in certain areas of psychomusicological endeavor, in which other approaches to expectation also continue to play a prominent role (e.g. Jones, 1981, 1982, 1992; Bharucha, 1999; Margulis, 2003, 2005a, 2007). Much of this work is summarized, consolidated, and developed in David Huron's book *Sweet Anticipation* (2006), to which extensive reference will be made in what follows.

Whatever their perspective, there is a consensus among writers that expectation works through a listener being able to predict, at any given moment, the future course of a piece of music based on his or her past experiences. These will comprise sounds that have just been heard, and may include previous hearings of the same performance (in the case of recorded music), earlier hearings of other performances, and other hearings of other pieces (Ockelford, 1999, p. 265). Curiously, most theoretical activity in the area of musical expectation has centered around the *first* hearing of a work, with the question of *repeated* hearings then having to be "explained away" as a separate issue (see, for example, Meyer, 1967, 42ff.; and Jackendoff's critique, 1991, pp. 224ff.). Yet, across styles and cultures, hearing pieces of music once is not the norm—indeed, according to Huron (2006),

99% of all musical experiences involve works that the listener has heard before.[1] Certainly, one's first hearing of a composition is not generally the preferred one. There is evidence (summarized in Hargreaves, 1986, pp. 110ff.; Smith and Cuddy, 1986, pp. 17, 18) that the relationship between favorability and familiarity can typically be represented as an inverted U, whereby the pleasure that is felt in hearing a piece grows as a listener becomes better acquainted with it, and then falls back again as boredom figures more and more in the equation.[2] Hence, as we shall see, the experience of multiple hearings should lie at the heart of a satisfactory model of musical expectation, which, for sure, should also be able to account for the capacity of listeners to make some sense of a piece the first time it is heard.

Irrespective of its source, informed prediction, and therefore expectation, is possible because music is coherent—patterned in an orderly way—which, to a greater or lesser extent, implies predictable modes of continuation, both perceptually (to the intuitive listener) and logically (to the theorist attending with an analytical mind-set). Hence zygonic theory, which considers the implicative connections that may exist between perceived sounds, offers an ideal way of modeling musical implication and expectation in theoretical terms, and in the same year that Huron's *Sweet Anticipation* appeared, I too attempted to draw together and interrogate a number of strands of thinking on expectation in music, using the conceptual framework offered by zygonic theory as a meta-analytical tool (Ockelford, 2006a). On the basis of this analysis, a new, composite theory of expectation in music was developed that acknowledges the potential implications of three sources of regularity in music: patterns *within* groups of notes, and *between* them—as encoded in short-term memory and long-term, both *veridically* and *schematically*. This is rehearsed again here and the potential phenomenological relevance of the new model to "typical" listening experiences is discussed. Finally, we consider two empirical studies that have taken place since the publication of my 2006 paper: Thorpe *et al.* (2012) and Trower (2011). A further foray (into expectation in atonal contexts) is considered in Chapter 9.

Expectations stemming from one note

Notwithstanding the importance of repeated hearings, the most straightforward scenario to model (and therefore the one that we shall tackle first) comprises the expectations that are potentially stimulated by a single unit of perceived sound, heard for the first time. What sense of continuation is this likely to arouse? That is, what can reasonably be predicted from what is heard?'[3] The fact that such prediction is possible at all implies that future perspective values

[1] This is the case even in most styles that involve improvisation (where each performance is to a greater or lesser extent unique), since extemporized pieces are generally based on standard frameworks or formulae, a knowledge of which is assumed in listeners. Huron (2006) posits a continuum upon which pieces can be placed with respect to their identity as unique and distinguishable artifacts. How expectation works for *performers* is another matter, beyond the scope of the present discussion.

[2] As long ago as 1933, Verveer, Barry and Bousefield had reached just this conclusion, with the proviso that an "intervening time interval . . . tends to enhance the pleasantness of subsequent repetitions" (Verveer *et al.*, 1933, p. 134).

[3] It is, of course, possible to imagine any perceived sonic event following any other, though in the context of music this is largely irrelevant, since a system in which all perspective values were reckoned to be equally likely (or unlikely) to follow one another—where nothing was perceived to be contingent on anything else—would be tantamount to chaos, incomprehensible, and therefore not "music," in the generally accepted sense of the term. Even "aleatory" music, in which perspective values are determined to a greater

are perceived in some way to be derived logically from those present or in the past. As we have seen, according to zygonic theory, logical derivation in music occurs through imitation, and listeners anticipate what is coming through the (typically non-conscious) projection of zygonic relationships into the future (p. 19).

In musical contexts, anticipation has two distinct and equally important components: the future is about knowing *what* is going to happen (in terms of perspective values) and *when* (cf. Wittmann and Pöppel, 1999–2000, p. 13).[4] The projection of "what" can occur in any perspective domain, except onset or the perceived location of the sound source. It can result from the ideation of 'perfect' or 'imperfect' relationships (between identical or similar values): the greater the degree of perfection, it is hypothesized, the surer the expectation. From a single value of onset, the projection of "when" can occur only through an imperfect zygonic relationship (since in this domain, perfection equates to simultaneity), corresponding to the fact that if a second value is to be musically pertinent to the first—if it is to constitute anything more than a further isolated perceived sonic experience—then it must occur within its perceived temporal ambit. Hence the musical implications and expectations that potentially stem from a single unit of perceived sound may be modeled zygonically in abstract terms as shown in Fig. 8.1.[5] [6] [7]

Figure 8.1 shows expectation occurring through a perfect zygonic relationship in domain X, which yields a single potential value. In domain Y a range of future values is implied through an imperfect zygon. No sense of contingency operates in domain Z; that is, the second value cannot be anticipated on the basis of the first. However, the zygonic bonds that do exist between the two units of perceived sound are sufficient for one as a whole to be deemed to be derived from the other, and thus for the second to be anticipated *as a whole* on the basis of the first—something

or lesser extent by chance—as, for example, in Cage's *Variations I* (1958) and *Variations II* (1961)—and, ironically, compositions whose values are in many respects controlled through transformations that are beyond the bounds of our auditory processing capacities, such as Boulez's *Structure Ia* (1951/1952), which may, at the first blush, sound chaotic, have sufficient regularity to cohere, at some level, as single extended entities in the domain of perceived sound. In *Structure Ia*, for example, contrasts between isolated sonic "points" become the norm, and these follow each other within a narrowly defined temporal range. As Ligeti says (1958/1960, p. 61): "the structure . . . is seen to be something highly variable and chancy, comparable to the way the network of neon lights flashes on and off in a main street; . . . but as the separate lights flash on and off, they combine to form a statistical complex." The cognition of "atonality," in which composers deliberately seek to avoid pitches following one another according to the probabilities associated with style systems, in effect forming musical "antistructure," is considered in Chapter 9.

[4] *Where*—the perceived location of the source of sound—is also an important factor, but one that has rarely constituted an issue in studies of musical expectation, since it is generally constant or *visually* predictable during the course of a piece—though see Huron's comments (2006, pp. 6, 7) in relation to the spatial works of Giovanni Gabrieli and Karlheinz Stockhausen; also Ockelford (1999, pp. 274ff.).

[5] Note that units of sound of perceptible duration may engender expectation that occurs *within* their perceived temporal span (see Ockelford 1999, pp. 121ff.).

[6] In reality, when listening to music, it is impossible to discount past experiences. At the most basic level, the very fact that orderly continuations have happened in the past means that these promote further rational prognostication.

[7] Although imperfect relationships of onset may seem a tenuous basis on which to construct expectation in the perceived temporal domain, the fact that one note follows another within a relatively short period of time is a fundamental property of music. Indeed the clearest signal that a movement or piece has ended is an extended period of silence (see Ockelford, 1999, pp. 322ff.).

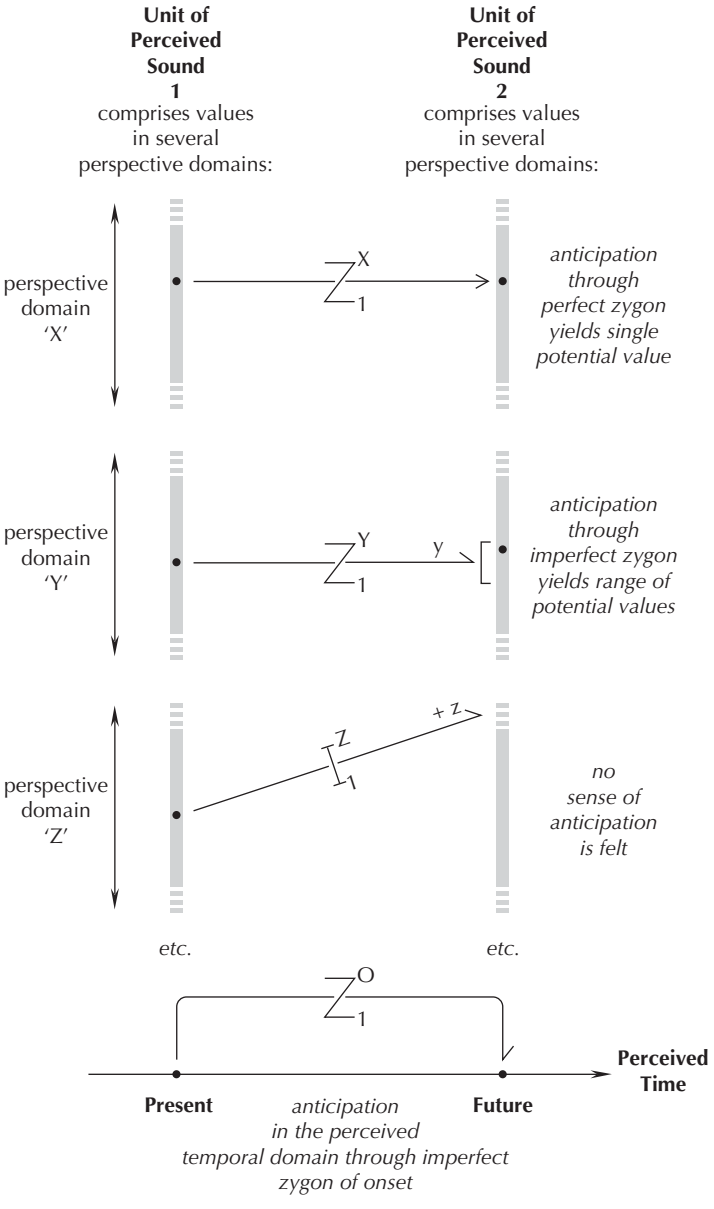


Fig. 8.1 Zygonic model of musical expectation stemming from a single unit of perceived sound.

that occurs, we may suppose, through a form of auditory "binding" (cf. Roskies, 1999; Huron, 2006, p. 124). Hence prospective contrast is conceivable within an overall sense of coherence (cf. Ockelford, 2004, p. 57). Even without this freedom (if all domains were zygonically linked), from any given perceived sonic unit a diversity of possibilities exists that may be perceived as being contingent upon it: a theoretical position which, as we shall see, is supported by empirical evidence. Take, for example, the single, short note that opens Schoenberg's *A Survivor from Warsaw* (1957). Orderly continuations in all perspective domains can be predicted as shown in Fig. 8.2 (using

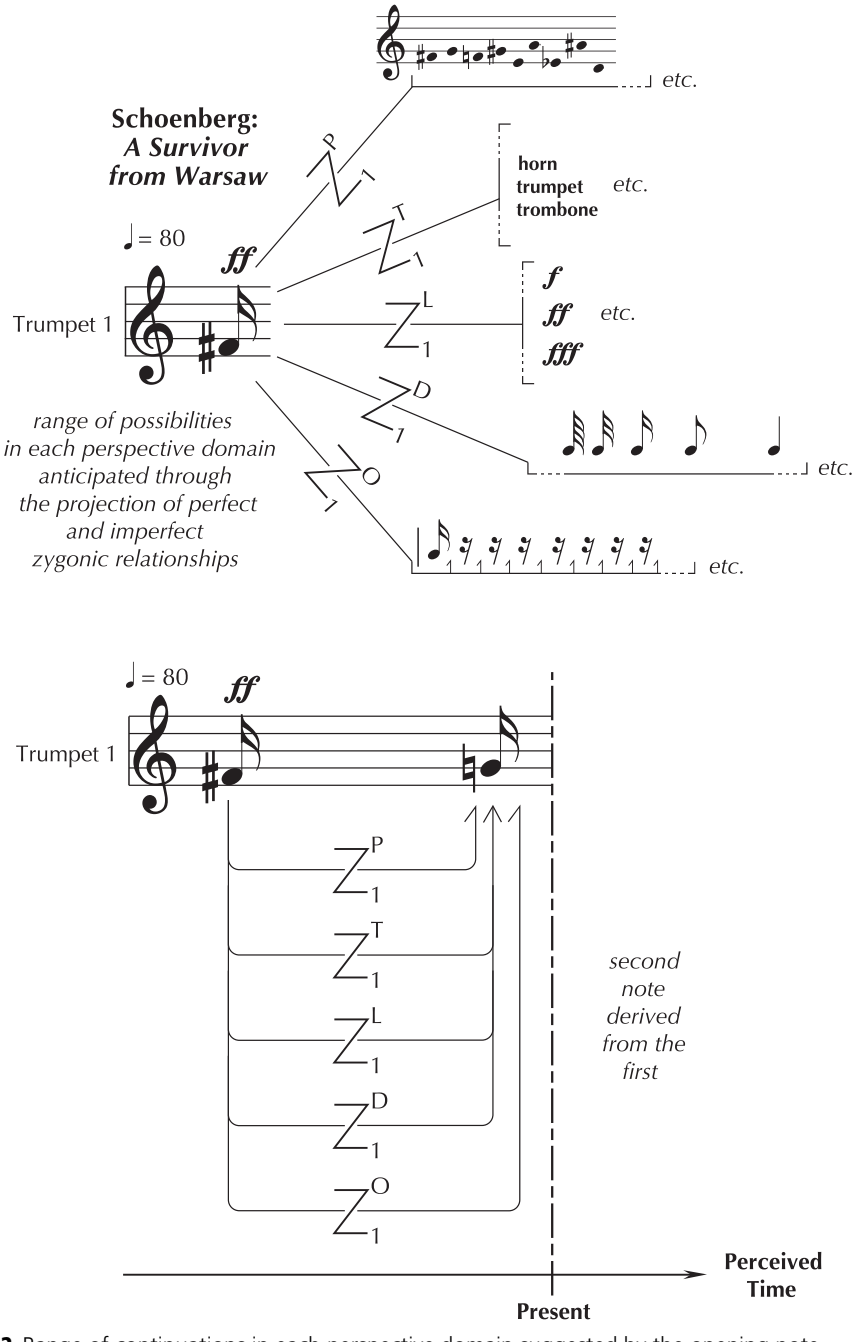


Fig. 8.2 Range of continuations in each perspective domain suggested by the opening note of *A Survivor from Warsaw*, and the option selected by Schoenberg.

perspective quanta typically associated with Western art music of the first half of the 20th century) (see also Fig. 3.3).

Schoenberg's actual choice (also shown in Fig. 8.2) was a perceived sonic event that lies well within the range of the aural logic set out, and, in retrospect, one that offers a mode of continuation that is entirely coherent. However, there is no reason why this particular cluster of perspective values should have been predicted from the opening note in preference to a number of others. Hence, one has to question what the role of expectation in this, the initial hearing of the very opening of a piece, is, beyond indicating in general terms likely future directions in each perspective domain. Of course, this is an extreme, and fleeting, scenario; one, it could reasonably be argued, that does not have much bearing on how implication and expectation typically work in music.[8] Is it the case, for example, that prognostication is surer on the basis of *two* values, which provide more information, and potentially initiate *inter*perspective trends at the primary level?

Expectations stemming from two notes

Certainly, this is the view of Eugene,[9] as expressed in the "two universal formal hypotheses" that underpin his "implication–realization" model of melodic perception (for example, Narmour, 1990). He postulates (Narmour, 1990, p. 3) that:

1 A + A → A (or, a + a → a); and
2 A + B → C (or, a + b → c).

Narmour unpacks Postulate 1 thus (Narmour, 1990, p. 3):

> When form (*A* + *A*), intervallic patterns (A + A), or pitch elements (a + a) of a given melody are similar (*A*, A, or a), the listener subconsciously or consciously infers some kind of repetition of pattern, element, or form.

Postulate 2 translates as:

> When form, intervallic patterns, or pitch elements are different (*A* + *B*, A + B, a + b), the listener subconsciously or consciously perceives some implied change in form, pattern or element (*C*, C, or c).

Postulate 1 is derived from the *Gestalt* principles of similarity, proximity, and "common direction," and is applied by Narmour to three aspects of the domain of pitch: "pitch specificity," "intervallic motion," and "registral direction" (which may be up, down, or lateral; Narmour, 1990, pp. 75, 76). In terms of the present theory these three dimensions may be expressed as shown in Fig. 8.3. Each of these dimensions is capable of bearing musical implication. Take, for

[8] As I suggest in my review of *Sweet Anticipation*, in the first few seconds of initially hearing an unfamiliar piece—particularly one that begins with a rapid succession of notes—the listener may have no specific expectations at all. This is shown in my phenomenological account of listening to the opening bars of Scarlatti's harpsichord sonata K. 18 without the score, a piece that I could not remember having heard before. On this occasion, "I felt that I was principally caught up with the business of taking in what was to me a novel arrangement of notes, and the effort of grounding my ongoing perceptions within the metrical and tonal frameworks that were implied (in order to make sense of what was going on) took up all of my conscious attention. If anything, the mode of listening I intuitively adopted appeared to me to be slightly retrospective . . ." (see Ockelford, 2008a, p. 371).

[9] Narmour's model centers on *pitch*, and, due to limitations of space, a similar focus will be adopted in this chapter (with the assumption that musical implication and expectation work in comparable ways in other non-temporal perspective domains).

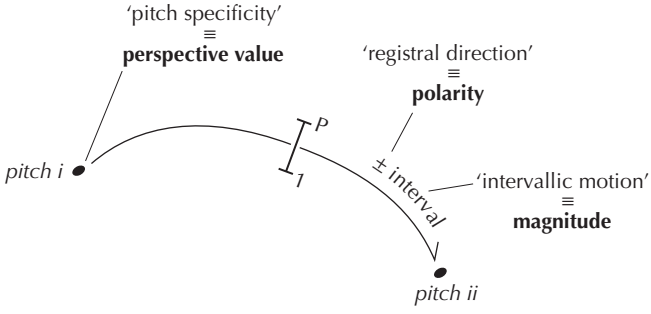


Fig. 8.3 Narmour's three dimensions of pitch in melody expressed in terms of zygonic theory.

example, the repetition of two notes (say, C–C). Narmour (1990) hypothesizes that these imply the following:

> the same pitch (= similarity; i.e., a second pitch like the first except for its temporal position), (2) the repetition of the same interval (= proximity; i.e. a third pitch the same unison distance from the second pitch as the second pitch is from the first), and (3) the same registral direction (= common direction; i.e. laterally or "sideways").

That is,

> all other things being equal, the listener will, on hearing the pitches C–C, subconsciously expect another C.

But is this all that he or she can reasonably be anticipated to expect? Recent empirical findings are discussed later. At this stage, we analyze whether the reasons for expectation set out by Narmour are accurate and complete on a *theoretical* level. In zygonic terms, Narmour's hypothesis can be interpreted as shown in Fig. 8.4.

"Interval" and "registral direction" are implied through a secondary zygonic relationship of pitch and "pitch specificity" is implied through a primary zygon. In addition, note that temporal position is implied through a secondary zygon of onset. Putting these findings in the context of the zygonic model set out in Fig. 8.1, which hypothesizes that a single value is sufficient to induce expectation, it is evident that pitch *iii* can additionally be derived directly from pitch *i*, although, of course, its onset will be related with a greater degree of imperfection to that of the first (see Fig. 8.5; see also Fig. 3.5).[10] [11]

The model shown in Fig. 8.1 then proposes that anticipation may occur through *imperfect* zygonic relationships, and Narmour's hypothesis can be extended to encompass this possibility. This accords with the admission elsewhere in Narmour's theory that implication can result in *similarity* (and not just *sameness*). For example (Narmour, 1990, p. 86):

> If interval (A^0) composed of two proximate pitches lying on the same plane or in ascending or descending directions occurs ($a^0 + a^{1,2,3,\cdots}$), then the listener subconsciously expects the same interval (A^0) or a similarly sized interval (A^1) in the initial registral direction.

---

[10] The importance of relationships between discontiguous notes is, however, acknowledged by Narmour elsewhere, in his concept of "registral return"—"aba" (see later).

[11] Moreover, if one C is able to imply another through the *Gestalt* principle of similarity, as Narmour states, then, by extension, why are *two* initial events necessary in the formulation of his first postulate ($A + A \rightarrow A$, or $a + a \rightarrow a$)? In fact, one is sufficient: that is, $A \rightarrow A$, and $a \rightarrow a$.

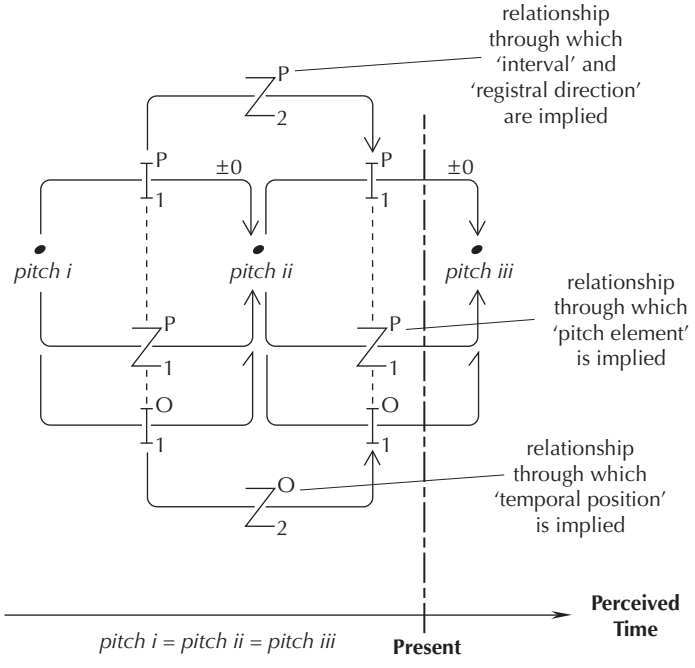


Fig. 8.4 Zygonic meta-analysis of the implications arising from two repeated pitches (after Narmour, 1990, p. 75).

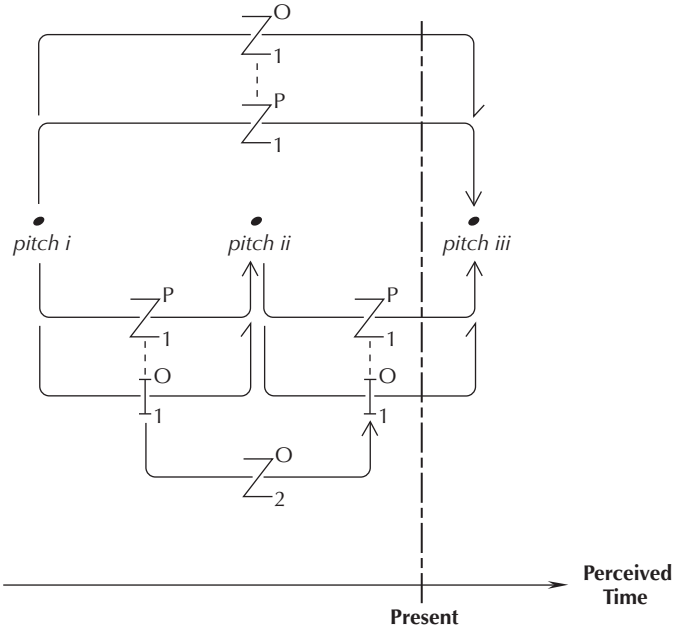


Fig. 8.5 Additional zygonic relationships linking pitch i and pitch iii implicatively.

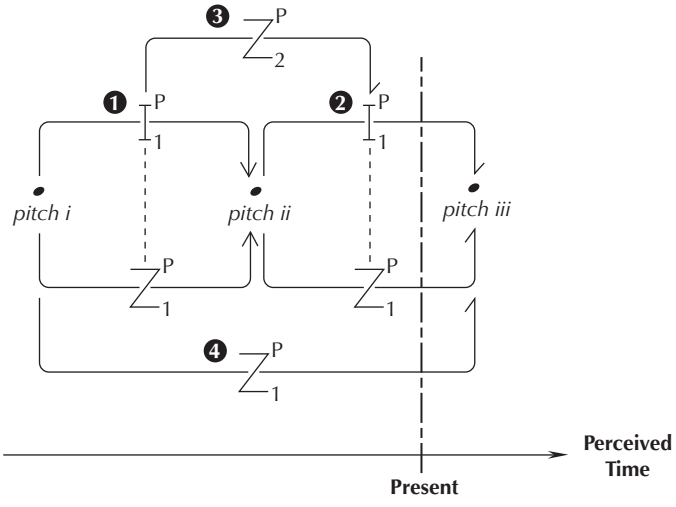


Fig. 8.6 Extension of Narmour's hypothesis through the incorporation of imperfect zygonic relationships.

Where the initial interval is between identical pitches (1 in Fig. 8.6), surely it follows that this can imply, through an imperfect secondary zygon (3), a relationship (2) (in either registral direction) between near-identical values? Moreover, similarity underpins Narmour's concept of "near registral return" (aba^1), which occurs when "a discontiguous pitch register nearly returns to the same register as the initial pitch" (Narmour, 1990, p. 131). This possibility, of imitation between discontiguous events, is captured in zygonic relationship (4) (see Fig. 8.6).[12]

To consider what the construct $a + a \rightarrow a'$ may mean in musical terms, consider, for example, the opening three notes of the theme of the second movement of Sibelius's *Karelia Suite*. Here, the third note of the melody is distinct from the first two, and the interval between adjacent scale steps that links them is of subsequent structural importance. At the same time, however, the F, which, within the diatonic system is as close as it is possible to get to the preceding Es, clearly owes something of its derivation to them, and is well within the range of coherent continuations which they imply (see Fig. 8.7).

Hence two notes of the same pitch imply a *range* of future options. Just how far this range can extend depends on where the boundaries of imperfect zygonic imitation are considered to lie, although these cannot be determined in a hard and fast way, since the cognition of derivation is dependent upon context (Ockelford, 1999, p. 92). However, broad markers can be put down that are based, for example, on Aarden's empirical work (Aarden, 2003, p. 49), which indicates, in general terms, that the strength of expectancy wanes with decreasing pitch proximity over the span of 11 semitones, with a pronounced reversal of this trend at the octave. Moreover, the tendency that Aarden identifies is broadly reflected in the cross-cultural distribution of intervals in

[12] Note, however, that Narmour considers registral return to be a "non-implicative pitch relation" (Narmour, 1990, p. 127). It is not clear why this should be so, since the concept of "return" embodies the reiteration of an event already heard: that is, the second appearance of a note is reckoned to derive from the first—it is perceptually implied by it.

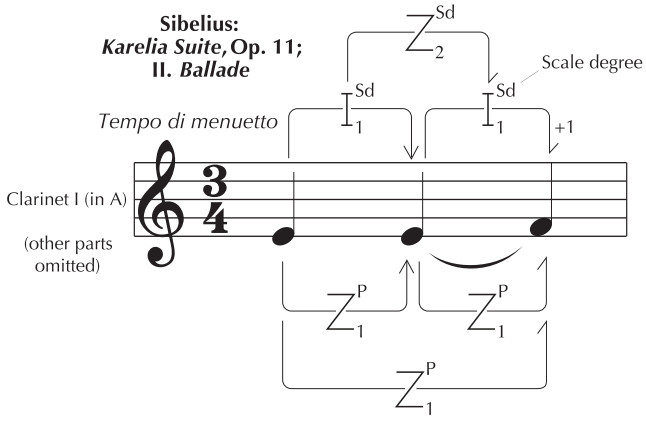


Fig. 8.7 Example of the construct a + a → a′ in the domain of pitch.

music (Huron, 2001b, p. 205). Hence it seems reasonable to assume that the range of anticipation through imperfect imitation will, other things being equal, typically span at least an octave in either direction from the pitch concerned. Note, however, that Narmour regards similarity rather more restrictively than this: at most, up to a tritone from a given pitch (Narmour, 1990, pp. 78ff.).

A further scenario considered by Narmour is that of two notes of *similar* pitch, separated by a small interval, for example, C–D: what implications do they generate? The fact, according to Narmour, that there are three dimensions of pitch that are of perceptual relevance ("pitch specificity," "intervallic motion," and "registral direction") means that a number of continuations are implied. For example (Narmour, 1990, p. 75):

> Given C major, the E in the ascending pattern C–D–E, for instance, is, all other things being equal, a realization of an implication of registral direction (the ascent of C–D followed by the ascent of D–E), of pitch (E was implied, not, say, E♭), and the implication of interval (the M2 of C–D followed by the M2 of D–E).

Zygonic analysis confirms that E offers one logical continuation of the interval C–D and its registral direction (Fig. 8.8). However, the issue of pitch specificity (that is, E or E♭) cannot be resolved from the interval C–D alone, but requires a fuller intervallic context (afforded by previous material, or harmonically). As Narmour observes (1990, p. 99):

> though implication of registral direction (up or down) is as specific as that of iteration, the size of the interval and concomitantly the specificity of pitch are often not so clear, particularly in the absence of a contextually defined mode. But, regardless of the implicative specificity of pitch, when realization of registral direction (A + A), intervallic similarity (A + A), and pitch proximity (a + a) occur, we say that a process [P] takes place . . . [if] X – Y equals m3 or less . . .

In terms of zygonic theory, this means that a primary interperspective value of pitch can imply a further primary interperspective value, provided that the difference between the two is a minor 3rd or less (although idiostructural context can affect this; see Narmour, 1990, p. 81) (see Fig. 8.9).

A further potential implication of C–D identified by Narmour yields the up–down pattern C–D–C, which is "a realization of intervallic motion (M2 plus M2), but not registral direction (up is followed by down) or pitch (C follows C–D instead of E)" (Narmour, 1990, p. 76). Figure 8.10 shows this in zygonic terms.

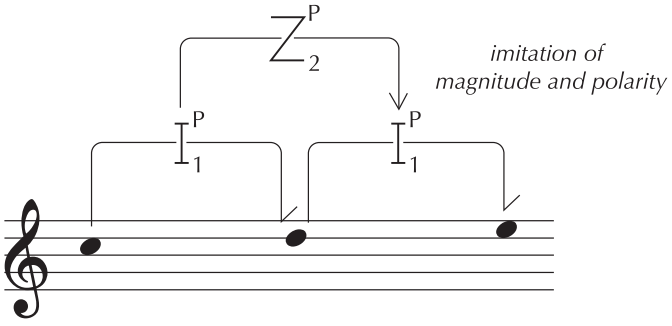


Fig. 8.8 Zygonic meta-analysis of Narmour's anticipated implication from C–D (ascending).

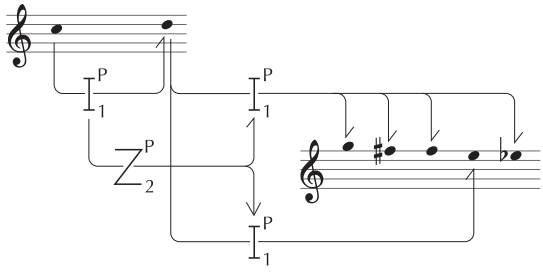


Fig. 8.9 Range of implicative possibilities stemming from an ascending major 2nd (after Narmour, 1990, p. 99), expressed in zygonic terms.

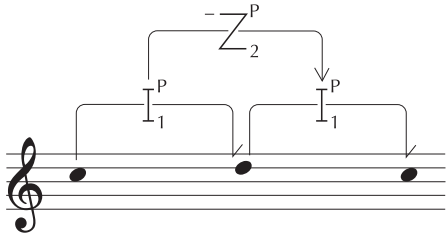


Fig. 8.10 Zygonic meta-analysis of Narmour's 'realization of intervallic motion . . . but not registral direction' (Narmour, 1990, p. 76).

Elsewhere (Narmour, 1990, p. 130), he cites the pattern C–D–C as an example of "registral return" (aba), which conceptually and symbolically implies the zygonic connection shown in Fig. 8.11. Again, imperfect repetition ("near registral return") is possible. Here, Narmour considers the boundary between similarity and dissimilarity to be "when the difference between two intervals equals a plus/minus major second or less" (Narmour, 1990, p. 131). Figure 8.12 shows this in zygonic terms.

So much for the implications (and "non-implications" in the form of registral return) identified by Narmour. Zygonic theory suggests other possibilities for logical continuation, which may but need not be realized. For example, the inversion of the ascending M2 may be rooted on the first C,

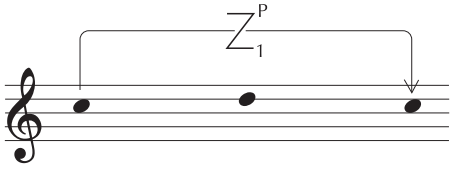


Fig. 8.11 Zygonic meta-analysis of 'registral return' (after Narmour, 1990, p. 130).

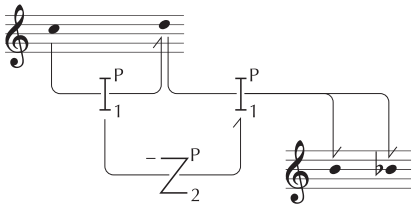


Fig. 8.12 Zygonic meta-analysis of 'near registral return' (after Narmour, 1990, p. 131).

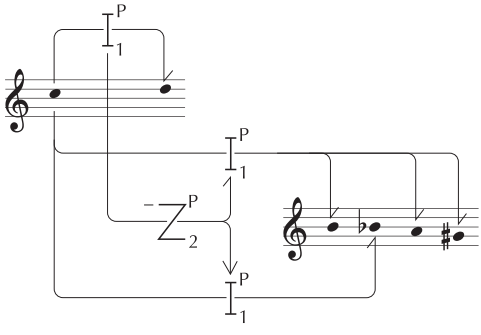


Fig. 8.13 Melodic inversion rooted on the first C.

giving the following range of outcomes (assuming, for imperfect relationships, Narmour's limit of a M2 difference between model and imitation, although this constraint is not implicit in zygonic theory) (see Fig. 8.13). Then, the first pitch, C, may imply a *range* of others that are similar, while the second pitch, D, may likewise suggest others that are similar or the same (see Fig. 8.14). Lastly, the interval between the first pitch and the third may be an inversion of that between the second and the third, forming the sequence C–D–C♯ (or D♭) (Fig. 8.15).[13]

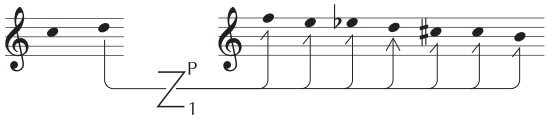



Fig. 8.14 Primary zygonic implications arising from the D.

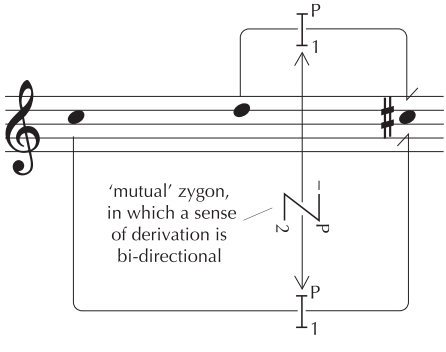


Fig. 8.15 Implication arising from inverse secondary zygon.

[13] An unusual combination, though one that is found, for example, in Sousa's *King Cotton March* (1923), the opening of the third theme, where the first note is the dominant.

A third scenario depicted by Narmour is that of an initial "large" interval, as framed, for example, by the pitches C–A (ascending). According to his second postulate (A + B → C), this initial difference implies change: specifically, melodic "reversal." This refers "both to an implied change of registral direction and to an implied reduction in the size of the interval to follow. . . . for a satisfactory realization, the interval following the initial one must satisfy the definition of intervallic differentiation following registral change, namely, difference of a minus minor third or more . . ." (Narmour, 1990, pp. 151, 153). Accordingly, there are seven possible realizations of reversal arising from C–A (see Fig. 8.16).

However, this proposition is not supported in the current theoretical context, as zygonic analysis shows. Essentially, Narmour's conjecture is that an initial difference implies a further (and distinct) difference; or, in terms of the present theory, that one non-zygonic relationship implies another. This prospect can at least be captured conceptually and symbolically, though musically it is, of course, so open-ended as to be of little value, as we shall see in Chapter 9 (see Fig. 8.17).

What *is* possible theoretically, though, is for the pattern of reversal (as defined by Narmour) itself to be imitated from a past occasion or occasions (Fig. 8.18). However, this is something quite different from the hypothesis posited by Narmour: rather than the "bottom-up" processing of an individual syntactic primitive from an incoming signal, it is the "top-down" processing of a conformant, albeit schematic, style structure (to paraphrase Narmour, 1990, p. 53). That is to say, zygonic theory suggests that "reversal" is possible, but functioning as a schema rather than a syntactic primitive (Narmour, 1990, p. 55).

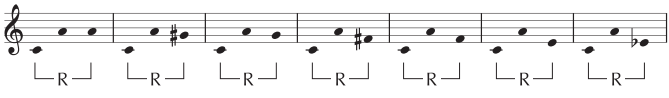



Fig. 8.16 The realizations of reversal arising from C–A (after Narmour, 1990, p. 154).

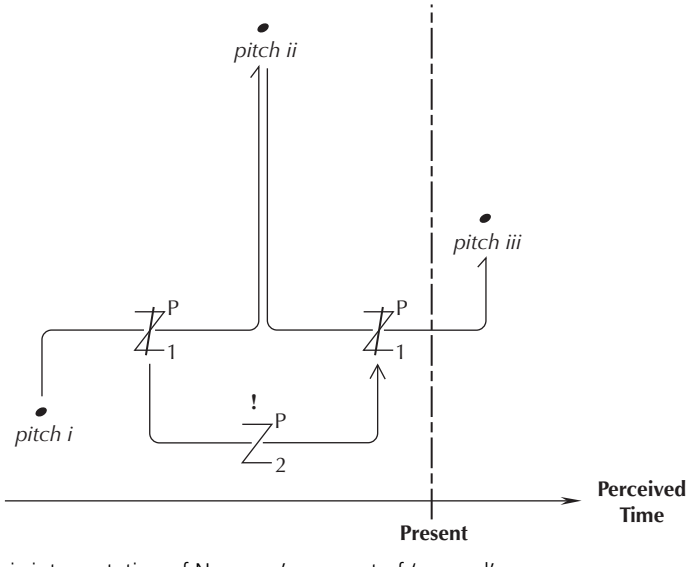


Fig. 8.17 Zygonic interpretation of Narmour's concept of 'reversal'.

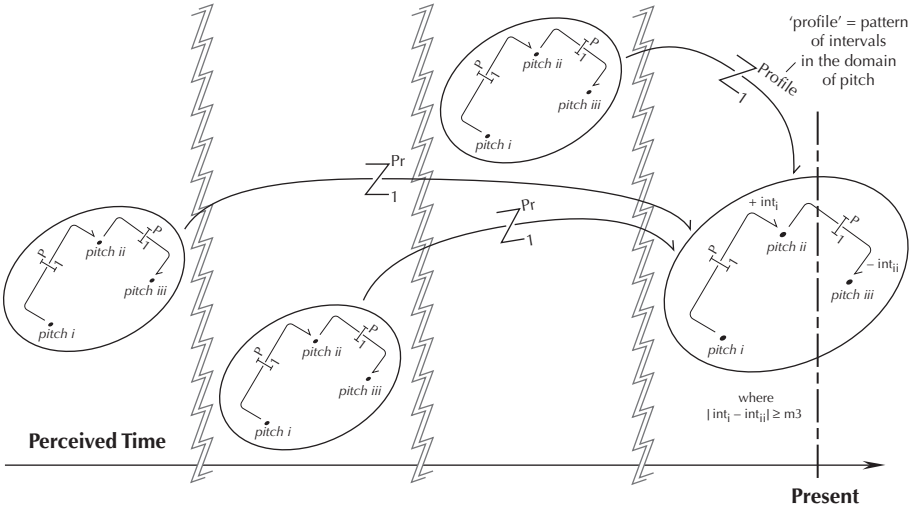


Fig. 8.18 Expectation of 'reversal' stemming from previous occurrences.

Expectation that occurs through organization of this type *between* groups is considered in some detail later. This apart, the interval C–A does, of course, bear potential *within*-group implication, which can be defined and analyzed in zygonic terms. The closest such an implication comes to Narmour's concept of reversal occurs when the interval between the two pitches is held to be the silent expression of the imagined movement of a single value from the first location in the perspective domain (C) to the second (A) through melodic "gap-fill" (cf. Gjerdingen, 1994).[14] That is, as they attend (consciously or non-consciously) to the leap between the two notes, it may be that listeners mentally sweep over the range of values between the two, any of which can function implicatively through the active projection of a primary zygonic relationship. Given the discrete steps of the chromatic scale, the possibilities are as shown in Fig. 8.19.

This series of potential realizations, extending down to D, D♭, and C, has a greater range than the outcomes of "reversal" identified by Narmour. In fact, these additional values, which fall within the ambit of registral return, are specifically excluded from Narmour's concept, since, in his terms, they represent a denial of intervallic motion ("magnitude" in current terminology). That is to say, if listeners are hard-wired, upon hearing an ascending major 6th, to expect a smaller, descending interval to follow, then to encounter instead a return to the first note (C) will come as something of a surprise (Narmour, 1990, p. 198). According to Narmour, it is only in retrospect that the sequence C–A–C can be heard as intervallic duplication. But is this logical? If an interval can be reckoned "after the event" to have implied an imitation of itself, why should this possibility not be recognized prospectively? (That is not to say, of course, that such anticipation necessarily *would* occur, particularly on a first hearing, but that it *could* take place.) Hence, implications for "return" exist as shown in Fig. 8.20, arising from primary and inverse secondary zygonic relationships.

Similarly, in the looking-glass world of reversal, Narmour interprets the three-note ascent C–A–F as a denial of intervallic motion *and* registral direction, although in retrospect this pattern

[14] See also Cohen (1991), who demonstrated that opening fragments of Bach preludes were sufficient for listeners mentally to re-create the scalar frameworks that pertained to their respective tonalities.

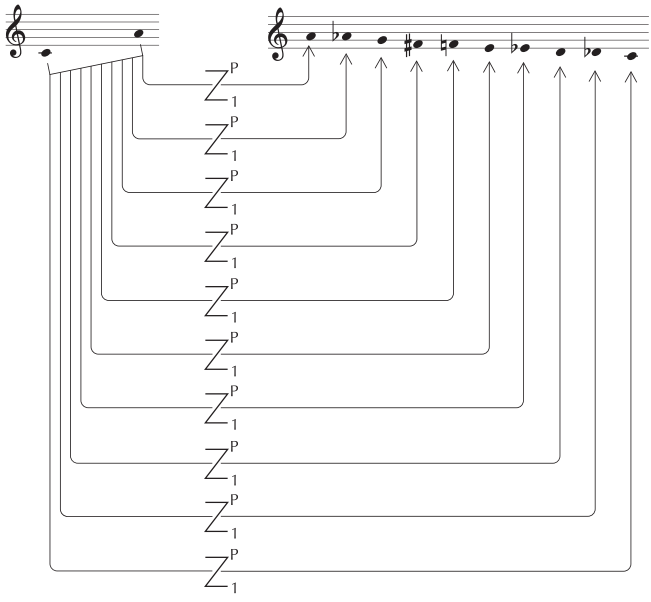


Fig. 8.19 Expectations arising from the principle of 'gap-fill'.

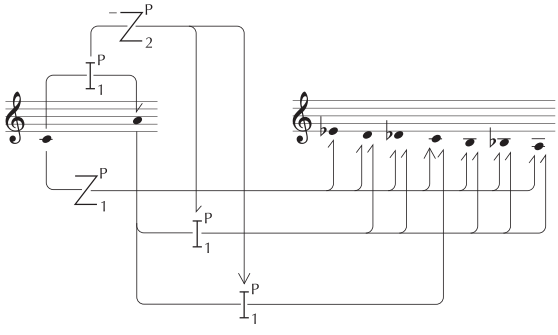


Fig. 8.20 Expectations arising from the principle of 'return'.

can be heard as melodic "process." Again, however, it would seem reasonable to suppose that if an event can be recognized as having been implied once it has occurred, then it can also be felt to be indicated *before* it happens. Hence, the following implications are possible too, although the particularly large leap between notes one and three of the sequence (where no primary zygonic connection exists) means, as we shall discover (cf. Fig. 8.31), that these are likely to be relatively tenuous in perceptual terms (see Fig. 8.21).

Lastly, there are a number of additional implications suggested by zygonic theory: imitation of the first pitch or second pitches (C or A), perfectly or imperfectly (cf. Fig. 8.14; see Fig. 8.22); inverse imitation of the interval between the first pitch and the third, and the second pitch and the third (cf. Fig. 8.15; see Fig. 8.23); and imitation through inversion of the ascending interval (cf. Fig. 8.13; see Fig. 8.24). Observe, however, that this scenario entails a large interval between notes two and three of the sequence, and so once more (cf. Fig. 8.21), while there is a logic to such organization, in most contexts it seems likely that the implication would be phenomenologically weak.

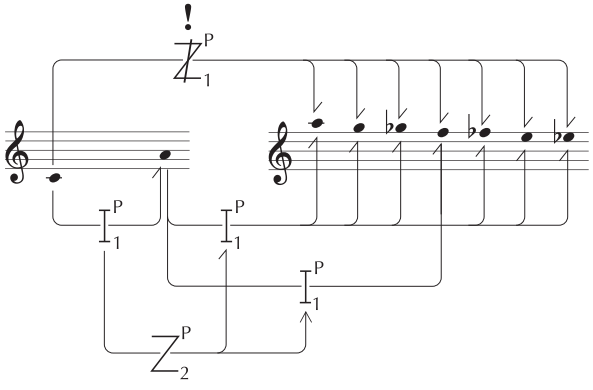


Fig. 8.21 Expectations through melodic 'process' from a large initial interval.

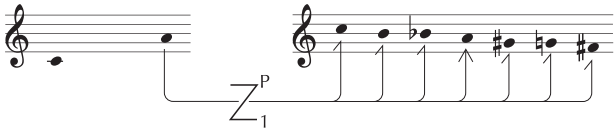


Fig. 8.22 Primary zygonic implications arising from the A.

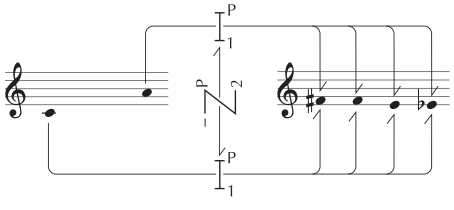


Fig. 8.23 Expectations potentially arising through inverse secondary zygonic relationships, linking primary relationships rooted on C and A.

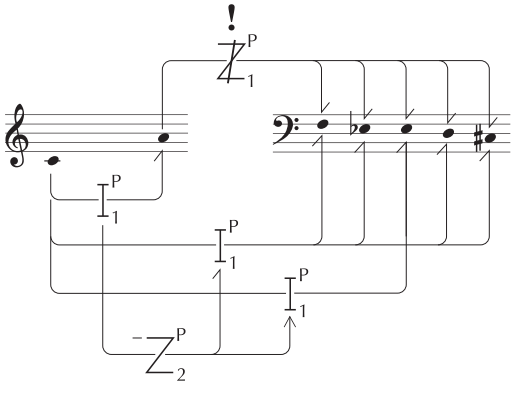
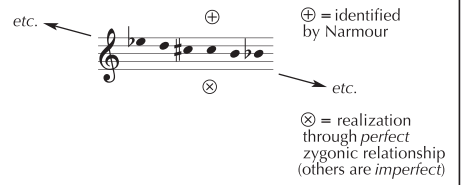
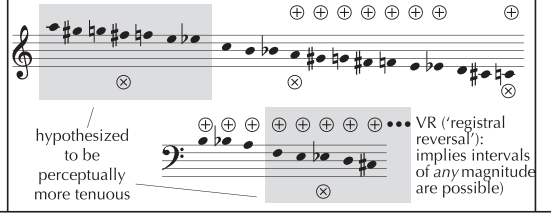


Fig. 8.24 Expectations potentially arising through inverse secondary zygonic relationships, linking primary relationships rooted on C.

In summary, then, potential realizations in the domain of pitch predicted from two initial values (which may be the same, similar, or distinctly different) deriving (a) from Narmour's model and (b) through zygonic analysis are as follows (see Fig. 8.25). According to Narmour, two identical pitches yield one realization; two a tone apart offer eight; and two separated by a major 6th in excess of 16. In contrast, zygonic theory suggests one, five, and four logical continuations,

implications arising from	potential realizations	sources		*total* number of realizations	number of *different* realizations			
		Narmour (1990)	*Current chapter*		Narmour (1990)	zygonic (perfect)	zygonic (imperfect)	zygonic total
		p. 75	Figure 8.4	6	1	1	5	6
		pp. 75 99 130 131	Figures 8.8 8.9 8.10 8.11 8.12 8.13 8.14 8.15	26	8	5	7	12
		pp. 154 198	Figures 8.19 8.20 8.21 8.22 8.23 8.24	>53	>16	4 2	24 14	>28 >16

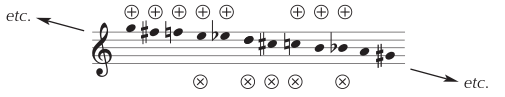



Fig. 8.25 Potential realizations from two pitches, derived from Narmour (1990) and zygonic meta-analysis of his hypotheses.

respectively (utilizing perfect relationships only) and 25, 27, and 34 (through perfect *and* imperfect relationships) or, in the last case, 16, if those hypothesized to be perceptually tenuous are excluded. Clearly, whichever model one adopts, two pitches typically imply a range, sometimes a wide range, of subsequent values. Despite similarities in the models, there are key differences too, and it is pertinent to enquire which more faithfully represents cognitive processing. One approach to answering this question is to ascertain which model corresponds more closely to relevant empirical findings from the field of music psychology.

The work of Schellenberg (1996; re-analyzed in 1997) provides a useful starting point. Investigating the implication–realization model, his data led him to develop a simplified model of expectancy in melody, with just two factors. The first is "*pitch proximity*". This states that "when listeners hear an implicative interval in a melody, they expect the next tone to be proximate in pitch to the second tone of the implicative interval (i.e. they expect a small realized interval)" (Schellenberg, 1997, p. 309). This accords entirely with zygonic theory (cf. Figs. 8.1, 8.2, 8.4, 8.6, 8.7, and 8.10). Figure 8.26 illustrates this in general terms.

Moreover, Schellenberg finds that when "a melody departs from conjunct motion, smaller leaps in pitch are less unexpected than larger leaps" (Schellenberg, 1997, p. 311). That is to say, perfect or near-perfect repetition is perceived to be the most likely continuation from a given value, followed by larger differences, whose probability decreases as a function of their size. On the whole, this accords with the work undertaken subsequently by Aarden, cited above, although his finding that exact repetition was relatively unexpected (Aarden, 2003, pp. 52, 53) is not predicted by zygonic theory, nor does it tie in with the statistics of melodic intervals that are available cross-culturally (Huron, 2001, p. 25). The finding may, perhaps, have been a feature of Aarden's experimental design, given that the unison, despite being a single intervallic category, had equal status with all magnitudes of ascent and of descent, each comprising many different classes of interval (see Fig. 8.27).

Schellenberg's research leaves open the question of whether (as Narmour claims) the pitch-proximity principle stems from a hard-wired perceptual predisposition or from a learned schema. Because small intervals are common in melodies, it seems to reasonable to assume that listeners will learn to expect that these are "typical" (Huron, 2006). However, the fact that small intervals predominate across cultures (see, for example, Dowling and Harwood, 1986, pp. 155ff.; Ockelford, 1999, pp. 460ff.; Huron, 2006, pp. 74ff.) also suggests an innate processing preference (Schellenberg, 1997, pp. 310, 311). It may well be that both forces play a role in expectation in the domain of pitch through proximity (see Fig. 8.28).

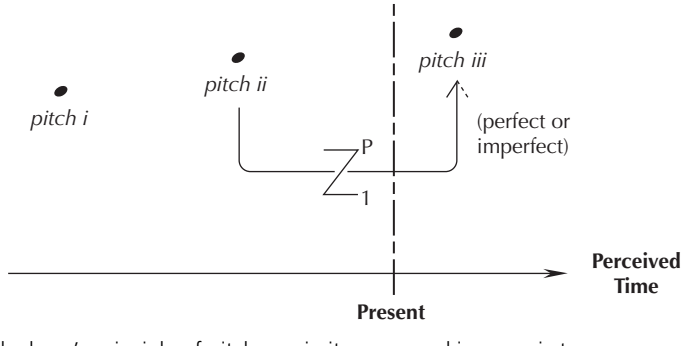


Fig. 8.26 Schellenberg's principle of pitch proximity expressed in zygonic terms.

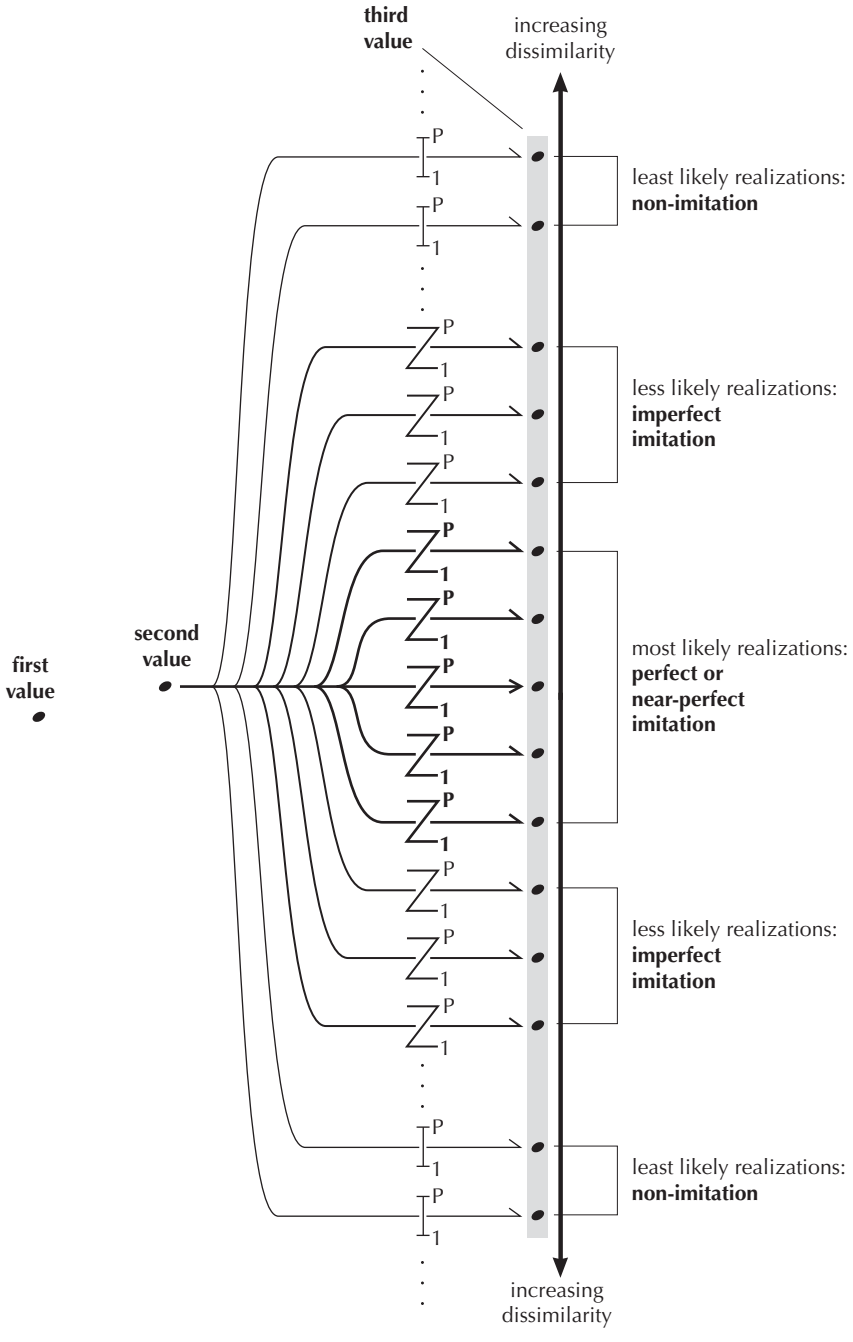


Fig. 8.27 The perceived probability of realization is related to closeness of imitation.

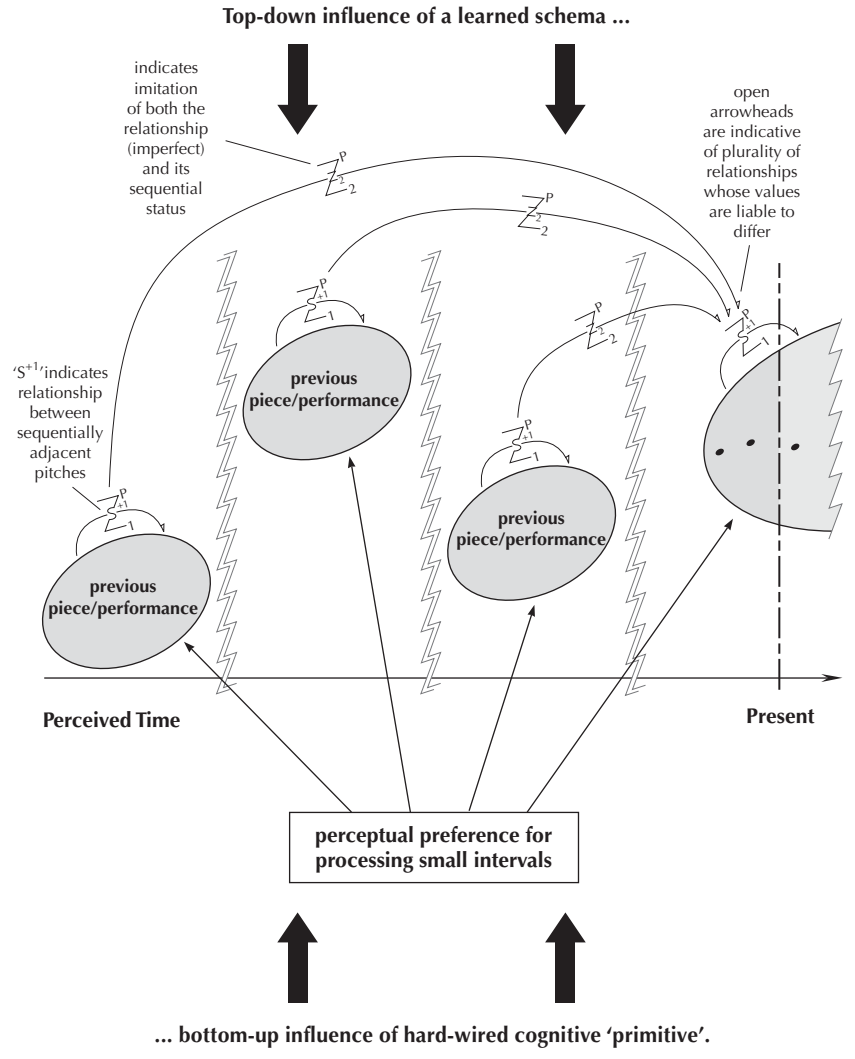


Fig. 8.28 Zygonic and non-zygonic forces at work in the expectation of pitch proximity in melodies.

Schellenberg's second principle is that of *pitch reversal*, which (Schellenberg, 1997, p. 312)

> extends the pitch-proximity principle to relations between noncontiguous tones. In addition to expecting the next tone in a melody to be proximate in pitch to the tone heard most recently, the principle claims that listeners often expect the next tone to be proximate in pitch to the tone that preceded the most recently heard tone. In other words, listeners often expect the second tone of a realized interval to be proximate to the first tone of the implicative interval. Hence, the pitch-reversal principle describes expectancies slightly more global than those described by the pitch-proximity principle.

This is shown in zygonic terms in Fig. 8.29.

In terms of the present theory, the "reversal" comes about since there is a tendency of the third pitch to imitate the first. This effect is particularly noticeable through the expectancies that arise (Schellenberg, 1997, p. 312)

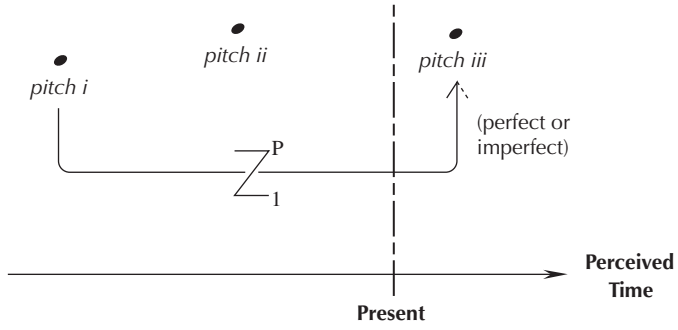


Fig. 8.29 Schellenberg's principle of pitch reversal expressed in zygonic terms.

when a melody violates the pitch-proximity principle (i.e. when a large implicative interval is heard). Once the coherence of the melody has been "threatened" by *disjunct motion* (a melodic leap), the principle asserts that listeners expect a reversal of pitch direction. If this expectancy is considered jointly with the expectancy for small intervals (as described by the pitch-proximity principle), the overall expectancy is for the resulting gap in pitch to be filled (i.e. listeners expect a change of direction *and* a relatively small interval).

This balance of perceived forces, emanating from the first and second pitches, can be modeled zygonically as shown in Fig. 8.30.

Again, as Schellenberg (1997) observes, there could be other factors at work here, such as human vocal limitations (since, for example, a note following a large interval in a melody that does *not* change direction is more likely to exceed a singer's range—hence it would be relatively unexpected). Indeed, von Hippel (2000) and von Hippel and Huron (2000) have subsequently shown through the analysis of a large number of melodies that tessitura *is* a significant constraint on melodic design. They conclude that, in many cases, melodies change direction after a skip

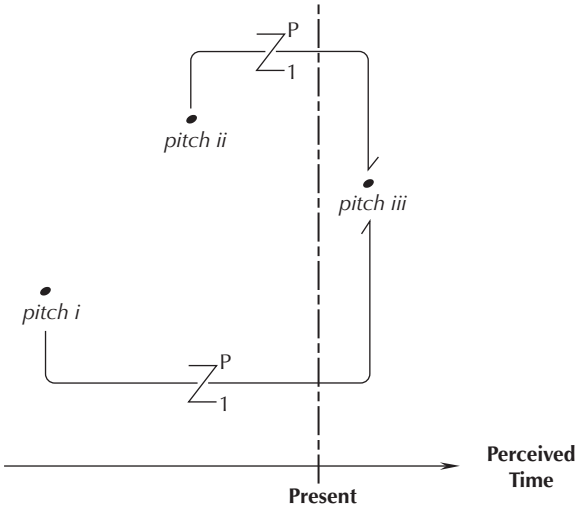


Fig. 8.30 Balance of imperfect primary zygonic forces from pitches i and ii implies a change of intervallic polarity and a relatively small magnitude.

"simply because they lack the space to do otherwise" (von Hippel and Huron, 2000, p. 83). Further research (von Hippel, 2002; Huron, 2006) has indicated that skip reversal is merely an artifact of regression towards the mean, which, through repeated exposure, experienced listeners have converted into an inexact but serviceable heuristic, whereby they expect a large interval to be followed by a change of direction. Furthermore, listeners will expect the new interval to be relatively small, simply because *most* intervals are relatively small. These principles tie in with the zygonic model set out in Fig. 8.18.

Schellenberg's experiments, and those of Cuddy and Lunney (1995) which he re-analyzed (Schellenberg, 1997), involved realizations deriving from a single implicative interval. However, given that the two principles that Schellenberg identifies, namely "pitch-proximity" and "pitch-reversal," can be shown to share a common primary zygonic ancestry, as Figs. 8.26, 8.29, and 8.30 illustrate, it is logical to consider whether, using zygonic theory, it would be possible to create a valid, single-factor model of within-group melodic expectation. This would pertain to a *series* of implicative values, and utilize Schellenberg's finding that the expectation of pitch-proximity applies to *non*-contiguous (as well as to adjacent) values. It would predict that expectation occurs through the extension into the future of proactive primary zygons from current and foregoing pitches, with a strength of effect, ceteris paribus,[15] proportional to their recency. Hence, it would accord with the principle of "regression to the mean" identified by Huron and von Hippel: indeed, it would provide the wherewithal for the cognitive extraction of the "mean" from a series of notes. A simple version of this model, in which a range of values for an anticipated 5th pitch is implied from four that are presented, is illustrated in Fig. 8.31. The thicknesses of the lines that depict the

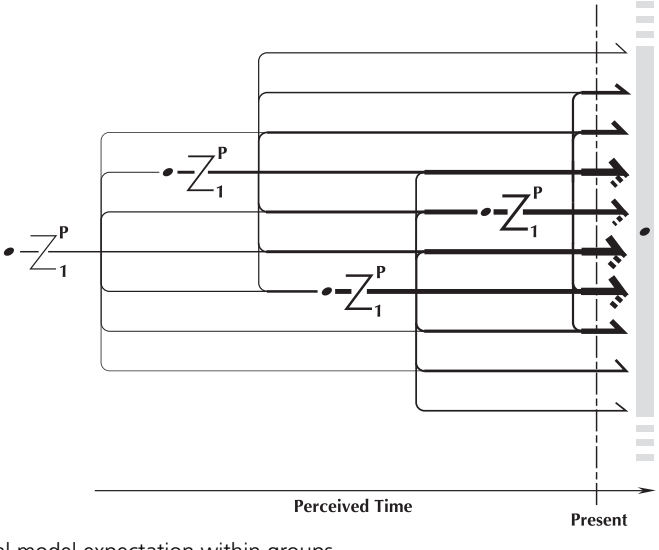


Fig. 8.31 General model expectation within groups.

[15] Inevitably, as Schellenberg makes clear (1997, p. 314), other factors, such as a melody's rhythmic and global pitch characteristics, including any tonal implications that may be present, all almost certainly exert an influence. Moreover, local within-group patterning, operating through secondary or even tertiary zygonic relationships, is also liable to have an effect.

relationships are intended to give an indication of the relative potency of the zygonic forces, and hence the strength of the expectation, that is present in each case. Where expectations coincide, their effect is imagined to be cumulative.

This model was tested empirically by a postgraduate student at the University of Roehampton, Michael Thorpe, and his findings will be reported later in this chapter. At this (theoretical) stage in our discussion, it is important to explore what function such a model suggests expectation may play upon first hearing a piece. At most, apparently, it can offer listeners only a broad indication of what is to come. As Jones states (1981, p. 571): "Expectancies, at least initially, . . . are continuous, rhythmically generated paths that allow us to guide our attention to approximately correct neighborhoods." Is this the whole story, though? Intuitively, while it accords with certain aspects of the experience of listening to a composition for the first time, it is often possible in the course of an unfamiliar piece to predict the nature of the sounds that are about to occur rather more precisely than the model in Fig. 8.31 would suggest. How is this greater precision achieved? I would suggest, principally, through the expectations that are engendered through the repetition of *groups* of notes. Such expectations involve projections from three values or more.

Expectations stemming from three notes or more

The presence of three values from which to predict represents a threshold in musical expectation, since, while individual values can exceptionally function as self-sufficient motivic entities in their own right (see p. 136 and Ockelford, 1999, p. 152, for example), typically at least two pitches are required to form a *Gestalt*, with enough individuality to bear purposeful replication.[16] Hence, as well as affording the opportunity for general projection *within* groups (see Fig. 8.31), three values may imply rather more specific continuation *between* them (for example Fig. 8.32).

A general model of projection between groups can be formulated as follows (see Fig. 8.33). Imagine the first few values of a group of pitches ("B") are heard. Next, assume that the musical mind is constantly and proactively engaged in seeking meaningful relationships, not only within this group but *between* this and others, whose traces are encoded in short- or long-term memory.

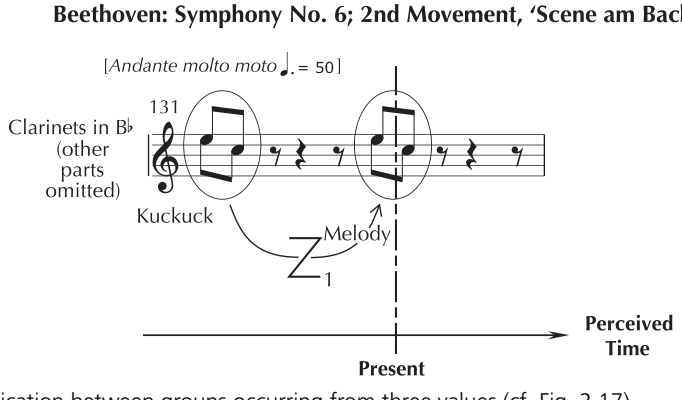


Fig. 8.32 Implication between groups occurring from three values (cf. Fig. 2.17).

[16] Even two values in the domain of pitch typically need to be teamed up with a distinctive rhythmic motive in order to function as a self-sufficient motivic entity, as the example in Fig. 8.32 shows.

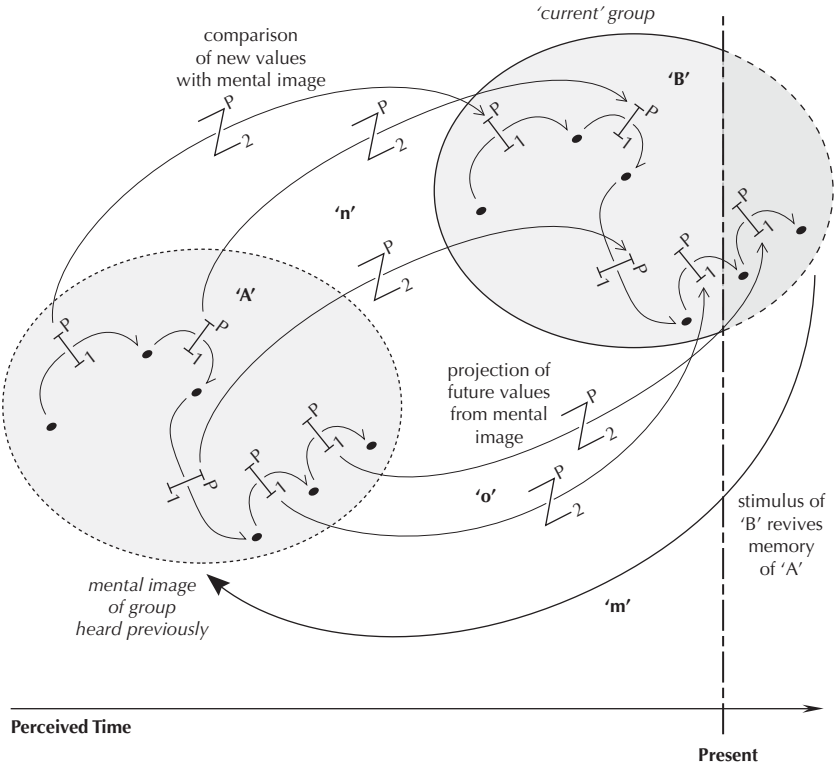


Fig. 8.33 General zygonic model of expectation between groups.

Through this process of comparison, as the shape of B unfolds, it becomes apparent (through relationship "m") that this is similar to a series of perspective or interperspective values that have been heard previously ("A"), and a mental image of that group is revived. This trace is then compared (at either primary or secondary level, which is depicted here) with the recently heard and incoming stimuli that constitute B (through relationships "n"). Significantly, in the current context, the memory of A also stimulates the listener to project likely future values of B (through relationships "o").[17]

This model suggests that expectation arising between groups of values is likely to be more prescribed than that stemming from within a group, and so be of greater service to listeners as they (subconsciously) strive to anticipate the future course of events during a piece of music. However, even projection between groups is far from straightforward, potentially occurring via a number of different routes. In summary, it may derive from:

- other material or materials occurring within the *same* hearing of the *same* performance of the *same* piece;

[17] For a detailed consideration of how this type of analysis fits with current research and thinking on motivic categorization in music—as reported, for example, in Deliège (1996, 2001), Deliège and Mélen (1997), and Deliège *et al.* (1997)—see Ockelford (2004).

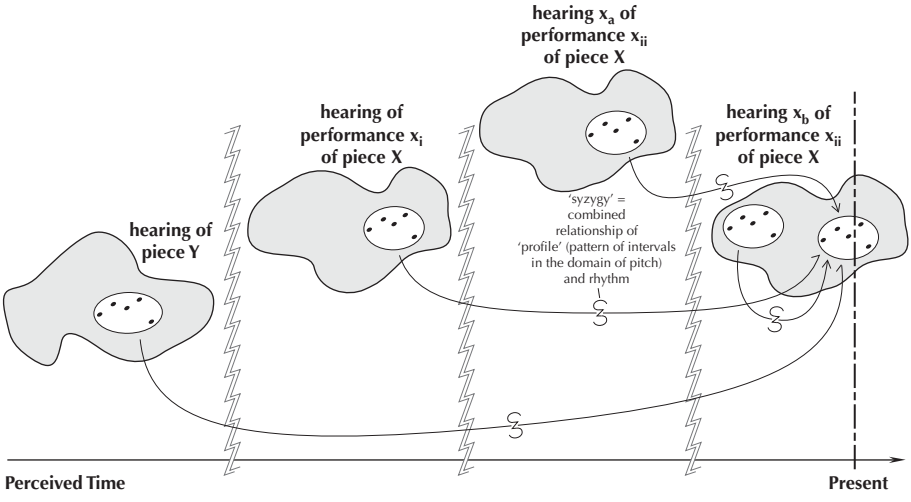


Fig. 8.34 Routes through which expectation between groups can occur.

- a *different* hearing or hearings of the *same* performance of the *same* piece (in the case of recorded music);
- a hearing or hearings of a *different* performance or performances of the *same* piece; or
- a hearing or hearings of a performance or performances of a *different* piece or pieces

cf. Ockelford (1999, p. 265) (see Fig. 8.34).

Groups vary enormously in length, ranging, for example, from the two notes of the cuckoo call in Beethoven's *Pastoral* symphony (see Fig. 8.32), to an entire movement. Similarly, the status of relationships between groups differs widely: contrast, for instance, those generated in the mind of the listener hearing the calls of Beethoven's cuckoo for the first time, amused and surprised, perhaps, and wondering how often the bird will sing, to those produced in the mind of the connoisseur listening to a favorite recording of this symphony for the *n*th time, reinforcing her already consummate knowledge of this rendition of the piece.

It is hypothesized that any of the relationships shown in Fig. 8.34 may be activated on a given occasion. Hence their potential for interaction is virtually limitless. For example, different memory traces may reinforce or contradict one another. Aspects of two or more groups may combine (for instance, in a variation where a means of motivic transformation is applied systematically). Perceived implications may but need not be realized, for a number of reasons: a chunk of material within a piece may well be modified on its reappearance, for example, or a listener may just misremember. These issues are considered in the empirical work that is reported later. At this stage, we will examine briefly how expectation *within* and *between* groups may theoretically interact.

Our exploration of expectation within groups suggested that, at best, this can offer only a broad indication of what is to come. This imprecision undermines Meyer's attempt to formulate a methodology for analyzing implication in tonal melody (Meyer, 1973, pp. 114ff.). His primary position (1973, p. 116) is that

> implicative relationships are like hypotheses which competent listeners entertain about the connections among musical events. To explain a melody . . . the critic must make these implicative hypotheses explicit. He must discover the patternings present in melody, and he must speculate—formulate explicit

> hypotheses—about how each of the patternings might be continued to reach the stability of relative closure, or perhaps silence: the end of the patterning. To do so, the critic will often perform a kind of mental "experiment". He will "stop" the melodic flow at particular points and try to imagine what continuations seem probable.

However, Meyer also acknowledges (1973, pp. 112, 113) that

> Because patterns are seldom simple and "single-minded," alternative consequents or continuations are as a rule implied by musical events. . . . We are specially liable to overlook or forget if the alternative consequent is separated from the implicative antecedent by time and the demands of contrasting, intervening events. In cases like these, implicative relationships may be understood largely, perhaps entirely, in retrospect. . . .
>
> Most of the time a pattern can be fully comprehended and its internal relationships analyzed only be seeing what follows from it.

Hence it appears that while implication within groups is central to the musical experience, because of the practical cognitive difficulties of juggling so many alternatives that may exist at any one time, in reality the import of a passage in implicative terms can be understood only in retrospect, once its associated realization is known (see Fig. 8.35).[18]

But does this position bear phenomenological scrutiny? Can implication still be regarded as implication when it is viewed in retrospect—or is the process in reality one of pattern *recognition*? For implication to function retrospectively would seem to imply mentally "replaying" the relevant passage. This may be conceivable for Meyer's critic, who "will study the composer's score to see

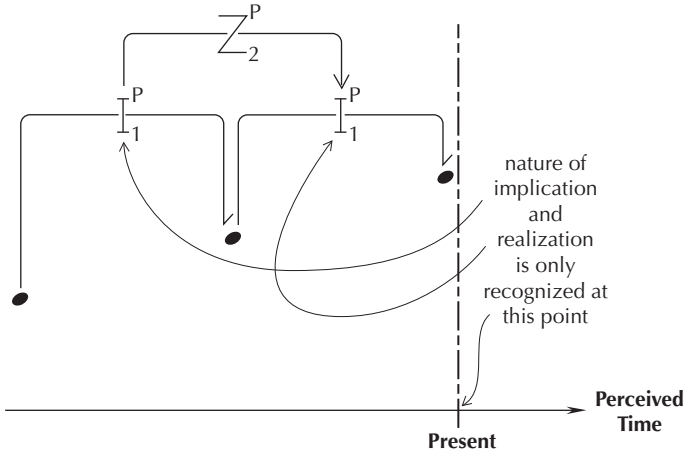


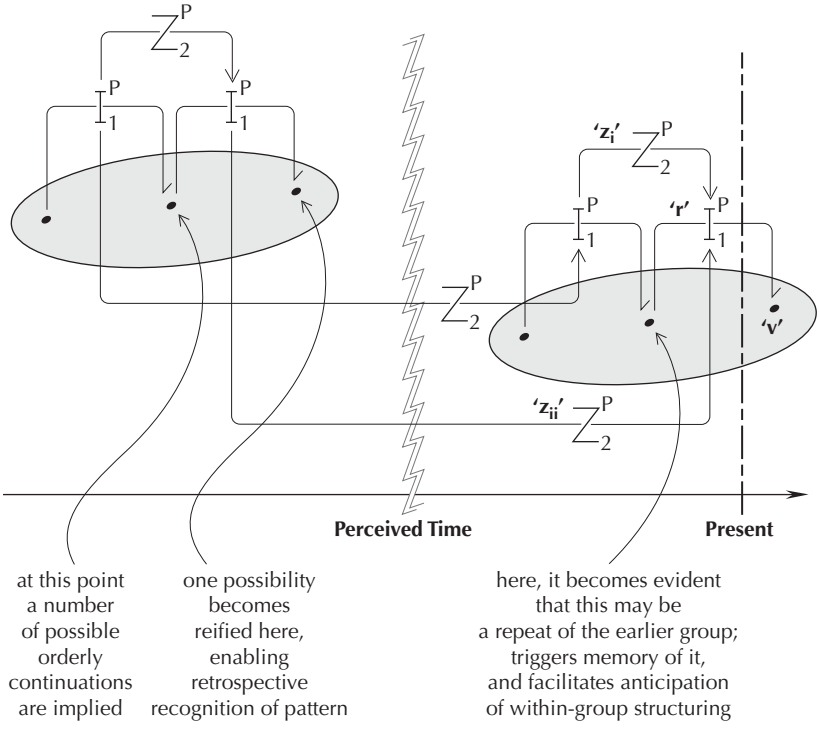
Fig. 8.35 Retrospective understanding of implication and realization.

[18] This is not to argue against the existence of "parallel processing" in music cognition (see Jackendoff, 1991, pp. 214ff.), whereby, at any given point in listening to a piece, a number of structural interpretations (each potentially bearing different implications) may be held in the mind—although only one of these is likely to permeate consciousness. As a particular passage unfolds, it is hypothesized (Jackendoff, 1991) that competing mental analyses are supported, continue to remain in abeyance, or are "pruned" if they prove incompatible with subsequent input. In my view, this model need not be understood in terms of retrospective implication, however, but of pattern recognition—albeit through the mind selecting from a number of simultaneously processed possibilities.

whether any of the envisaged (alternative) continuations actually occur" (Meyer, 1973, p. 116). Here, there is time aplenty to contemplate, and run and re-run the music in the mind. But what of the "typical" listener, who listens to a piece in "real time"? By the time an implication has been realized, the music will be moving on, affording no opportunity for reflection, since this would mean failing to attend to the next burst of perceptual input. How, then, can implication within groups work?

Zygonic theory suggests that this is possible when the anticipated course of patterning within a group is informed by relationships that operate *between* groups. This dual process effectively takes the uncertainty out of expectation within groups and enables such implications to function *pro*spectively. In general terms, the combined operation within and between groups can be modeled as shown in Fig. 8.36.

There are a number of other ways in which relationships between groups can influence anticipation within them. One occurs through the tendency of pieces to use limited sets of perspective or primary interperspective values.[19] In the case of pitch, for example, the framework of the "major mode," outlining values separated by the ascending intervals *tone*, *tone*, *semitone*, *tone*,



Hence, value **'v'** is projected through relationship **'r'**, which is stimulated in two ways: within groups (through **'z_i'**) and between groups (through **'z_{ii}'**).

Fig. 8.36 Zygonic model of expectation within and between groups.

[19] For a detailed exploration of perspective and interperspective pitch sets, and a zygonic account of their derivation, see Ockelford (1999, pp. 472ff.).

tone, *tone*, *semitone*, . . . is used (albeit with chromatic inflections) as the basis for a good deal of Western music. Within such a context, "expectations are generated automatically by the activation of learned, schematic representations that have abstracted typical relationships from the music to which one has had extensive exposure" (Bharucha, 1987, p. 4). Schematic expectations of this type can be modeled zygonically as in Figs. 8.37 and 8.38. Figure 8.37 presents the scenario in which the opening notes of a piece suggest (in the experience of a particular listener) either or both of two primary interperspective sets of pitch X and Y as possible frameworks. Hence, there is potential ambiguity in the process of schematic expectation. By the point t_{ii}, however (see Fig. 8.38), the presence of further pitches has made the position clearer, and set X emerges as the framework that is likely to be used, either contradicting, clarifying, or confirming the previous expectation (see, for example, Brown *et al*., 1994; Vos and Verkaart, 1999).

Schematic projection of this type can inform anticipation within groups as well as expectancies occurring "veridically" within them, "which are generated either by the activation of memory traces for specific pieces or by explicit prior knowledge of what is to come" (Bharucha, 1987). Expressing these possibilities in zygonic terms makes the balance of forces clear in each case. Figure 8.39 shows how expectation arising from two identical pitches which, through imperfect imitation, potentially suggest a large number of microtonal values, is constrained within the context of a diatonic pitch set, yielding just three possibilities which lie in the intersection of the two sets. Conversely, Fig. 8.40 illustrates how implication between groups is tempered by the presence in the background of a diatonic pitch set, which renders the expectation of otherwise perfect repetition imperfect.

In most musical contexts, perspective and interperspective pitch sets offer more than just a schematic framework upon which veridical expectations are hung. The manner in which their pitches are typically used is constrained too, offering further sources of implication. The factor of "pitch proximity," for example, has already been noted (see Fig. 8.28), and the work by von Hippel (e.g. 2000) which suggests that not only the *sizes* of melodic intervals are predictable, but their *directions* as well. "In general . . . intervals will retreat from the extremes of the tessitura and approach the middle: intervals that start on high pitches will proceed downward, and intervals that start on low pitches will proceed upward." Moreover, "interval sizes will vary depending on the melody's position in its tessitura. Near the middle of a melody's tessitura, the new definition predicts small intervals, but near the extremes, the new definition predicts relatively large intervals" (von Hippel, 2000, p. 325). That is to say, both the magnitude and the polarity of melodic intervals tend to be sensitive to tessitura (cf. Cross, 1995, p. 507)—a tendency, once more, that can inform expectation through the projection of zygonic relationships into the future.

The principle of pitch proximity, whether in its basic form or in von Hippel's more refined version, offers listeners information that can be used to aid prognostication in the most general way. However, the typically asymmetrical nature of pitch sets means that greater specificity is possible, since values can be used idiosyncratically with respect to the unique position that each occupies within a set. This tendency, whereby pitches are felt to fulfill distinctive functions in relation to one another, characterizes most music, and underpins the notion of "tonality" (though see, for example, Vos, 2000, pp. 404ff.) (and see p. 405). Tonal schemata can be generated in various ways, including the relative frequency with which values occur (see, for example, Krumhansl *et al*., 1999). Aarden (2003) demonstrated that *context* of occurrence of pitch degrees is important too, and that the Krumhansl/Kessler "key profiles" (Krumhansl and Kessler, 1982), which were developed through the probe-tone method (which requires that the musical passages in question *stop*), correspond more closely to the statistical profile of pitch degrees used to *close* melodies

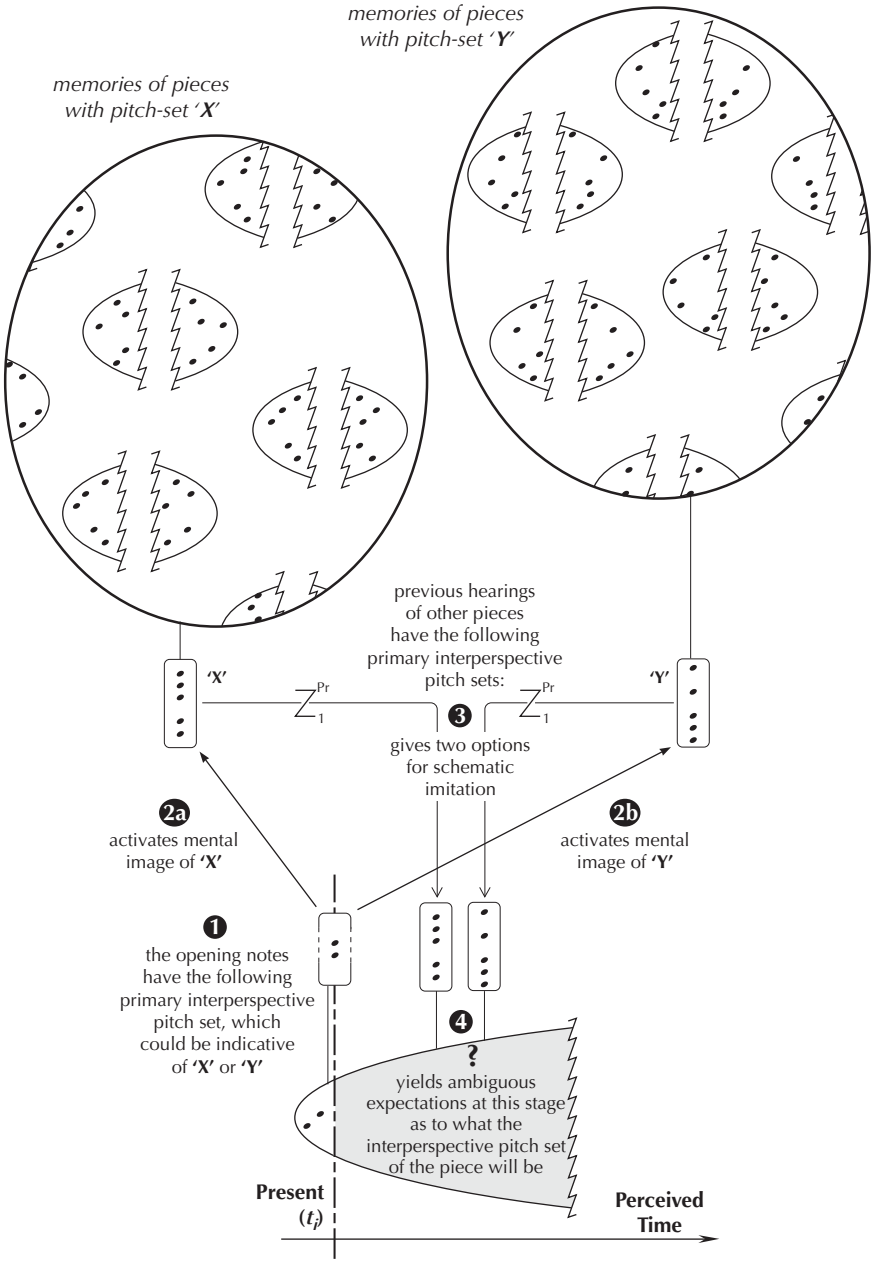


Fig. 8.37 Schematic expectation of primary interperspective pitch set (time *t*).

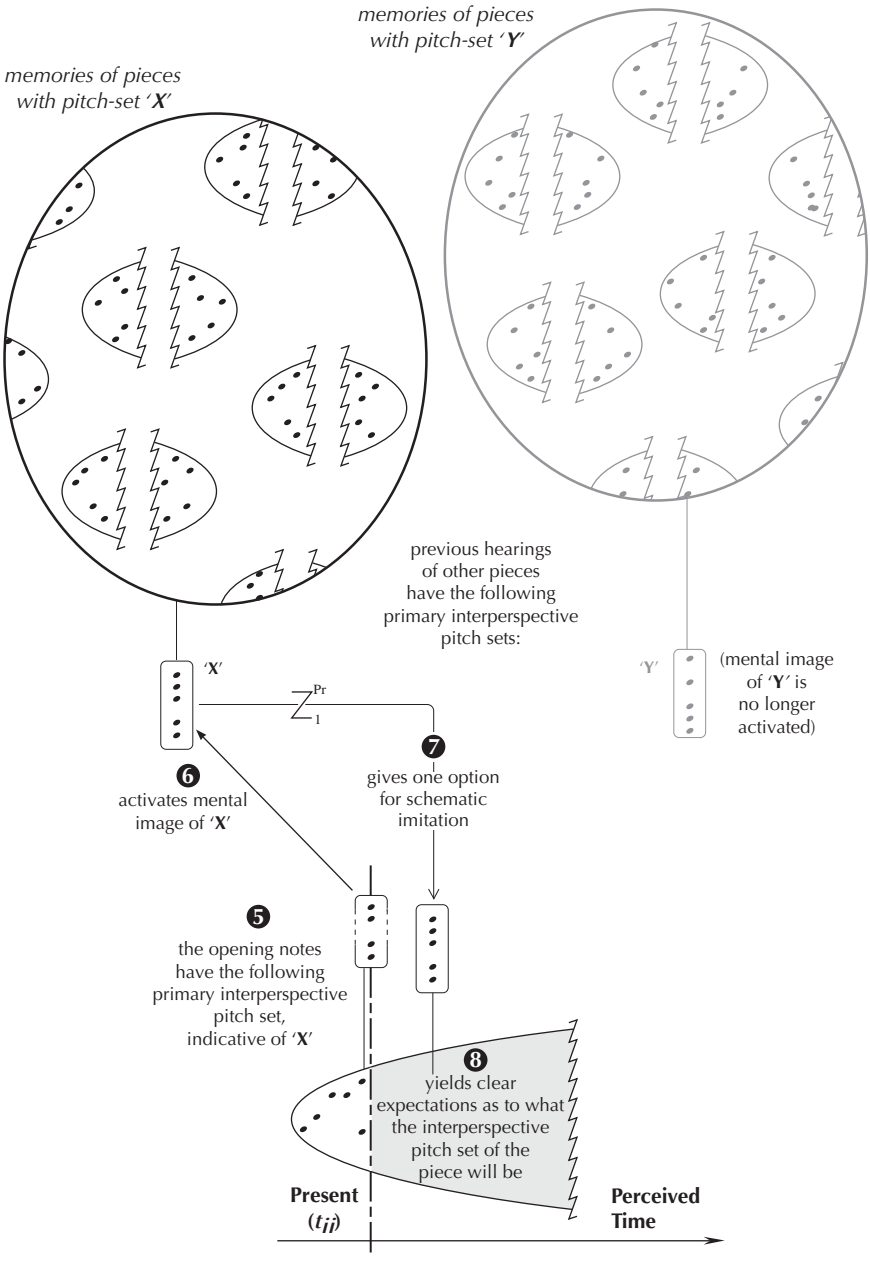


Fig. 8.38 Schematic expectation of primary interperspective pitch set (time t_{ii}).

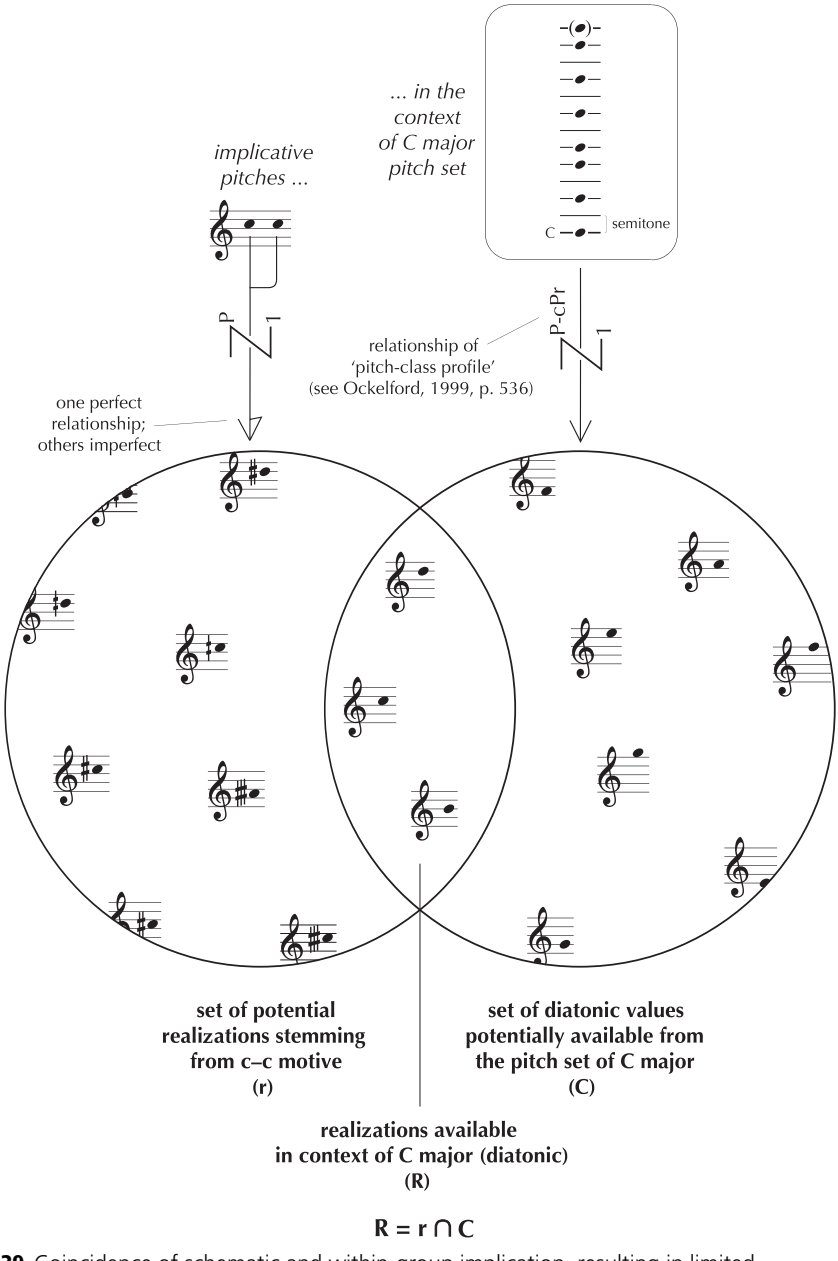


Fig. 8.39 Coincidence of schematic and within-group implication, resulting in limited expectation arising from the intersection of the two sets of possibilities.

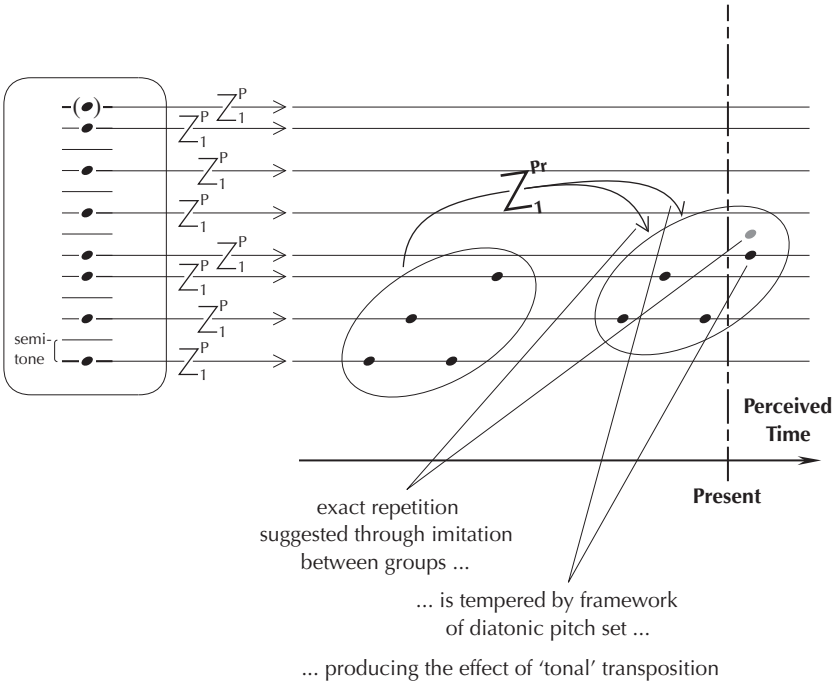


Fig. 8.40 Coincidence of schematic and veridical implication (between groups), resulting in 'tonal' transposition.

rather than to their general distribution (see also Huron, 2006). This subtlety notwithstanding, the fact that exposure to music in which the frequency distribution of values is reasonably consistent can translate into future expectation as to their future probabilities of occurrence, can be modeled zygonically as in Fig. 8.41. Here, the thickness of lines used in relationships represents both the relative rate of past utilization of perspective values, and their felt probability of future recurrence. The model uses data from the study by Krumhansl *et al.* (1999, p. 161), which was undertaken in the context of Finnish spiritual folk hymns.

More specifically, in tonal music, *transitions* between values have distinctive frequencies of occurrence too—see, for example, Pinkerton (1956) and Simonton (1984), whose study of the first five two-note transitions of over 15,000 themes from the Western classical tradition revealed that "a relatively small number of pairs account for the vast majority of transitions, and certain pairs dominate melodic structure" (Simonton, 1984, p. 5). In fact, Simonton discovered that the four most commonly occurring pairs altogether make up over a fifth of all two-note transitions. This finding has found support in the work of Huron (2006, pp. 158, 159), whose analysis of more than a quarter of million pairs of notes in a corpus of Germanic folksongs found that the dyads $\hat{3}$-$\hat{2}$, $\hat{5}$-$\hat{5}$, $\hat{2}$-$\hat{1}$, and $\hat{4}$-$\hat{3}$ accounted for 18% of the total. This characteristic can inform expectation in the domain of pitch, as a number of studies show (summarized in Krumhansl *et al.*, 1999, pp. 162ff.). There is strong empirical support for the theory that such expectation occurs through the creation and activation of neural networks, both in relation to individual pitch degrees and harmonies. Nets of this kind are thought to "learn" through exposure to large numbers of inter-event relationships and prime sets of expectancies according to the cognition

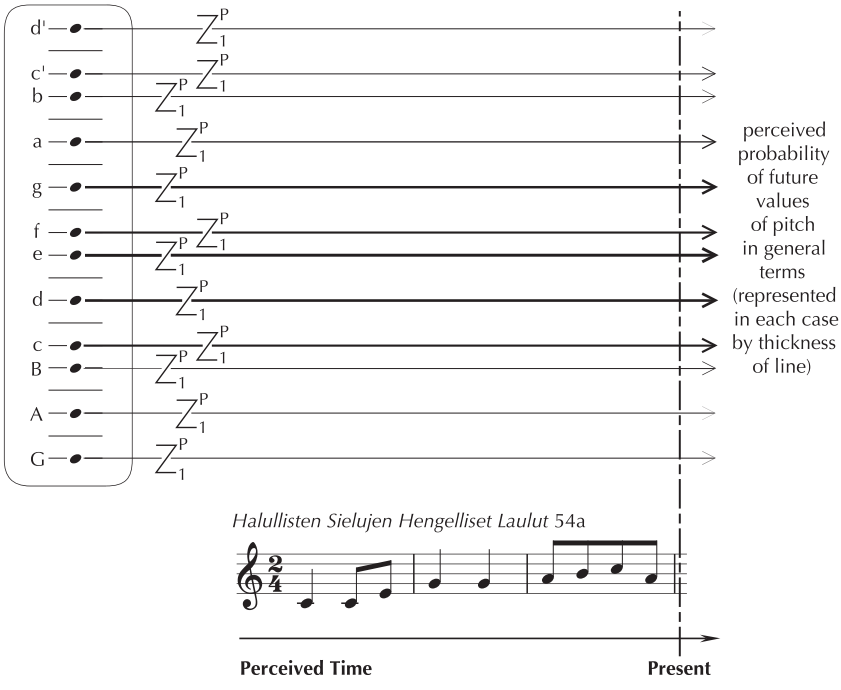


Fig. 8.41 Past frequency of distribution of values informs future expectation in general terms (after Krumhansl *et al*., 1999, pp. 161, 167).

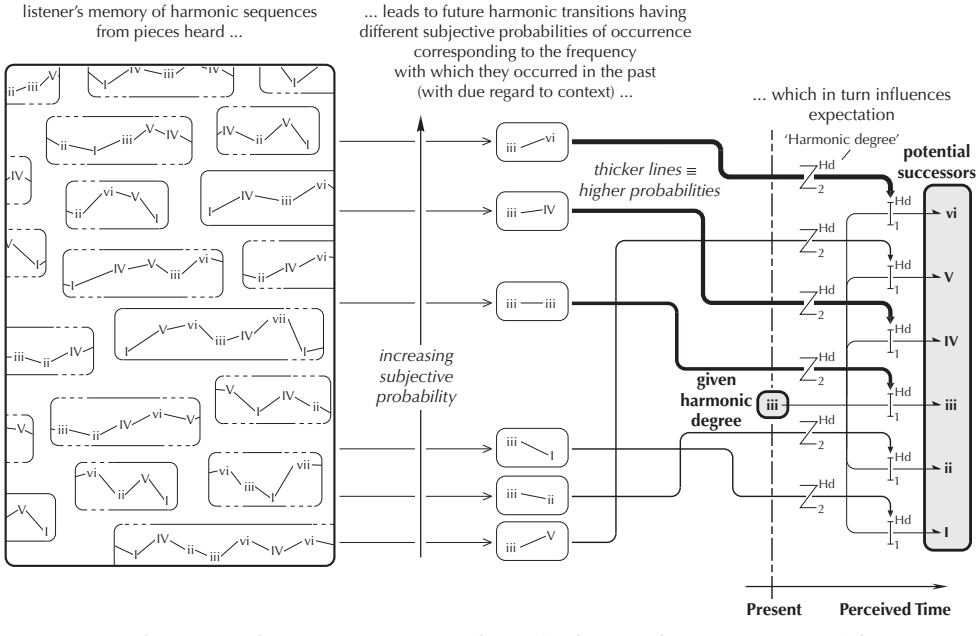


Fig. 8.42 Past frequency of harmonic transitions (from iii) informing future expectation (after Ockelford, 1999, p. 616).

of the events' distribution (see, for example, Bharucha, 1987, 1994, 1999; Bharucha and Stoeckig, 1987; Bigand and Pineau, 1997). This neuropsychological model captures and reinforces the previous intuitions of music-theorists such as Piston (1941/1978, p. 21), who produced a "table of usual root progressions," "based on observation of usage": anecdotal impressions that have indeed found qualified empirical support (Schmuckler, 1989, pp. 128ff.). So, according to Piston, upon encountering, for instance, chord iii within, say, a classical sonata, an appropriately experienced listener would most strongly expect to hear vi, other things being equal, although IV would also be a strong contender, with I, ii, or V being rather less probable. Zygonically, this can be modeled as a network of relationships of "harmonic degree" (H(d)) (cf. Ockelford, 1999, p. 616) (see Fig. 8.42).

The interaction of general and specific expectations in music

The demands of brevity and clarity have meant that this chapter has focused mainly on expectation in the domain of pitch, and postulated how zygonic constructs may elucidate the cognitive processes that underlie this phenomenon. However, anticipating what will occur on the basis of current and past perceived sonic input is, of course, much more broadly based than this. As Narmour (2000, p. 329) observes:

> Iterative rules appear everywhere in music cognition, creating strong expectations. . . . There are many kinds of deduction . . .. Typical examples included melodic sequence, partial melodic sequence, and alternating melodic sequence . . .. Intervallic expansion and reduction in melody also involve higher-order abstractions. Various mirrored forms in music entail rule-mapping as well . . .. Listeners can likewise deduce additivity and subtractivity at work in harmony, tempo, texture, pace and dynamics.

In short, wherever aspects of music are orderly, expectation is possible; and, since music is replete with organization of relevance to listeners (see, for example, Ockelford, 1999, pp. 704ff.) so expectation pervades all areas of music perception. To demonstrate this in action—to give some impression of the complex, cumulative effect of expectation operating within and between perspective domains—we present a "snapshot" of a single moment in the experience of listening to the first movement of Mozart's piano sonata K. 333, frozen in time, to enable a comprehensive metacognitive analysis to be undertaken (cf. Chapter 2, pp. 21–6).

The point in time to be considered lies at the end of the first eighth note of bar 94: in formal terms, just after the beginning of the recapitulation. The performance is that recorded by Christoph Eschenbach in 1971.[20] The listener, we will assume, knows the sonata well, and is particularly familiar with Eschenbach's interpretation. Beyond this, he or she has a sound knowledge of Mozart's œuvre, especially his piano sonatas, and has a broad awareness of stylistically congeneric works. The issue, then, is what expectations can we reasonably assume to be in play at the juncture identified (see Fig. 8.43)?

To answer this question, let us first return to the principle that in musical contexts, expectation is about anticipating the *what* and the *when* of perceived sound. As the illustrations above show, both factors exist on a continuum of specificity–generality, and together yield expectations which may be more or less determinate. So, for example, someone listening to the recording of a piece with which he is very familiar may feel wholly sure that he knows *what* is going to happen and

[20] On Deutsche Grammophon (419 452-2).

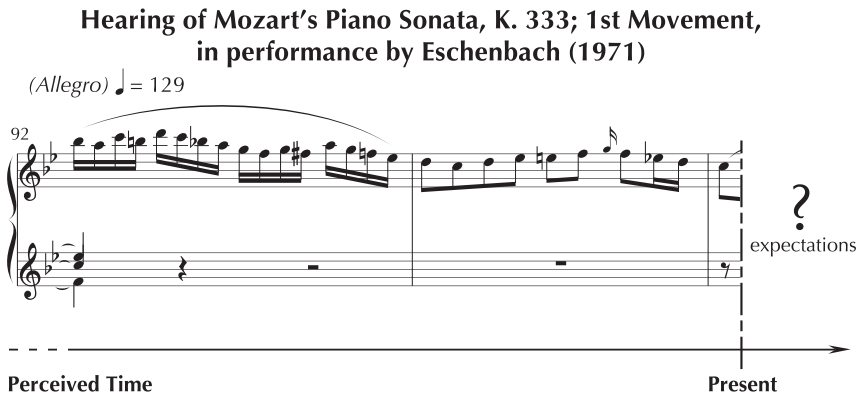
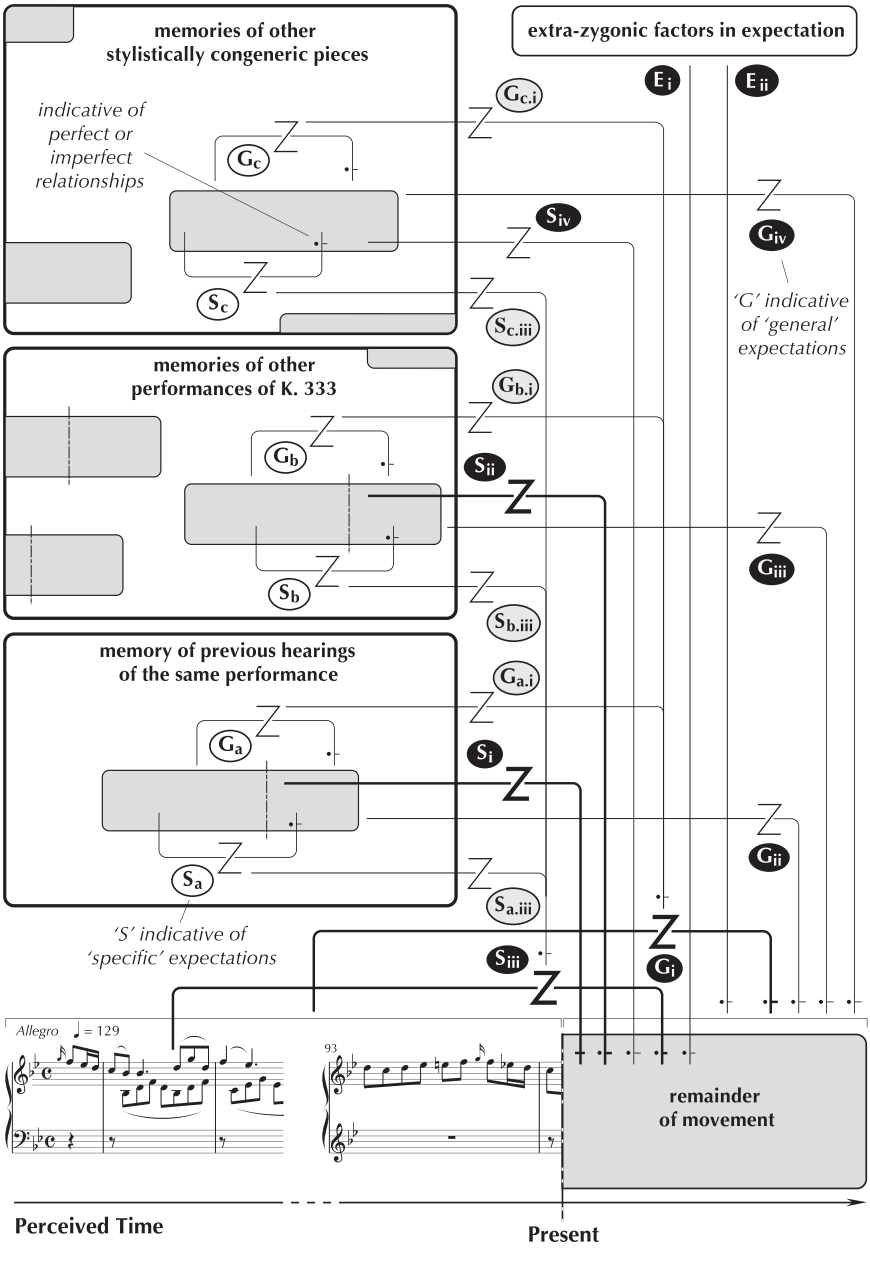


Fig. 8.43 What expectations are in play at this juncture, in the context described?

when. However, a listener encountering a work in unfamiliar style for the first time can be reasonably sure *when* events will occur (within a given range), since notes "tend to follow one another without a cessation in perceived sound, or with only short breaks" (see footnote 7; Ockelford, 1999, p. 327), though not *what*, specifically, each of these will be. Conversely a person hearing a new piece in "common practice" tonal style to which she is accustomed will intuitively have a good idea of *what* is going to occur in general terms (since pitches and inter-onset intervals tend to be used with prescribed frequencies), though not precisely *when* any of these will crop up.

It is generally accepted that "specific" and "general" expectations work together in music cognition, and research has been undertaken to suggest how the two psychological mechanisms may function in parallel, one complementing the other (see, for example, Bharucha and Stoeckig, 1987; DeWitt and Samuel, 1990: Jackendoff, 1991; Bharucha, 1994; Krumhansl *et al*., 1999). Expectations of differing specificity, arising from a variety of sources, can also be modeled zygonically to good effect; and to return to the case of our sophisticated listener, attending to the first movement of K. 333, the position can be summarized in zygonic terms as shown in Fig. 8.44. Clearly, the situation is complicated, since there are so many potential sources of expectation. In brief, *general* expectations may arise from the current hearing (through relationships labelled G_i) and through memories of previous hearings of the same performance (through G_{ii} and $G_{a.i}$), other performances of K. 333 (through G_{iii} and $G_{b.i}$); and other stylistically congeneric pieces (through G_{iv} and $G_{c.i}$).[21] Similarly, *specific* expectations may arise from the current hearing (through relationships labeled S_{iii}) and through memories of previous hearings of the same

[21] Just how these memory traces are built up, and what form they ultimately take is not clear, although listeners' accounts offer some indications. For example, after an initial hearing of the first movement of K. 333, it seems that we will typically be left with an overall impression of the music, and a series of fleeting traces that we find memorable: more or less accurate, more or less detailed, and more or less complete. Gradually, after successive hearings of the same performance, the picture becomes more complete and coherent until, eventually, a comprehensive representation may be constructed, enabling us to detect the slightest deviations from the original version. However, to what extent hearings of *different* performances of a piece are stored separately is unclear, although with sufficient exposure to a particular interpretation, it seems that this can develop a distinct memory trace of its own.



Mozart: K. 333; 1st Movement (as performed by Eschenbach, 1971)

Fig. 8.44 Zygonic model of the expectations arising after the first quaver of bar 94 of the first movement of K. 333 ('expert' listener).

performance (through S_i and $S_{a.iii}$), other performances of K. 333 (through S_{ii} and $S_{b.iii}$); and other stylistically congeneric pieces (through S_{iv} and $S_{c.iii}$).

Despite its complexity, Fig. 8.44 can offer nothing more than a highly simplified representation of the cognitive channels through which anticipation may flow, any, all, or none of which may be activated at the point in time that is identified. For even expert listeners "may well pay scant attention to certain features, while focusing on others attentively; and, for sure, they forget a good deal of what is heard" (Ockelford, 1999, p. 254). Furthermore, the plexus of fleeting mental operations through which music listening occurs will differ from one occasion to another.

Despite these obvious limitations, the model does offer insights as to the balance of anticipatory forces that will typically be in play. For example, it is likely that the axis of specific expectations arising from previous hearings of K. 333 (through relationships S_i and S_{ii})[22] and expectations stemming from the current hearing (through G_i and S_{iii}) will predominate; and these relationships are highlighted in Fig. 8.44. We may surmise that the interaction between these pairs operates along the lines shown in Fig. 8.45. The memory traces from previous hearings exist in abstraction, as a mixture of interperspective and perspective values, whose fidelity to their model will vary according to the listener's perceptual abilities in the auditory domain. However precise the stored image is, it will be overwhelmed by the compelling effect of the current framework of perceived time, pitch, timbre, loudness, perceived location, and perceived reverberation (see Ockelford, 1999, pp. 266ff.), and, chameleon-like (cf. Ockelford, 2005b, pp. 96ff.), it will take on the general characteristics of the perspective background they offer. The listener may (but need not) be aware of this accommodation.

In terms of perceived time, this means that the remembered inter-onset intervals between notes and their durations will be mapped onto the grid formed by the regular beat and consistency of meter characteristic of the first movement K. 333—the two sources of prediction combining in one expectation. Clearly, in the case of hearing the same performance again, tempo (a percept drawn from the values of inter-onset intervals) will need no adjustment; with different performances, it is likely that some accommodation will be needed. Similarly, in the domain of pitch, the listener will if necessary, wittingly or unwittingly, recast the memory of profile (the pattern of intervals) to conform to the current absolute values contributing to the framework of B♭ major (which may vary between performances); again, the two factors result in a single expectation.[23] With regard to timbre, adjustment may be required even with a further hearing of a familiar performance, due to the varying nature of sound reproduction systems and the acoustical environments in which they are situated, and loudness may be even more susceptible to variation between hearings.

The S_i–S_{ii} combination interacts with expectation within hearings in other ways too, serving to reinforce specific anticipation occurring through S_{iii}. That is, the within-group and between-group implications for continuation arising within the current hearing after the first half beat of bar 94 will combine with our listener's knowledge of how the piece has previously continued at this point, giving a cognitively irresistible feeling for what the future will bring (Fig. 8.46).

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[22] Clearly, the specificity of the expectations will depend on the fidelity of the memory trace in question.

[23] Levitin's (1994) study suggests that many listeners store absolute pitch information to a high degree of fidelity in veridical memory (that is, in traces of specific musical fragments)—something which contrasts with the widespread *in*ability to remember absolute pitches in general terms (as in the percept of "the key of B♭ major," for example). That is, in relation to the model set out in Fig. 8.44, while the relationships S_i and S_{ii} may, in the domain of pitch, convey absolute information, this is far less likely to occur in the case of relationships G_{ii} and G_{iii}.

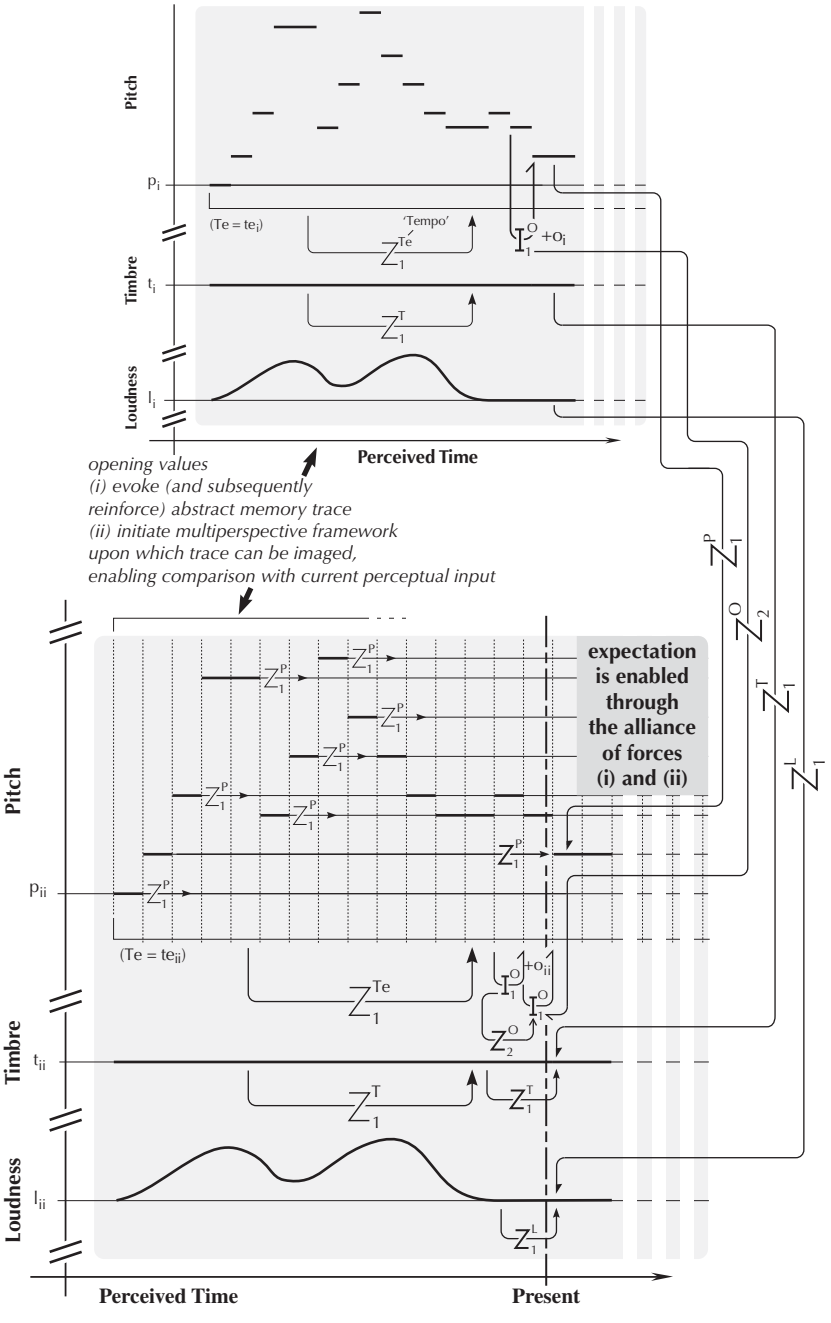


Fig. 8.45 Expectation arising through a balance of veridical and schematic zygonic forces.

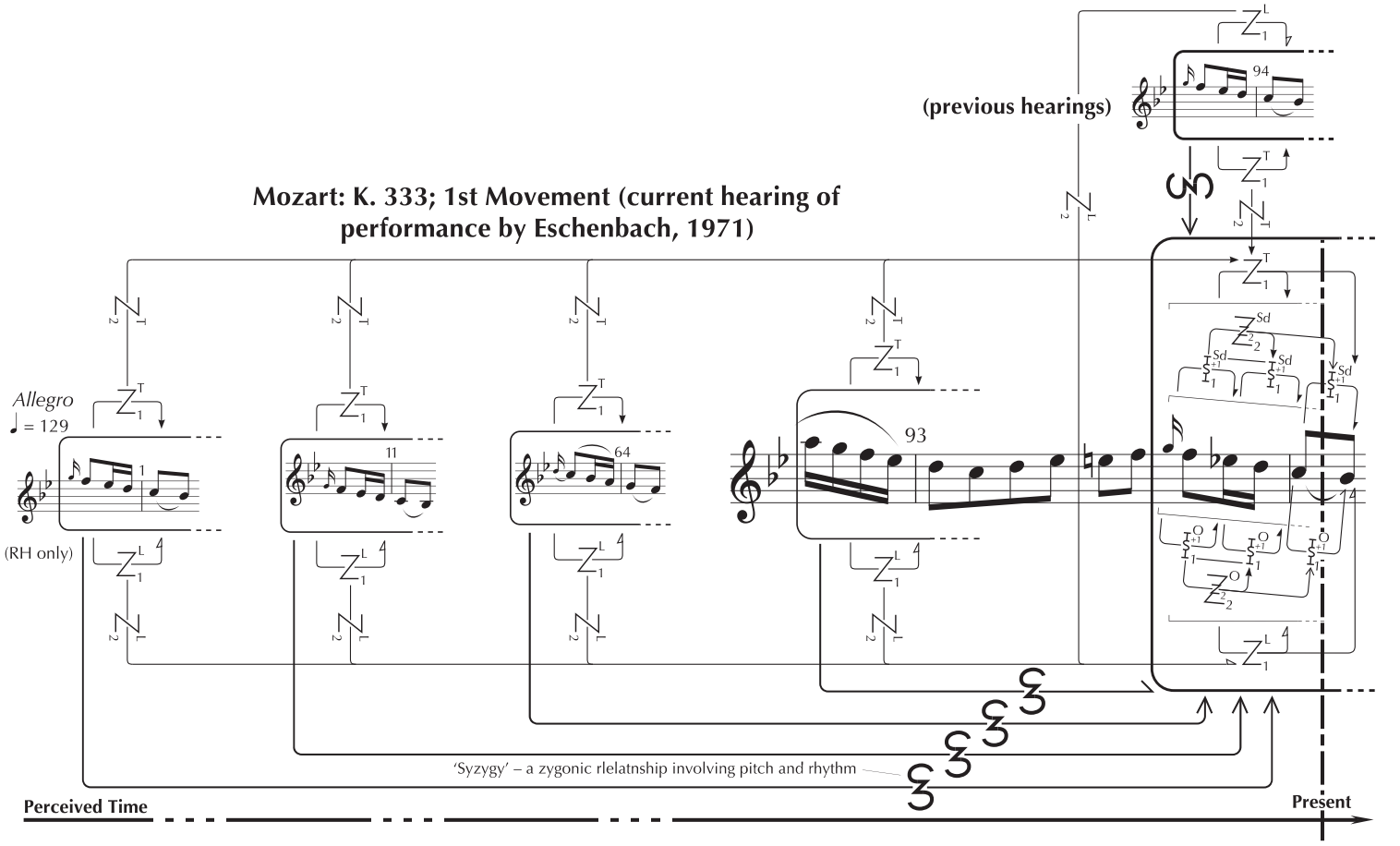


Fig. 8.46 Forces of expectation within a hearing and between other hearings reinforcing one another.

The S_i–S_{ii}/G_i–S_{iii} axis aside, expectation will, to a lesser extent, intuitively be drawn from other sources too. For example, *general* features of K. 333 and of other pieces, internalized during previous hearings, may inform anticipation (through relationships G_{ii}, G_{iii}, and G_{iv}). These include:

- *The presence of a regular beat, its tempo, and the consistency of its hierarchical organization as* "*meter*" (for example, in Eschenbach's 1971 recordings,[24] the first movements of the following Mozart piano sonatas, all of which are in common time, maintain the same beat throughout and are performed at these broadly similar tempi: K. 279, ♩ = 121; K. 310, ♩ = 129; K. 311, ♩ = 143; K. 333, ♩ = 129).
- *The use of limited sets of relative durations and inter-onset ratios, and the relative frequency with which they occur* (for example, in the first movements of K. 284, K. 310, K. 311, and K. 333, 50–68% of all durations are 𝅘𝅥𝅯, 12–32% are 𝅘𝅥𝅮, 8–9% are ♩, and 5–7% are 𝅗𝅥—these four durations together making up 94–98% of the relative values that are used, whose distribution shares an 86% similarity across the four movements concerned; with regard to inter-onset ratios (involving relationships between successive notes), 1:1 is by a considerable margin the most common, making up 78–84% of the total, with 2:1 and 1:2 accounting for between 3–12%, and all others totaling between 10% and 17%—their distribution sharing a 92% similarity across the movements) (see Fig. 2.9).
- *A texture comprising two simultaneous streams of sound which function largely as "melody" in the right hand and "accompaniment" in the left* (a typical feature of music in the Classical style).
- *The use of limited sets of pitches and intervals, whose range, size, and distribution of members are also constrained* (for example, in the first movement of K. 283, 88% of intervals between adjacent notes are a major 3rd or less; in K. 311 the proportion is 83%; in K. 332, 82%; and K. 333, 86%—the distribution of intervals sharing a 77% similarity across the four movements) (see Fig. 2.11).
- *The ubiquitous use of tertian harmony (that is, chords based on thirds)* (a virtually universal feature of homophonic and polyphonic Western music of the period 1450–1900).
- *The distribution of principal harmonic functions and transitions* (for example, in the first movement of K. 309, tonic and dominant harmonies account, respectively, for 44 and 28% of the total, while transitions of +4 degrees make up 51% of all such intervals and transitions of +5 degrees 20%; in the first movement of K. 311, the proportions are 50 and 28%, and 48 and 31%, respectively; in K. 330, the figures are 49 and 22%, and 45 and 36%; and in K. 333, 39 and 29%, and 43 and 20%—similarities of 89 and 75%, respectively, across the four movements).
- *The relative duration of tonal regions* (for example, in the first movement of K. 309, the tonic key prevails for 57% of the time, and the dominant for 23%; in the first movement of K. 311, the equivalent proportions are 58 and 23%; in K. 330, 61 and 34%; and in K. 333, 57 and 34%—a similarity across movements of 92%).
- *The manner in which melody and harmony interact—particularly with respect to the use of dissonance* (for example, in the first movement of K. 333 over half the melody notes are

[24] On Deutsche Grammophon (419 452-2).

> consonant with the harmonies with which they sound, functioning directly as the root, 3rd, or 5th of the chord concerned; and although dissonant notes are widespread too, their use invariably conforms to one of a few archetypal patterns, including passing notes, appoggiaturas, and chromatic auxiliaries—defining features of the Classical style).

Clearly, observations and quanta such as these can only give an indication of the likely impact of statistical regularities on expectation in music, since, as von Hippel (2002) and Huron (2006) observe, exposure to regularities in music leads to the formation of schemata that only approximate to the stimulus patterns from which they derive. Moreover, even among a relatively homogeneous group such as "expert listeners" experiences are varied, and we may surmise that differing degrees of familiarity with varying selections of pieces will yield subtly different perceived probabilities with which relevant stylistic features may subsequently be expected to occur. Nonetheless, the accounts of listeners suggest that there is sufficient commonality for a given piece of music to speak similarly to those broadly familiar with its style.

Exceptionally, *specific* expectations may be aroused through the memory of aspects of other pieces (through relationships S_{iv} in Fig. 8.44); consider, for example, that our expert listener may be familiar with the opening of the first movement of the sonata Op. 5, No. 3 by J. C. Bach—one of a set with which Mozart is known to have been acquainted (see, for example, Roe, 1989, p. x), so constituting what may be regarded as one of K. 333's most immediate musical ancestors (see Einstein, 1946, pp. 130, 131). Both specific and general expectation may be reinforced by the very fact that the underlying organization through which it occurs has itself been heard before (through relationships $S_{a.iii}$, $G_{a.i}$, $S_{b.iii}$, $G_{b.i}$, $S_{c.iii}$, and $G_{c.i}$). Examples include the fact that our listener will anticipate levels of loudness to have few abrupt changes, generally passing by in a stream of sameness or similarity, since this is typical of stylistically congeneric pieces; she will expect timbral constancy within melodies, since this is the norm for the late 18th century; and she will look forward to themes being recapitulated in the tonic since this is a characteristic of the Classical style. Huron (2006) notes that expectation such as the latter, which pertains to large-scale formal features, appears to operate through *conscious* mental processing, so functioning rather differently from expectations operating on a more local level, of which listeners are typically unaware.

Finally, one should not discount the significant role that extra-zygonic factors are likely to play in expectation, both general and specific (E_i and E_{ii} in Fig. 8.44). As Huron (2006, p. 204) puts it, "How does a brain know which schema to apply to some experience? In selecting a schema it appears that brains rely on . . . *environmental markers* . . .." That is (Ockelford, 1999, pp. 256, 257):

> Although music may be regarded as self-sufficient, since it does not need the assistance of other media to get its message across, a considerable contribution to the listening process is almost invariably made by "extra-operative" information (that is, data not vested in the fabric of works themselves). At the most basic level, for example, the members of a prospective audience would normally arrive armed with at least some knowledge of what they were about to hear: people do not generally buy a blank ticket to a concert (programme undetermined), but to a performance of particular pieces, whose titles alone usually convey something of their musical substance. Moreover, in some cultures, elaborate programme notes form an accepted—even expected—part of the paraphernalia associated with the presentation of music (see Simonton, 1995). Failing any of this, even the simple act of sitting in a concert hall, seeing those who are about to play or sing while listening, perhaps, to the ambient chat, yields an abundance of clues as to what is to come.

A zygonic model of expectation in music

In the course of the analysis and thinking presented in the previous sections, the elements of a new, composite model of expectation in music have emerged, which are summarized in Fig. 8.47.

It is proposed that expectation in music (which typically occurs non-consciously, and inevitably varies from listener to listener and from one occasion to another) occurs through the projection of zygonic relationships operating in three contexts: from "current" structures (which form part of the present hearing process, are encoded in short-term memory, and operate *within* and *between* groups) (A); and "previous" structures (which formed part of past hearing processes, and operate *between* groups). The latter may be encoded schematically (B) or veridically (C). Current "within-group" structures can offer only a *general* indication of what is to come, since, as we have seen, all musical events have a plurality of potentially logical continuations. "Between-group" expectation working within "current" structures may be prompted by features that are particularly salient, brought about, for example, by repetition. Schematic information derived from structures heard previously offers a *general* picture of what the future may hold, according to heuristics based on past trends and tendencies. There is an interaction between A and B, whereby A provides a local context for the projections stemming from B, which in turn lend greater specificity to the implications arising from A. Veridical memory traces (C) offer a more or less specific indication of what is to come, depending on the degree of similarity of the new material, as it unfolds, with that heard in the past. C adds specificity to the implications deriving from A and B, which together provide the context in which expectations from C can be realized.

This basic model can be used to explore how the three forces of expectation that are identified interact in different circumstances, particularly as a listener becomes increasingly familiar with a piece. For example, with regard to the first hearing, we may infer that *general* implications (and therefore expectations) stemming from internal patterning[25] (A) and stylistic data (B) will tend to dominate, with *specific* implications and expectations limited, for example, to immediate or otherwise memorable repetition or variation of chunks of material, as found, for instance, in ostinati, recapitulations, and sequential passages (C). With subsequent hearings, we may suppose that this balance gradually changes as veridically based expectations come to dominate more and more.

What role A and B have to play once a piece is well-known, when much or even all of it can be anticipated accurately, is a complex one that has engendered some debate. On the one hand, it seems clear (as shown in Fig. 8.45) that general forces of expectation deriving from current and previous material will continue to fulfill a function in providing a temporal, tonal, timbral, and dynamic framework upon which short-term and veridical between-group memories can be hung; something that is particularly important for hearings of new *performances*, where the "background" characteristics of the auditory scene may differ from that which is familiar. The ongoing cognitive function of expectation deriving both from certain immediate tendencies (a rising scale approaching the tonic, for example) and some schematically induced expectations (the general tendency of chord V^7 to be followed by I, for instance) is more contentious, however. What role can such expectations play when it is known through previous occurrences of the passages in question that the scale reaches the leading note then falls back to the dominant, or that chord V^7 is in fact followed by vi? Surely the specific veridical memory traces render the more general implications redundant? Yet the relatively unexpected twists and turns in music that make such an impression on its first hearing *do* seem to go on playing a part in the enjoyment of a piece once it is well known, when the unexpected is no longer a surprise. How can this be?

[25] It is reasonable to hypothesize that such expectations become better adapted as a work progresses (see Coons and Kraehenbuehl, 1958; Huron, 2006).

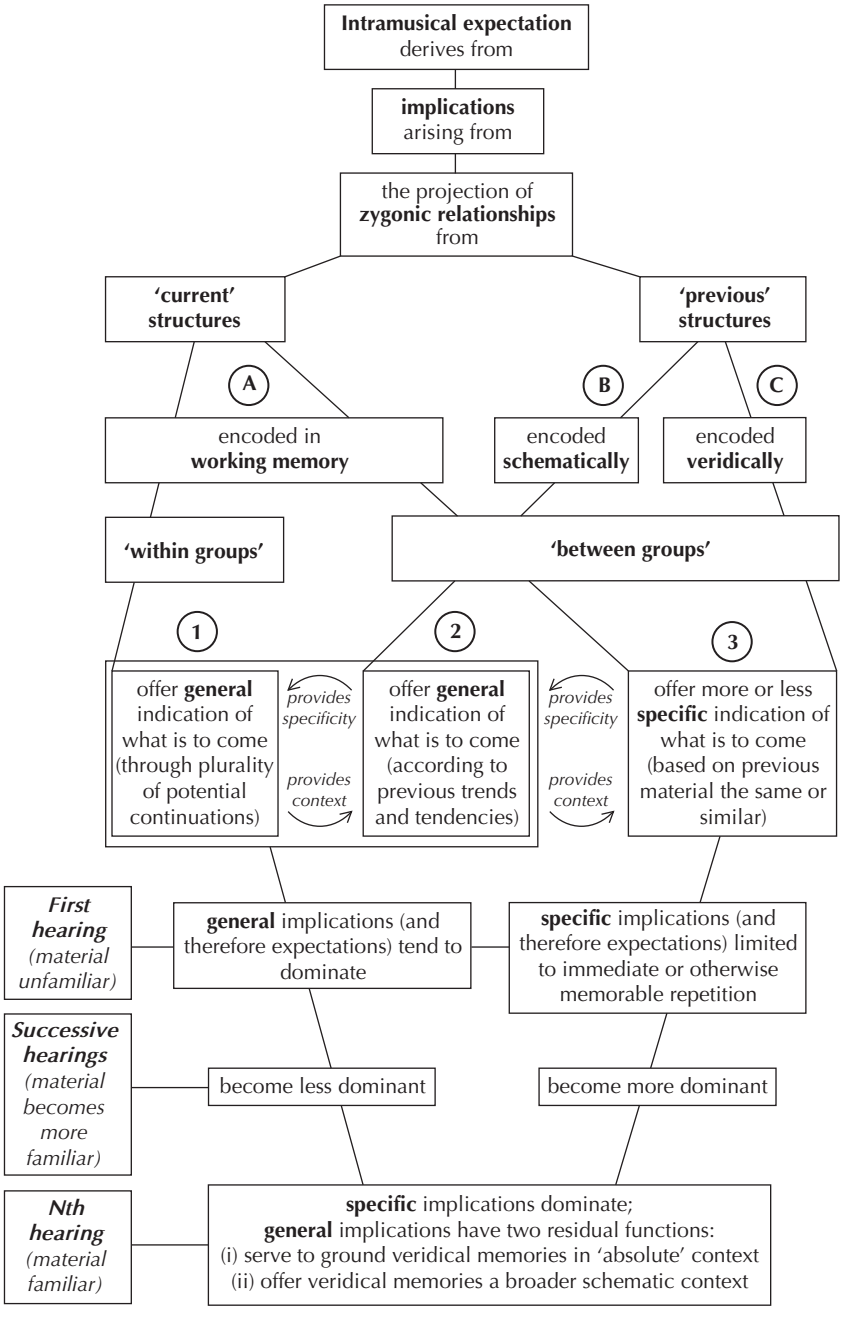


Fig. 8.47 Zygonic model of implication and expectation in music.

In seeking an answer to this question, we will take a step back and return to the work of Leonard Meyer, whose seminal thinking over five decades has provided much of the stimulus for the theoretical and empirical efforts described and analyzed in this chapter and Chapter 9. An early proposition of Meyer's was that an affective response will be aroused when an expectation activated by a musical stimulus, a tendency to respond, is temporarily inhibited or permanently blocked (Meyer, 1956, p. 31). Since its original formulation over 50 years ago, this thesis has stimulated considerable debate. A recurring concern has been how to reconcile the uncertainty purported to be necessary to stimulate affect (Meyer, 2001) with the matter of repeated hearings, since, as we noted in the Introduction, one can perform or listen to the same piece of music many times and continue to enjoy it. Indeed, we typically react most strongly to music with which we are familiar (Panskepp, 1995, p. 172). Yet it cannot be the case for a piece that one has memorized, for example, "that the ebb and flow of partially fulfilled expectations control one's enjoyment of it: every note is exactly what is expected" (Bever, 1988, p. 166). Meyer himself counters arguments of this type in a number of ways (Meyer, 1967, pp. 42ff.). One to which he returned in this last thoughts on the subject is the "willing suspension of disbelief," through which listeners supposedly enter into an esthetic illusion, unwittingly (or even deliberately) ignoring their knowledge of a piece, and hearing it as if for the first time (Meyer, 2001, p. 352).

There are, however, a number of difficulties with this view. Consider, for example, the opening of the third movement of Rachmaninov's second symphony. Based on listeners' retrospective accounts, Sloboda (1991, p. 115) found this to be prototypical of passages that provoke tears, in that it utilizes melodic appoggiaturas, and forms a melodic and harmonic sequence whose underlying chords descend through the cycle 5ths to the tonic (see Fig. 8.48). Sloboda believes that this finding and others similar offer some confirmation of Meyer's theory that affect stems from the creation and potential violation of expectancy within musical structures. But is this actually what the passage shows?

Take, for example, the appoggiaturas, which Meyer considers to cause "affective expressive experience" since "they delay (inhibit) the arrival of the expected and anticipated structural tone" (Meyer, 1956, p. 207). One can test this out by mentally replaying the first bar of the Rachmaninov movement, feigning ignorance of what should follow, in accordance with Meyer's proposition. What melodic continuations can reasonably be anticipated at this point? As we are discounting memories of previous hearings of the passage, there are two sources of predictive information that we are able to draw upon. The first is the opening material itself. If, for the sake of simplicity, we project only perfect primary and secondary zygonic relationships of pitch degree (see A in Fig. 8.47) within the diatonic framework that is indicated through stylistic precedent (see B in Fig. 8.47) (cf. Fig. 8.39) then seven theoretical possibilities are available as shown in Fig. 8.49 (here with potential harmonizations).[26]

In fact, all these melodic options (situated in a range of harmonic, rhythmic, and textural contexts) are taken up by composers working within the Western Classical tradition, as Barlow and Morgenstern's (1948) *Dictionary of Musical Themes* reveals (see Table 8.1). There is, of course, no suggestion that the relative frequencies with which these series of pitch degrees occur translate directly into probabilities within an expectancy framework, through schematic memory and recall (B in Fig. 8.47). Clearly, other factors would have to figure in any such equation, including the listener's degree of familiarity with the works concerned. The important point here is that

[26] Assuming a tonality of A major; arguably, a first-time listener may hear the passage in D. In either case, the principle of general expectation outlined here would be the same.

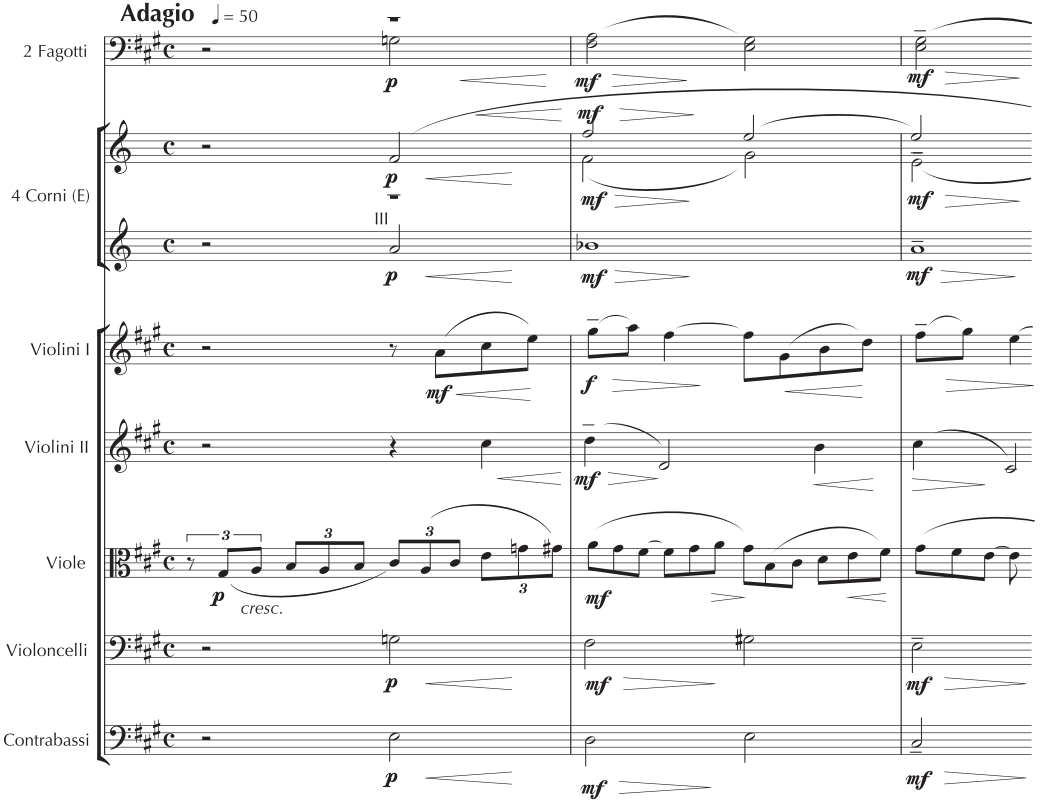



Fig. 8.48 The opening bars of Rachmaninov's 2nd symphony, 3rd movement.

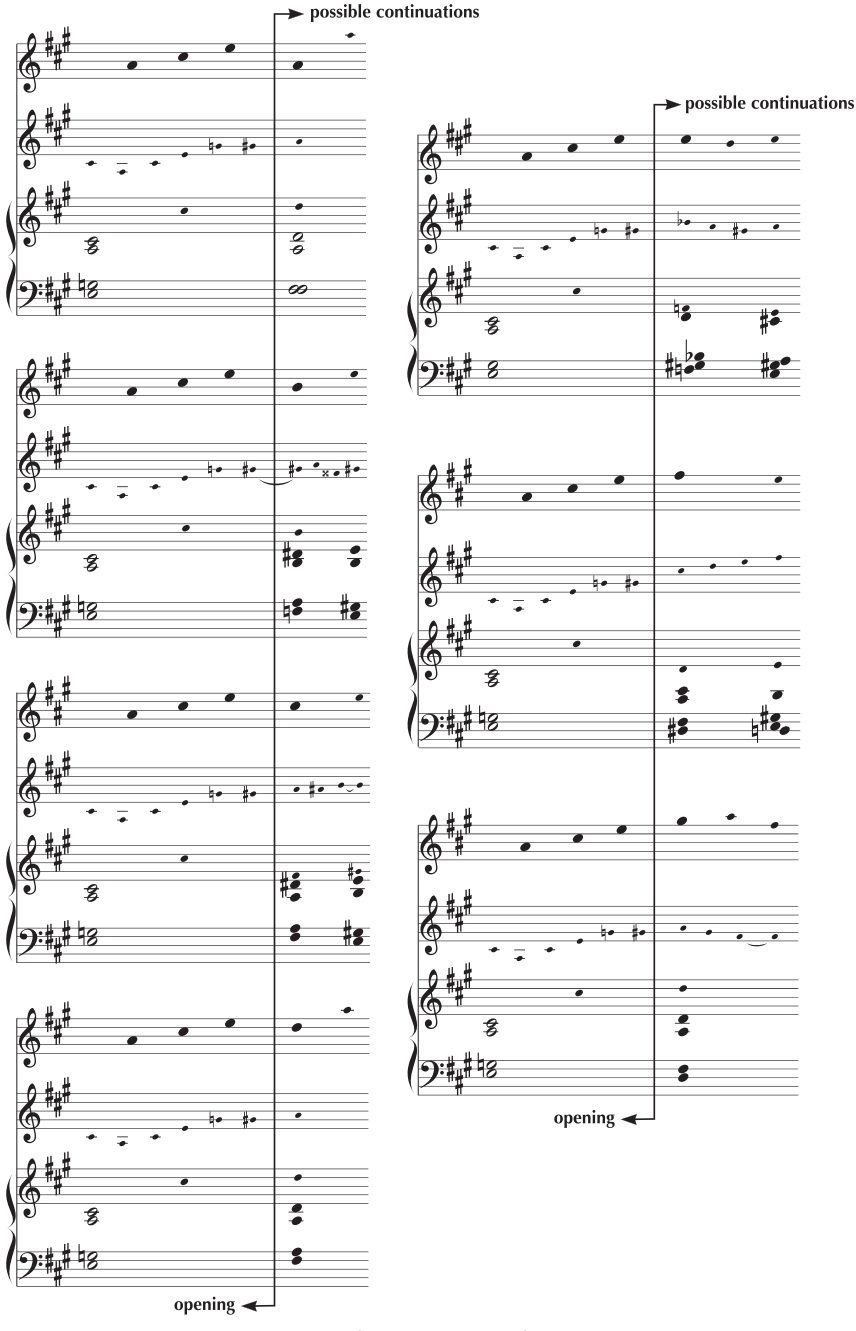



Fig. 8.49 Potential coherent continuations following bar 1 of the 3rd movement of Rachmaninov's 2nd symphony, based on within group and schematic structures.

Table 8.1 Examples of melodic continuations following the opening i–iii–v in the Western Classical tradition

Tonal degree following initial i–iii–v	Example from Western Classical repertoire	Number of instances cited in Barlow and Morgenstern (1948)	Relative frequency
i	Bach: prelude No. 9 in E major, BWV 854	50	0.33
ii	Handel: sonata in D major, Op. 1, No. 13 for violin and continuo; 1st movement	4	0.03
iii	Schubert: sonata for violin and piano, Op. 137, No. 1; 1st movement	25	0.17
iv	Mozart: symphony No. 40 in G minor, K. 550; trio	14	0.09
v	Haydn: symphony No. 104 in D major; minuet	31	0.21
vi	Wagner: *Parsifal*; overture	18	0.12
vii	Stravinsky: *Capriccio for Orchestra* (rev. 1949); 3rd movement	8	0.05
Totals		150	1

since all the seven pitch degrees are identified as offering musically acceptable modes of continuation (judged both from the standpoints of logical analysis and historical precedent), it seems reasonable to assume that, on a first hearing at the moment in question, listeners' expectations should potentially embrace them all. Hence, in considering how bar 2 of the third movement of Rachmaninov's third symphony may begin, a reasonable assumption would be that the fourth melody note is likely to conform to the major diatonic framework (with possible chromatic inflections) and be within an octave range of those preceding it (cf. Fig. 8.31).

Accordingly, there is no reason to believe (in the absence of empirical data) that the immediate "structural tone" that Rachmaninov actually does employ—the fifth octave A—will be anticipated to the exclusion of any other. This implies a level of uncertainty which would surely *preclude the appoggiatura prospectively being felt to inhibit its arrival*.[27] Admittedly, within the "common practice" style to which the symphony conforms, this G♯ has a perceived urge to resolve by step to the nearest diatonic consonance (the A) (see Huron, 2006), but this effect (and any corresponding affect) will occur *as the discord is heard*. Hence, while expectation may well play a part in our esthetic response at this (slightly later) point in the melody, it will derive from the stylistic tendency of appoggiaturas to resolve to neighboring notes, not from the preceding melodic context—the "anticipation before the event" mentioned by Meyer. Before this (as the third note of the melody is heard) there appears to be *too great* a level of uncertainty to enable the theory of inhibited response to function. Conversely, once the resolution has been heard, in retrospect, the

[27] In fact, the resolution is échapée-like; the structural tone arguably being the F♯ following the A.

position is rather different: listeners may well appreciate (typically at a subconscious level) that the G♯ did indeed delay the arrival of the A, taking the melody on a circuitous route; but at this stage, clearly, there could be *no uncertainty*, since the events have passed.

Hence Meyer's proposition that emotion and meaning in music stem through expectation from events around which there is an element of doubt appears to be in difficulty, even for a first-time listener. Moreover, the model set out in Fig. 8.47 suggests that this thesis becomes even harder to sustain as the passage proceeds, since *between-group* projections kick in: subsequent appoggiaturas *and their resolutions* are strongly implied through the sequential nature of what follows: secure predictions being enabled through primary and secondary zygonic invariants (series of relationships operating in parallel). A similar sense of inevitability, a teleological drive, characterizes the inner parts too (listen to the movement of the second violins, violas, and cellos) and, crucially, the bassline, since it bears the harmonic burden of the musical fabric as a whole. Here, at the bottom of the texture, the ascending third of the melody spanning bars 2 and 3 is mirrored in the descent from the 5th degree to the 3rd, and concomitant transition from the dominant harmony to the mediant (see Fig. 8.50).

In summary, then, it seems inconceivable that one could listen to these opening bars without *anticipating* the appoggiaturas with which they begin (after the first). To the stylistically competent listener, even if he is listening to the passage for the first time, there is little or no uncertainty as to the course of the melody once the sequence gets under way. Moreover (as we noted above) the first-time listener is the exception rather than the rule. So what is one to make of Meyer's theory? As Jackendoff (1991, pp. 224, 225) puts it: "Everyone has the experience of thinking 'Here comes that beautiful place!'—enjoying it in the full knowledge of exactly what it is going to sound like, with both memory and affect fully engaged." The problem with Meyer's argument is that it attempts to "conflate enjoying a piece with not remembering how it goes." However, Jackendoff (1991, p. 228) does offer the possibility of "rescuing" Meyer's expectation theory, suggesting that violations of what is expected may occur on a subconscious level, involving a closed module for music-processing—a "parser"—which in effect always hears a piece as if for the first time, thereby ensuring that affect remains intact (cf. Fodor, 1983; see also Margulis, 2005a). Similarly, Schmuckler (1989, p. 114) contends that "expectancies are formed along the basis of ingrained stylistic regularities (such as tonal structure, melodic process, and common harmonic progressions) which operate impervious to one's experience of a particular piece. Working atop this general frame is specific knowledge, which selectively affects some expectancies, particularly at highly unstable points, where unusual events occur." Bharucha (1994, pp. 215, 216) describes the position thus: "Even when a piece has been heard often enough to be familiar, it cannot completely override the generic, automatic expectations. Surprises in a new piece thus continue to have a surprising quality because they are heard as surprises relative to these irrepressible expectations." Perhaps, then, Meyer's original assertion would be better couched in terms of expectation in music working through the *non-conscious* (rather than the willing) suspension of disbelief.

To sum up: whatever the neurocognitive processes involved, reflection on the listening experience as set out in this chapter suggests that *being able to anticipate what is in stylistic terms the relatively unexpected enables us to relish it all the more*. This accords with Huron's hypothesis (2006) that a key component in the pleasurable experience that music affords—its "sweet anticipation"—is the succession of non-conscious cognitive rewards that our ability to make correct prognostications offers. These are all ultimately enabled by repetition of one form or another, whether "statistical" or "specific," whose universal presence and function in music lies at the heart of zygonic theory.

Until recently, despite its intuitive consonance with the esthetic experience of listening to music, the zygonic theory of expectation, remained just that—a theory. While it would be difficult to test

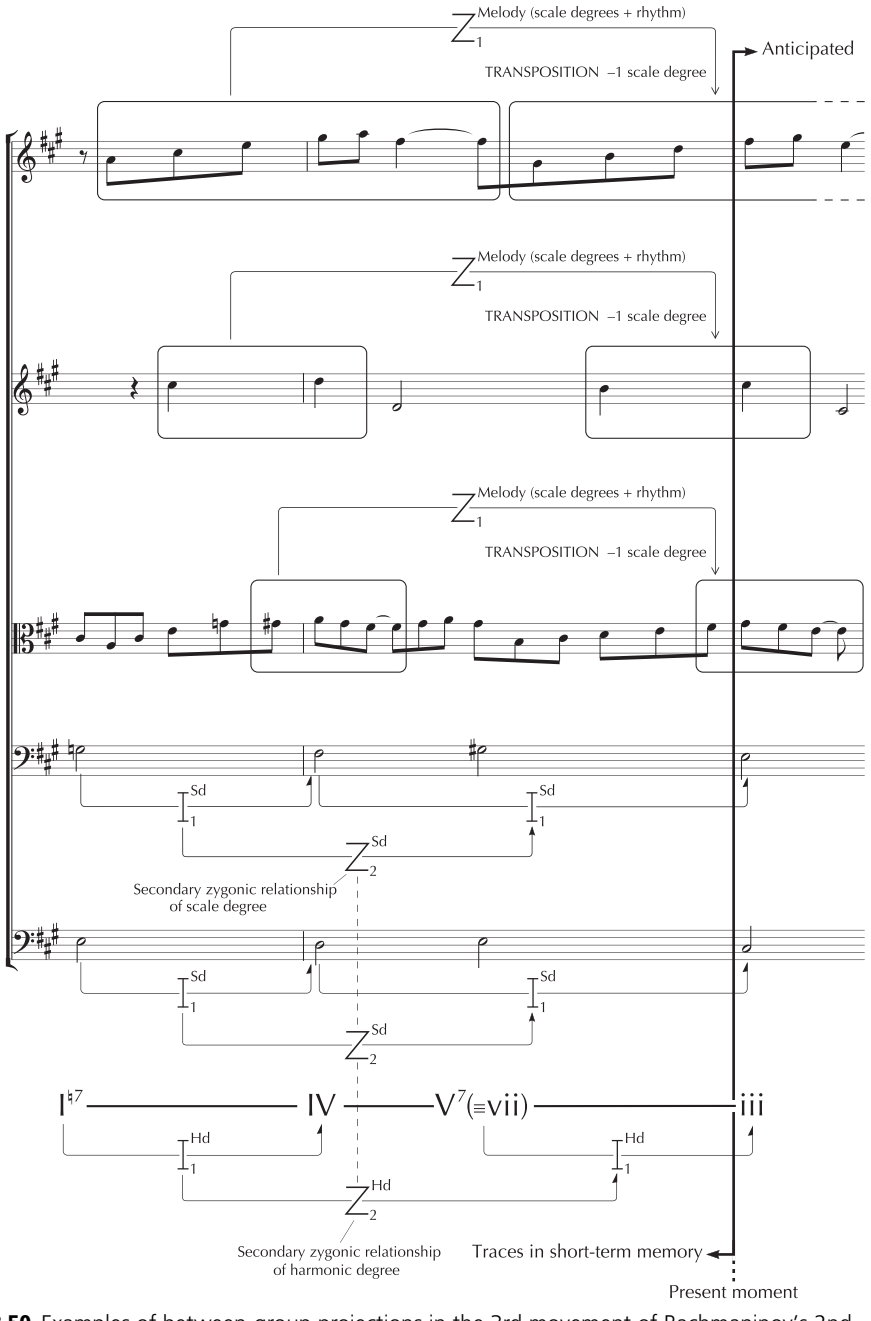


Fig. 8.50 Examples of between-group projections in the 3rd movement of Rachmaninov's 2nd symphony.

the whole model empirically at one time, given certain reasonable assumptions features of it can be used to produce testable predictions. Two of these, pertaining to tonal music, will be reported in this chapter. One, relating to expectation in serial contexts, will be considered in Chapter 9.

The study by Michael Thorpe

In 2010, as part of his masters course in music psychology at the University of Roehampton, Michael Thorpe investigated three elements of the zygonic model shown in Fig. 8.47, with research questions as follows:

(a) Is there evidence to support the hypothesis that, ceteris paribus, expectations arising from "current structures, within groups" and "previous structures, schematically encoded" interact to produce a *general* sense of what may follow?

(b) Is there evidence to support the hypothesis that expectations arising from "current structures, between groups" produce a *specific* sense of what is to follow?

(c) Is there evidence to support the hypothesis that (b) and (a) interact, whereby (b) adds greater specificity to (a), and (a) grounds (b) in a local context?

These questions engage A and B and their correlates 1, 2, and 3 in Fig. 8.47. The results were published by Thorpe *et al.* (2012) in *Psychology of Music*, and are summarized here.

It was evident that a number of constraints were required to make Thorpe's empirical work manageable, and to enable his research questions to be answered. First, it was necessary to place restrictions on the design and utilization of the stimulus:

Constraint 1

The domain of study should be *pitch*, since this constitutes the principal structure-bearing dimension of the "what" in music (see p. 325). This meant that tessitura, tempo, timbre, and loudness should be as "neutral" and constant as possible, to avoid potentially confounding effects.

Constraint 2

As the major tonal system is the one used most commonly in Western popular and Classical music, it was decided that pitches should be limited to the framework provided by the major diatonic scale, and that the material should conform to Western tonal "common practice," with which a broad spectrum of subjects would be familiar. To facilitate prediction and analysis of the results, all seven available scale degrees should appear within the span of an octave.

Constraint 3

The stimulus should be as simple as possible and use a single melodic line, thereby avoiding the complexity of expectations in one part potentially influencing those in another (see Ockelford, 2008a, p. 371).

Constraint 4

The stimulus should comprise newly composed material, to avoid the danger that C in Fig. 8.47 (previous structures encoded veridically) would play a part in subjects' responses.

Constraint 5

For the same reason, subjects should be limited to one hearing.

Constraint 6

To gauge the impact of between-group structures (an element of A), the melody should include clusters of notes that are repeated or transposed, as well as having sections in which no such connections exist.

Constraint 7

Given the method of data collection that was used (in which participants sang the note they expected to come next—see later), and given that both adult males and females were involved, the melody should be capable of placement within two alternative pitch spans that were mid-range for "typical" men's and women's voices.

Given these constraints, a stimulus was created as shown in Fig. 8.51.

In accordance with Constraint 1, the tempo is moderate, and there is little rhythmic variety, with only two note lengths being used (the longer durations serving to mark the ends of phrases); timbre is constant and rich (though stylistically "non-specific"); and most musical information is presented in the domain of pitch. Each scale degree occurs at least once, over the range of a minor 7th (Constraint 2). The melody is set in the key of D major, placing the pitches in the 4th octave

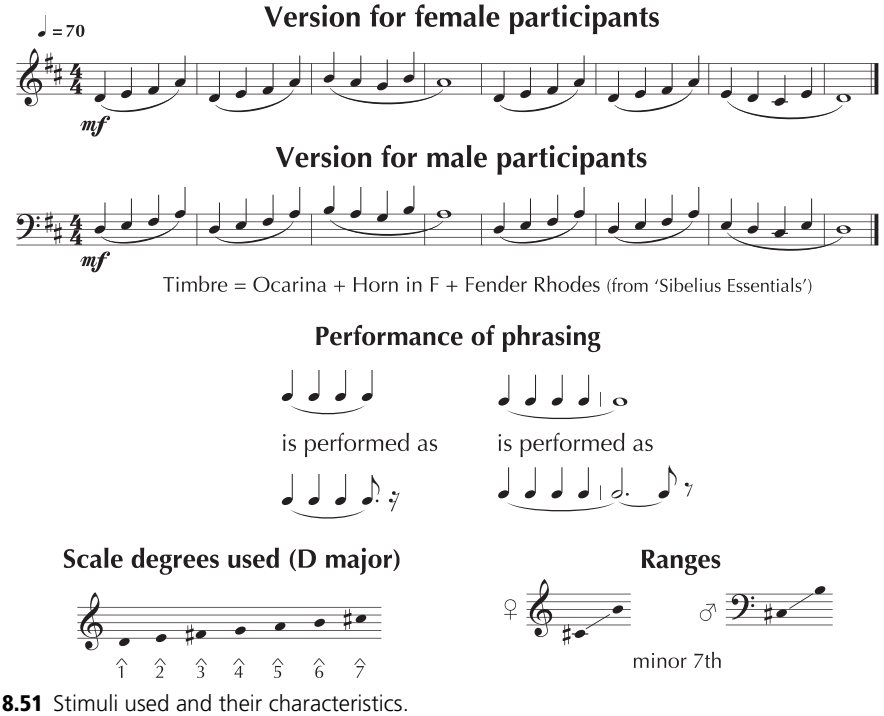


Fig. 8.51 Stimuli used and their characteristics.

for women and the 3rd octave for men (Constraint 7). The tune is unaccompanied (Constraint 3), and does not conform to any well-known themes in the Western Classical or popular repertories (Constraint 4).

The formal structure of the melody is a_1 a_1 b_1 a_1 a_1 b_2 (Constraint 6), which can be summarized as A_1 A_2 (see Fig. 8.51). Since Thorpe was seeking to determine how the perception of between-group relationships impacts on expectation, it was crucial for him to gauge the detectability of the structure of the melodic line, albeit non-consciously, in first-time listening. To this end, a psychomusicological analysis was undertaken, using zygonic theory. This drew on the analytical intuitions of Thorpe and his collaborators (who had composed the tune), and was therefore susceptible to problems of subjectivity. However, for the empirical work to get off the ground, a predictive model was essential, meaning that certain assumptions were inevitable. We felt that these could subsequently be modified, if necessary, in the light of the results obtained from a range of listeners, hearing the stimulus with no structural preconceptions. The assumptions are illustrated in Fig. 8.52 and listed below.

Assumption 1

We assumed that the boundary between the first group $a_1$and its repetition would be detected as the second D was heard, on account of any or all of three signals: the shortening of the preceding A, which leaves a discernible gap in the continuity of sound [see Lerdahl and Jackendoff's (1983, pp. 43ff.) grouping preference rules]; the interval of the descending 5th between the A and D, which is comparatively large, providing relative melodic discontinuity (Bregman, 1990, pp. 461ff.); and the fact the D is a repetition of the opening pitch—potentially an indication that the first motif (or a variant of it) is about to restart [see Lerdahl and Jackendoff's (1990, p. 51) notion of "parallelism"]. That is, we hypothesized that schemata pertaining to the way in which formal structures typically unfold (an aspect of B in the zygonic model of expectation shown in Fig. 8.47) may play a part in determining group boundaries.

Assumption 2

We assumed that the second A (at the end of bar 2) would be heard as concluding the second group a_1 due to the equivalent note in the first appearance of a_1 fulfilling that function (Lerdahl and Jackendoff, 1990). We further assumed that this structural cognition will be reinforced on hearing the B that opens bar 3, through the short break in sound that occurs before it.

Assumption 3

We assumed that b_1 (bars 3 and 4) would be heard as single group, due to the adjacency of successive pitches, the continuity of sound, and the longer duration of the final note that, it was expected, would strongly signal a phrase boundary, something that would subsequently be reinforced upon hearing the brief gap in sound before the next note, D.[28]

[28] Note that, here, the repetition of a pitch, B5, would not be expected to signal a group boundary, since the two notes occupy different positions in the bar, implying a conflict with the prevailing meter. While this is perfectly possible (as in the chorus of Gershwin's aptly named *Fascinating Rhythm*, for example) the ear would need a signal, such as a break in the sound or a dynamic accent, to detect the syncopation prospectively (rather than in retrospect).

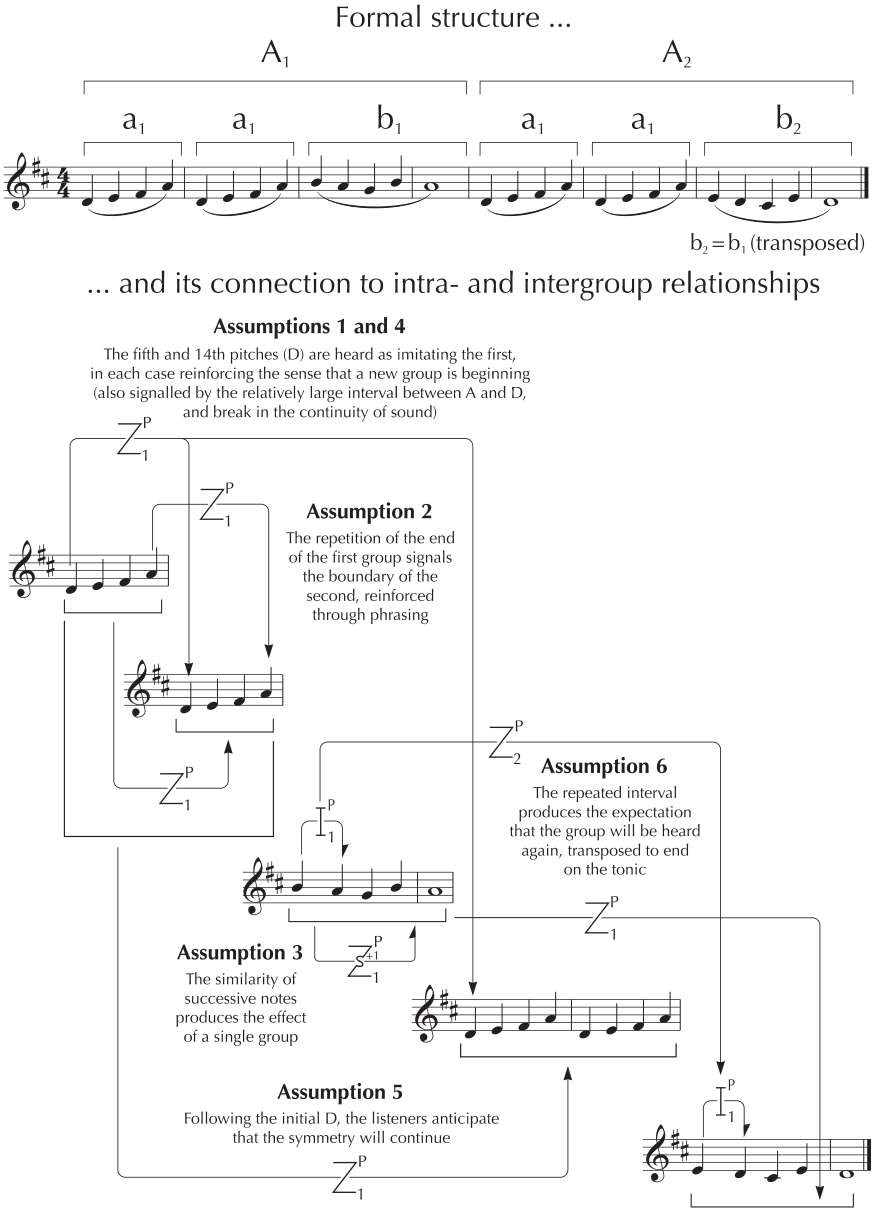


Fig. 8.52 Stimulus melody and musicological and psychomusicological analyses.

Assumption 4

We assumed that this third D would indicate a return to the opening segment A_1 (or a variant of it), due to the symmetry implied (through listeners' assumed experience of archetypal formal structures) by the repeat of the opening note after the end of the first phrase. It was anticipated that the perception of meter would be established by this point (bolstered by the recognition of previous grouping structures,

with their strong metrical correspondence), and that listeners would suppose that the initial 4/4 would continue, running in parallel with any motivic repetition and transformation, thereby reinforcing expectation in the domain of pitch (cf. Temperley, 1995, p. 141; Ockelford, 2009b, p. 75).

Assumption 5

We assumed that listeners would anticipate that the symmetry would continue, with $a_1 + a_1$ followed by b_1 or a variant of it (which, in simple tonal melodies, would typically resolve the dominant that was heard at the half way point, A, onto the tonic, D).

Assumption 6

We assumed that the E at the beginning of bar 7 (after the second reprise of a_1) would register with listeners as an indication that something different was about to happen. However, it is not until the onset of the following D (which, like the opening of bar 3, frames a descending major 2nd), that we expected listeners to anticipate a transposed version of b_1, concluding on the tonic.

Further constraints and assumptions, arising partly from the design of the melody, impinged upon the way in which the patterns of expectation that evolve as the stimulus is heard were modeled according to zygonic theory—limitations and suppositions that enabled quanta to be assigned to the anticipated relative strengths of expectation involved.

Constraint 8

In relation to A1("current structures, within groups", see Fig. 8.47), since little is known about how expectations arising from pitches or intervals interact, it was decided for this initial investigation to model only the impact of perfect and imperfect *primary* zygons that may conceivably operate from a given note (cf. Fig. 8.27).

Assumption 7

We assumed that such relationships will be subject to an *adjacency* effect, since zygonic theory suggests that, ceteris paribus, the strength of expectation will be inversely proportional to the dissimilarity of a predicted note to the stimulus, although the precise nature of the relationship is not determined (cf. Ortmann, 1926, p. 30) (again, see Fig. 8.27). Turning to the available empirical data pertaining to the melodic intervals occurring between successive notes from Ortmann (1926) and Huron (2001, p. 25), the statistical picture is in reality more complex than this: exact repetition tends to be used less frequently than intervals of a second (the desire for similarity apparently outweighing the wish for duplication), and the interval of an octave arises more often than 6ths and 7ths (arguably due to the influence of the harmonic series; see Ortmann, 1926, p. 31). Combining the findings of the two studies yields intervallic data relating to over 340 pieces from 10 cultures, which can be expressed in terms of differences between scale steps as shown in Table 8.2).

These data were used to form what Huron (2006) terms a "serviceable heuristic" in order to quantify the expectations pertaining to B2 in Fig. 8.47 ("previous structures, between groups, encoded schematically"). This heuristic is constrained by the fact that it reflects intervals from a limited number of

Table 8.2 Intervallic probabilities, after Ortmann (1926) and Huron (2001a)

Interval	Ortmann/Huron relative frequency
0 scale-steps (unison)	0.24
± 1 scale-step (2nd)	0.42
± 2 scale-step (3rd)	0.17
± 3 scale-step (4th)	0.08
± 4 scale-step (5th)	0.03
± 5 scale-step (6th)	0.02
± 6 scale-step (7th)	0.01
± 7 scale-step (octave)	0.03
Total	**1.00**

pieces and extends only an octave in each direction from the target pitch. Moreover, the data do not take into account context-specific features, such as the scale-steps involved, the position of a given interval in a particular melody, or its direction (ascending or descending). However, in terms of building a general model, we assumed that these surface details could reasonably be set aside for the time being (and, if necessary, be subsequently revisited in the light of empirical findings): the important issue was to identify trends with which the data accorded, and which were likely to be intuitively apprehensible.

Given that the overall probability had to total 1, and on the working assumption that the heuristic was bidirectional and operated symmetrically about the pitch that was presented, the model predicted that, following the first note of the stimulus melody, pitches would be anticipated with the probabilities shown in Table 8.3.

Assumption 8

We assumed that the significance of adjacency in prediction may extend to stimuli other than the one heard most recently, and a *recency* effect was postulated, whereby the closer the stimulus to the point at which expectation occurs, the greater its likely impact on anticipating what will happen next (see Fig. 8.31). To enable this model to function predictively—to indicate which pitches are likely to be expected, and with what probabilities—two factors needed to be quantified: the *number* of notes (that is, how far back in the sequence to reach) and the *nature* of the relationship between events in terms of their relative impact (for example, a more contemporaneous note could be deemed to exert twice the effect of the one preceding it, and so on). Two principles were used to inform the process of quantification: the psychological constraints of working memory, and the mathematical consideration that some of the proportions involved in predictions from just one note are already very small, meaning that significant reduction would render them trivial. Given these two constraints, a model was devised that took into account a maximum of *four* events, with a *linear* decrement of impact. The latter is calculated such that the predicted probability (P) of an nth pitch (p_n) (occurring after $n - 1$ events) is given by the equation

$$P(p_n) = \frac{n-1}{\sum(n-1)} P(p_{n-1}) + \frac{n-2}{\sum(n-1)} P(p_{n-2}) + \cdots \frac{1}{\sum(n-1)} P(p_1). \quad (8.1)$$

Table 8.3 Predicted probabilities of expectation using the adjacency model following the first note of the melody

Current pitch	Next pitch	Interval	Predicted probability
	D5	octave up	0.02
	C5	7th up	0.01
	B4	6th up	0.01
	A4	5th up	0.02
	G4	4th up	0.05
	F4	3rd up	0.10
	E4	2nd up	0.24
D4	D4	unison	0.14
	C4	2nd down	0.24
	B3	3rd down	0.10
	A3	4th down	0.05
	G3	5th down	0.02
	F3	6th down	0.01
	E3	7th down	0.01
	D3	octave down	0.02
		Total	**1**

To show this principle in action, the predicted probabilities of notes 3, 4, and 5 from the stimulus melody are given in Table 8.4.[29]

Assumption 9

In relation to A3 of the zygonic model illustrated in Fig. 8.47 ("current structures, between groups"), we assumed that groups would be recognized from the first note onwards in the case of exact repetition (see Assumptions 1 and 4 and Fig. 8.52) and from the first interval (that is, the second note) in the case of transposition.

[29] Observe that, in this first iteration of the model, the adjacency/recency quantification took into account only *pitch* relationships, and ignored other factors that would be likely to exert a perceptual influence, such as "relative metrical location" (RML; the position of the note in the bar; see Ockelford, 2009b, p. 71). Future models could be refined to acknowledge cross-domain effects of this type.

Table 8.4 Predicted probabilities of expectation using the adjacency + recency model following the first 2, 3, and 4 notes of the melody

Following the first two notes

Probabilities based on adjacency + recency			Probabilities based on adjacency only			Probabilities of next pitch based on adjacency only			Probabilities based on pitches 1 & 2		
1st pitch			2nd pitch			3rd pitch			3rd pitch		
D5	0.02	**0.01**	E5	0.02	**0.01**	E5	**0.01**		E5	**0.01**	
C 5	0.01	**0.00**	D5	0.01	**0.00**	D5	**0.01**		D5	**0.01**	
B4	0.01	**0.00**	C 5	0.01	**0.01**	C 5	**0.01**		C 5	**0.01**	
A4	0.02	**0.01**	B4	0.02	**0.01**	B4	**0.02**		B4	**0.02**	
G4	0.05	**0.02**	A4	0.05	**0.03**	A4	**0.04**		A4	**0.04**	
F 4	0.10	**0.03**	G4	0.10	**0.06**	G4	**0.08**		G4	**0.08**	
E4	0.24	**0.08**	F 4	0.24	**0.16**	F 4	**0.19**		F 4	**0.19**	
D4	0.14	**0.05**	E4	0.14	**0.09**	E4	**0.17**		E4	**0.17**	
C 4	0.24	**0.08**	D4	0.24	**0.16**	D4	**0.20**		D4	**0.20**	
B3	0.10	**0.03**	C 4	0.10	**0.06**	C 4	**0.14**		C 4	**0.14**	
A3	0.05	**0.02**	B3	0.05	**0.03**	B3	**0.06**		B3	**0.06**	
G3	0.02	**0.01**	A3	0.02	**0.01**	A3	**0.03**		A3	**0.03**	
F 3	0.01	**0.00**	G3	0.01	**0.01**	G3	**0.01**		G3	**0.01**	
E3	0.01	**0.00**	F 3	0.01	**0.00**	F 3	**0.01**		F 3	**0.01**	
D3	0.02	**0.01**	E3	0.02	**0.01**	E3	**0.01**		E3	**0.01**	
		x0.33			**x0.67**			**1.00**			**1.00**

Following the first three notes

Probabilities based on adjacency + recency			Probabilities based on adjacency only			Probabilities of next pitch based on adjacency only			Probabilities based on pitches 1–3		
1st pitch			2nd pitch			3rd pitch			4th pitch		
D5	0.02	**0.00**	E5	0.02	**0.00**	F 5	0.02	**0.01**	F 5	**0.01**	
C 5	0.01	**0.00**	D5	0.01	**0.00**	E5	0.01	**0.00**	E5	**0.01**	
B4	0.01	**0.00**	C 5	0.01	**0.00**	D5	0.01	**0.01**	D5	**0.01**	
A4	0.02	**0.00**	B4	0.02	**0.01**	C 5	0.02	**0.01**	C 5	**0.01**	
G4	0.05	**0.01**	A4	0.05	**0.02**	B4	0.05	**0.02**	B4	**0.03**	
F 4	0.10	**0.02**	G4	0.10	**0.03**	A4	0.10	**0.05**	A4	**0.07**	
E4	0.24	**0.04**	F 4	0.24	**0.08**	G4	0.24	**0.12**	G4	**0.16**	
D4	0.14	**0.02**	E4	0.14	**0.05**	F 4	0.14	**0.07**	F 4	**0.16**	
C 4	0.24	**0.04**	D4	0.24	**0.08**	E4	0.24	**0.12**	E4	**0.20**	
B3	0.10	**0.02**	C 4	0.10	**0.03**	D4	0.10	**0.05**	D4	**0.15**	
A3	0.05	**0.01**	B3	0.05	**0.02**	C 4	0.05	**0.02**	C 4	**0.10**	
G3	0.02	**0.00**	A3	0.02	**0.01**	B3	0.02	**0.01**	B3	**0.04**	
F 3	0.01	**0.00**	G3	0.01	**0.00**	A3	0.01	**0.01**	A3	**0.02**	
E3	0.01	**0.00**	F 3	0.01	**0.00**	G3	0.01	**0.00**	G3	**0.01**	
D3	0.02	**0.00**	E3	0.02	**0.01**	F 3	0.02	**0.01**	F 3	**0.01**	
		x0.17			**x0.33**			**x0.50**			**1.00**

Following the first four notes

Probabilities based on adjacency + recency			Probabilities based on adjacency only			Probabilities of next pitch based on adjacency only			Probabilities based on adjacency + recency			Probabilities of next pitch based on adjacency only			Probabilities based on pitches 1–4		
1st pitch			2nd pitch			3rd pitch			3rd pitch			4th pitch			5th pitch		
												A5	0.02	**0.01**	A5	**0.01**	
												G5	0.01	**0.00**	G5	**0.00**	
									F 5	0.02	**0.01**	F 5	0.01	**0.00**	F 5	**0.01**	
			E5	0.02	**0.00**	E5	0.01	**0.00**	E5	0.01	**0.00**	E5	0.02	**0.01**	E5	**0.01**	
D5	0.02	**0.00**	D5	0.01	**0.00**	D5	0.01	**0.00**	D5	0.01	**0.00**	D5	0.05	**0.02**	D5	**0.02**	
C 5	0.01	**0.00**	C 5	0.01	**0.00**	C 5	0.02	**0.01**	C 5	0.02	**0.01**	C 5	0.10	**0.04**	C 5	**0.05**	
B4	0.01	**0.00**	B4	0.02	**0.00**	B4	0.05	**0.01**	B4	0.05	**0.01**	B4	0.24	**0.10**	B4	**0.11**	
A4	0.02	**0.00**	A4	0.05	**0.01**	A4	0.10	**0.03**	A4	0.10	**0.03**	A4	0.14	**0.05**	A4	**0.09**	
G4	0.05	**0.00**	G4	0.10	**0.02**	G4	0.24	**0.07**	G4	0.24	**0.07**	G4	0.24	**0.10**	G4	**0.19**	
F 4	0.10	**0.01**	F 4	0.24	**0.05**	F 4	0.14	**0.04**	F 4	0.14	**0.04**	F 4	0.10	**0.04**	F 4	**0.14**	
E4	0.24	**0.02**	E4	0.14	**0.03**	E4	0.24	**0.07**	E4	0.24	**0.07**	E4	0.05	**0.02**	E4	**0.14**	
D4	0.14	**0.01**	D4	0.24	**0.05**	D4	0.10	**0.03**	D4	0.10	**0.03**	D4	0.02	**0.01**	D4	**0.10**	
C 4	0.24	**0.02**	C 4	0.10	**0.02**	C 4	0.05	**0.01**	C 4	0.05	**0.01**	C 4	0.01	**0.00**	C 4	**0.06**	
B3	0.10	**0.01**	B3	0.05	**0.01**	B3	0.02	**0.01**	B3	0.02	**0.01**	B3	0.01	**0.00**	B3	**0.03**	
A3	0.05	**0.00**	A3	0.02	**0.00**	A3	0.01	**0.00**	A3	0.01	**0.00**	A3	0.02	**0.01**	A3	**0.02**	
G3	0.02	**0.00**	G3	0.01	**0.00**	G3	0.01	**0.00**	G3	0.01	**0.00**				G3	**0.01**	
F 3	0.01	**0.00**	F 3	0.01	**0.00**	F 3	0.02	**0.01**	F 3	0.02	**0.01**				F 3	**0.01**	
E3	0.01	**0.00**	E3	0.02	**0.00**										E3	**0.00**	
D3	0.02	**0.00**													D3	**0.00**	
		x0.10			**x0.20**			**x0.30**			**x0.40**			**1.00**			

Assumption 10

We assumed that the combined "adjacency/recency" effect (A1 + B2) (which we termed "interagency") would interact with the "between-groups" effect (A3), such that the strength of expectation generated by a group of repeated or transposed notes would increase rapidly as the sequence of pitches and intervals was heard again. That is, as listeners became more assured that what they are hearing was familiar, we assumed that they would make increasingly specific predictions as to what was likely to follow. No empirical data were available to quantify this conjecture, but we postulated that the impact ratio between the two factors, (A1 + B2) : A3, would change exponentially as one proceeded further through the group that was repeated or transposed, such that, after the *n*th pitch, the "between-group" and "interagency" (or "within-group") influences would be deemed to be $1 - (1/2n)$ and $1/2n$, respectively, in the case of repetition, a ratio of $(2^n - 1) : 1$, and, in the case of transposition, $1 - (1/2^{n-1})$ and $1/2^{n-1}$, a ratio of $(2^{n-1} - 1) : 1$. Table 8.5 shows the ratios in relation to notes 1–6 of a group and Table 8.6 shows these equations operating in relation to notes 5, 6, 7, and 8 of the stimulus.

Through the construction of tables such as these, it quickly became apparent that although the principles driving the model were straightforward its quantification resulted in a plethora of data, whose manipulation was time-consuming and arguably of little perceptual consequence at the periphery of the action (where values are very small). For example, after only four notes of a repeated group, the relative impact of interagency is negligible at the extremes of pitch, although the model still sets out the calculations. We came to the conclusion, however, that a certain degree of over-specificity was probably inevitable in the early stages of developing any such protocol that seeks to emulate complex human behavior when key parameters were still being determined. However, we hoped that future empirical work would suggest refinements and ways in which the model could be simplified without losing its flexibility or anticipated predictive power.

At this point then, Thorpe and his two associates (Aleks Aksentijevic and I) had three versions of the zygonic model of expectation theory that we believed would enable us to tackle the research questions: the one-factor "adjacency" model Z1; the two-factor "interagency" model Z2; and the three-factor "interagency/between-groups" model Z3. The next issue that we had to tackle was a methodological one: how to elicit and record responses with which the predictions could be compared. There are a number of ways of testing musical expectation (Huron, 2006, pp. 42–52), of which three could potentially produce data that were suitable for comparison with the outputs of the zygonic model: the progressive probe-tone method (Krumhansl, 1990, pp. 214ff.); the betting paradigm (Huron, 2006, pp. 47–9), and the "production method"—either through

Table 8.5 Predicted ratios between 'within-group' and 'between-group' influence

If group is a repetition	If group is a transposition	'Within-group' influence	'Between-group' influence
After note 1	After note 2	0.5	0.5
After note 2	After note 3	0.25	0.75
After note 3	After note 4	0.125	0.875
After note 4	After note 5	0.0625	0.9375
After note 5	After note 6	0.0313	0.9688
After note 6	After note 7	0.0156	0.9844

Table 8.6 Predicted probabilities of expectation using the adjacency + recency + intergroup model following notes 5, 6, 7, and 8

Following the first five notes															Following the first six notes					Following the first seven notes					Following the first eight notes				
Probabilities based on adjacency + recency																													
2nd pitch		3rd pitch		4th pitch		5th pitch		6th pitch			x0.5 = 'within-gorup' factor	'Between-group' factor	**Predicted probability of expectation**	7th pitch		x0.25 = 'within-gorup' factor	'Between-group' factor	Predicted probability of expectation	8th pitch		x0.13 = 'within-gorup' factor	'Between-group' factor	Predicted probability of expectation	9th pitch		x0.06 = 'within-gorup' factor	'Between-group' factor	Predicted probability of expectation
				A5	**0.01**			A5	0.01	**0.00**			**0.00**	A5	0.00	**0.00**		**0.00**	A5	0.00	**0.00**		**0.00**	A5	0.01	**0.00**		**0.00**
				G5	0.00			G5	0.00	**0.00**			**0.00**	G5	0.00	**0.00**		**0.00**	G5	0.00	**0.00**		**0.00**	G5	0.00	**0.00**		**0.00**
		F 5	0.00	F 5	0.00			F 5	0.01	**0.00**			**0.00**	F 5	0.00	**0.00**		**0.00**	F 5	0.01	**0.00**		**0.00**	F 5	0.01	**0.00**		**0.00**
E5	0.00	E5	0.00	E5	**0.01**			E5	0.01	**0.00**			**0.00**	E5	0.01	**0.00**		**0.00**	E5	0.01	**0.00**		**0.00**	E5	0.01	**0.00**		**0.00**
D5	0.00	D5	0.00	D5	0.01	D5	0.01	D5	0.02	**0.01**			**0.01**	D5	0.02	**0.00**		**0.00**	D5	0.01	**0.00**		**0.00**	D5	0.02	**0.00**		**0.00**
C 5	0.00	C 5	0.00	C 5	0.03	C 5	0.00	C 5	0.04	**0.02**			**0.02**	C 5	0.03	**0.01**		**0.01**	C 5	0.02	**0.00**		**0.00**	C 5	0.05	**0.00**		**0.00**
B4	0.00	B4	0.01	B4	0.07	B4	0.00	B4	0.09	**0.04**			**0.04**	B4	0.06	**0.02**		**0.02**	B4	0.05	**0.01**		**0.01**	B4	0.11	**0.01**		**0.01**
A4	0.00	A4	0.02	A4	0.04	A4	0.01	A4	0.07	**0.04**			**0.04**	A4	0.06	**0.02**		**0.02**	A4	0.07	**0.01**	0.88	**0.88**	A4	0.09	**0.01**		**0.01**
G4	0.01	G4	0.05	G4	0.07	G4	0.02	G4	0.15	**0.07**			**0.07**	G4	0.12	**0.03**		**0.03**	G4	0.16	**0.02**		**0.02**	G4	0.19	**0.01**		**0.01**
F 4	0.02	F 4	0.03	F 4	0.03	F 4	0.04	F 4	0.12	**0.06**			**0.06**	F 4	0.16	**0.04**	0.75	**0.79**	F 4	0.16	**0.02**		**0.02**	F 4	0.14	**0.01**		**0.01**
E4	0.01	E4	0.05	E4	0.01	E4	0.10	E4	0.17	**0.09**	0.50	**0.59**	E4	0.16	**0.04**		**0.04**	E4	0.19	**0.02**		**0.02**	E4	0.14	**0.01**	0.94	**0.94**
D4	0.02	D4	0.02	D4	0.01	D4	0.05	D4	0.10	**0.05**			**0.05**	D4	0.15	**0.04**		**0.04**	D4	0.14	**0.02**		**0.02**	D4	0.10	**0.00**		**0.00**
C 4	0.01	C 4	0.01	C 4	0.00	C 4	0.10	C 4	0.12	**0.06**			**0.06**	C 4	0.12	**0.03**		**0.03**	C 4	0.10	**0.01**		**0.01**	C 4	0.06	**0.00**		**0.00**
B3	0.00	B3	0.00	B3	0.00	B3	0.04	B3	0.05	**0.02**			**0.02**	B3	0.05	**0.01**		**0.01**	B3	0.04	**0.01**		**0.01**	B3	0.03	**0.00**		**0.00**
A3	0.00	A3	0.00	A3	0.01	A3	0.02	A3	0.03	**0.01**			**0.01**	A3	0.03	**0.01**		**0.01**	A3	0.02	**0.00**		**0.00**	A3	0.02	**0.00**		**0.00**
G3	0.00	G3	0.00			G3	0.01	G3	0.01	**0.00**			**0.00**	G3	0.01	**0.00**		**0.00**	G3	0.01	**0.00**		**0.00**	G3	0.01	**0.00**		**0.00**
F 3	0.00	F 3	0.00			F 3	0.00	F 3	0.01	**0.00**			**0.00**	F 3	0.01	**0.00**		**0.00**	F 3	0.01	**0.00**		**0.00**	F 3	0.01	**0.00**		**0.00**
E3	0.00					E3	0.00	E3	0.00	**0.00**			**0.00**	E3	0.01	**0.00**		**0.00**	E3	0.01	**0.00**		**0.00**	E3	0.00	**0.00**		**0.00**
						D3	0.01	D3	0.01	**0.00**			**0.00**	D3	0.01	**0.00**		**0.00**	D3	0.00	**0.00**		**0.00**	D3	0.00	**0.00**		**0.00**
	0.10		0.20		0.30		0.40		1.00	**0.50**			**1.00**		1.00	**0.25**		**1.00**		1.00	**0.13**		**1.00**		1.00	**0.06**		**1.00**

singing (Carlsen *et al*., 1970) or playing (Schmuckler, 1989; Povel, 1996). The first two approaches produce a *range* of responses for every listener in relation to each note of the stimulus: probabilities are generated for a set of pitches that indicate each one's perceived suitability as a potential successor to those that are presented. This has the advantage that each subject produces a full set of data that can be compared with the multiple, probabilistic continuations projected by the zygonic models. However, this benefit is outweighed by problems associated with the progressive probe-tone method and the betting paradigm, which are very time-consuming to administer and, in the case of the former, restrict subjects to a limited number of continuations to react to, and in the latter, constrain the choice of subjects to those with formal music education.

Both the production methods—singing and playing—mean that subjects can produce only one response per note. Hence, in order to obtain a range of perceived probabilities pertaining to a number of potential future pitches, the responses of many subjects have to be amalgamated. Therefore, if this method were to be used, a further assumption was required.

Assumption 11

We assumed that a valid impression of human musical expectation in relation to the differing probabilities that potentially pertain to different melodic continuations could be obtained by combining a number of listeners' responses.

The "playing" production method requires subjects to be able to play by ear, restricting the pool of potential research participants, and conceivably resulting in an atypical sample. On the other hand, the potential challenge of having subjects *sing* responses is that these may be constrained by the tessitura of the voice, and, in the absence of vocal training, that pitches may be produced inaccurately. The first difficulty can be obviated by avoiding registral extremes (Constraint 7), and the second can be countered by using frequency detection software and making reasonable assumptions as to what was intended. However, a number of issues remain: the task is artificial, since listeners do not usually listen to music in incrementally increasing chunks; they have to sing notes, consciously reflecting on and extrapolating from the listening experience in a way that is unnatural; and the pitches they produce—particularly if they prove to be incorrect—may be distracting. Hence, a final assumption was necessary.

Assumption 12

We assumed that a singing protocol of the type described would not interfere with subjects' listening experiences to such an extent that the responses they offer failed to present a reasonable picture of the expectations that would otherwise occur.

Forty subjects, 24 women and 16 men, aged between 21 and 76 (mean 34 years) took part in the study. They were recruited irrespective of whether they had had musical or, more specifically, vocal training. However, only 11 (28%) reported having had *no* formal music education. Of the remaining 29, five (17%) had had less than 2 years specialist input, six (21%) had had 2 to 4 years, nine (31%) had had 4 to 8 years, and nine (31%) had had more than 8 years. Seventeen (59%) also reported having had voice or singing lessons. All subjects reported listening to music every day (15% for less than 30 minutes, 45% for between 30 and 60 minutes, and 40% for more than 60 minutes) and had had significant exposure to Western mainstream styles. Three also reported listening regularly to music from other cultures, including Indian ragas and Slovakian folk music.

The stimulus used was the melody shown in Fig. 8.51, in different ranges for males and females. The timbre was instrumentally and stylistically non-specific (to avoid experience of specific instruments and composers' use of them affecting subjects' expectations) yet rich in harmonics and musically "realistic" (to make the task as ecologically valid as possible), and, to this end, three sounds were blended from the Sibelius 5 software: the ocarina, horn in F, and flute.

Since listeners were being asked to do something that was outside their experience, another (very short) practice melody was created. This was similar to the main stimulus, yet differed from it, so that, when the principal melody was subsequently heard, it would be regarded as a distinct musical entity, and "previous structures," "between groups," and "veridical" memories would not be invoked (see C3 in Fig. 8.47). Hence a musical fragment was constructed in a different key (C major) with a contrasting melodic contour. The version that was used for the women is shown in Fig. 8.53 (the men's form was an octave lower).

To set the auditory scene in each case, two introductions were produced, using the relevant diatonic major scale ascending and descending. This bi-directionality was again intended to counter any "previous structures," "between groups" effect—reinforced by using a different timbre (the piano) (see Fig. 8.54). Data were collected in a quiet room, with only one researcher (Thorpe) and the subject present, to minimize any discomfort that he or she may otherwise have felt in having to sing in front of someone else. The apparatus was set up so that Thorpe was outside subjects' field of vision, and assurances were given that they were not being judged on their singing ability; rather, they were encouraged to relax and follow their musical intuitions.

The stimulus materials were saved as MP3 files, and replayed using a Dell Dimension 3100C PC with a Lexicon Alpha soundcard and Harman Kardon speakers, which presented the stimuli to subjects at around 60 dB. Responses were recorded through a Sony ECM-MS907 microphone connected to the same Dell PC. Vocal frequencies were measured in hertz (Hz) using Praat, version 5.1.03 (developed by Paul Boersma and David Weenink). This software was selected for its track record in the field of psychological research (e.g. Steinbeis *et al*., 2006; Sergeant and Welch, 2009).

In both the practice and experimental conditions, subjects were presented with the introduction, followed after a short pause by the first note of the melody. They were asked to sing the note that they thought would be most likely to come next. Then the first two notes of the melody were

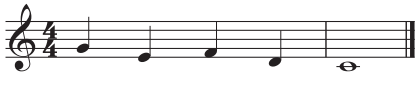



Fig. 8.53 'Practice' melody.

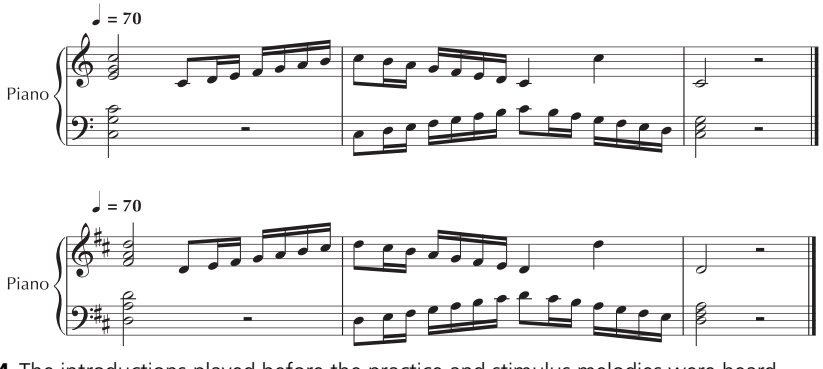



Fig. 8.54 The introductions played before the practice and stimulus melodies were heard.

Table 8.7 Observed, scaled responses

Note in stimulus melody

Observed proportions of expectancies	D4	E4	F 4	A4	D4	E4	F 4	A4	B4	A4	G4	B4	A4	D4	E4	F 4	A4	D4	E4	F 4	A4	E4	D4	C 4	E4
B5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D5	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.03	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
C 5	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B4	0.00	0.00	0.03	0.23	0.00	0.00	0.00	0.13	0.13	0.05	0.03	0.13	0.05	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00
A4	0.05	0.00	0.10	0.08	0.05	0.00	0.47	0.00	0.59	0.13	0.05	0.63	0.08	0.03	0.05	0.78	0.05	0.00	0.03	0.85	0.05	0.05	0.03	0.03	0.00
G4	0.03	0.00	0.62	0.25	0.03	0.03	0.11	0.05	0.08	0.26	0.00	0.05	0.31	0.03	0.03	0.10	0.00	0.05	0.00	0.03	0.13	0.13	0.00	0.00	0.00
F 4	0.10	0.69	0.08	0.13	0.05	0.60	0.03	0.03	0.03	0.41	0.68	0.05	0.05	0.03	0.75	0.03	0.00	0.00	0.80	0.08	0.00	0.33	0.00	0.05	0.00
E4	0.48	0.10	0.00	0.05	0.36	0.08	0.11	0.03	0.03	0.03	0.15	0.03	0.00	0.58	0.05	0.05	0.00	0.78	0.05	0.03	0.00	0.10	0.15	0.33	0.00
D4	0.15	0.03	0.15	0.13	0.18	0.20	0.26	0.53	0.03	0.05	0.08	0.05	0.33	0.25	0.05	0.03	0.80	0.10	0.08	0.00	0.03	0.35	0.20	0.33	0.93
C 4	0.00	0.05	0.00	0.00	0.18	0.00	0.03	0.05	0.00	0.05	0.00	0.00	0.05	0.05	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.33	0.10	0.05
B3	0.08	0.05	0.00	0.00	0.03	0.03	0.00	0.03	0.03	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.03	0.03	0.03	0.03	0.00	0.03	0.20	0.13	0.00
A3	0.05	0.05	0.03	0.10	0.08	0.08	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.03	0.03	0.03	0.05	0.03	0.03	0.00	0.00	0.00	0.03	0.03	0.00
G3	0.03	0.03	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00
F 3	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03
E3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
D3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Np	**9**	**7**	**6**	**9**	**10**	**6**	**6**	**12**	**9**	**8**	**6**	**9**	**10**	**8**	**8**	**6**	**7**	**6**	**6**	**5**	**6**	**7**	**8**	**8**	**3**
Rp	**13**	**6**	**8**	**10**	**9**	**6**	**5**	**13**	**9**	**10**	**7**	**13**	**11**	**10**	**8**	**7**	**11**	**7**	**7**	**6**	**13**	**6**	**9**	**8**	**5**
Vp	**11**	**6.5**	**7**	**9.5**	**9.5**	**6**	**5.5**	**12.5**	**9**	**9**	**6.5**	**11**	**10.5**	**9**	**8**	**6.5**	**9**	**6.5**	**6.5**	**5.5**	**9.5**	**6.5**	**8.5**	**8**	**4**

= pitch that actually occurred

presented, and again, subjects were requested to sing the pitch that they thought would follow. This process continued until the penultimate note of the melody. After each response, subjects signified how confident they felt that their guess was correct on a Likert scale from 1 ("not at all confident") to 7 ("extremely confident"). They were encouraged to use the whole of the scale, but reserving endpoints for extreme cases. The experiment took about 20 minutes.

The raw data comprised recordings of 1000 brief vocalizations (25 responses from each of 40 subjects). Each was measured in Hz, determined by taking the average frequency of the most consistent portion of the response. Occasionally there was significant variation: for example, where the vocal pattern started at a particular frequency, rose up to a higher one, then fell back again. Here, subjects' efforts were evaluated by an independent judge, who determined perceptually the point at which they seemed to settle on their intended pitch.

The frequencies obtained were assigned to categories from the D major scale, assuming equal temperament, and given that D4 (the D above middle C on the piano) is equal to 294 Hz. Responses from male participants were transposed up an octave in music-notational terms, to facilitate male and female data being considered together.

Combining the responses of the 40 subjects (in line with Assumption 11), and scaling them so that the sum pertaining to each note was 1, yielded the data set given in Table 8.7.

We considered the diversity to be striking. The *number* of different predictions following a given note (N_P) varied from 3 to 12 ($M = 7.36$, $SD = 1.96$), and the *range* in scale degrees (R_P) from 5 to 13 ($M = 8.68$, $SD = 2.58$). Combining these factors to give a "coefficient of variability" (V_P), such that

$$V_P = \frac{1}{2}(N_P + R_P) \tag{8.2}$$

revealed that the specificity of expectations increases only by around a quarter, as Fig. 8.55 shows. Despite designing the melody with a structure that was thought to be readily apprehensible

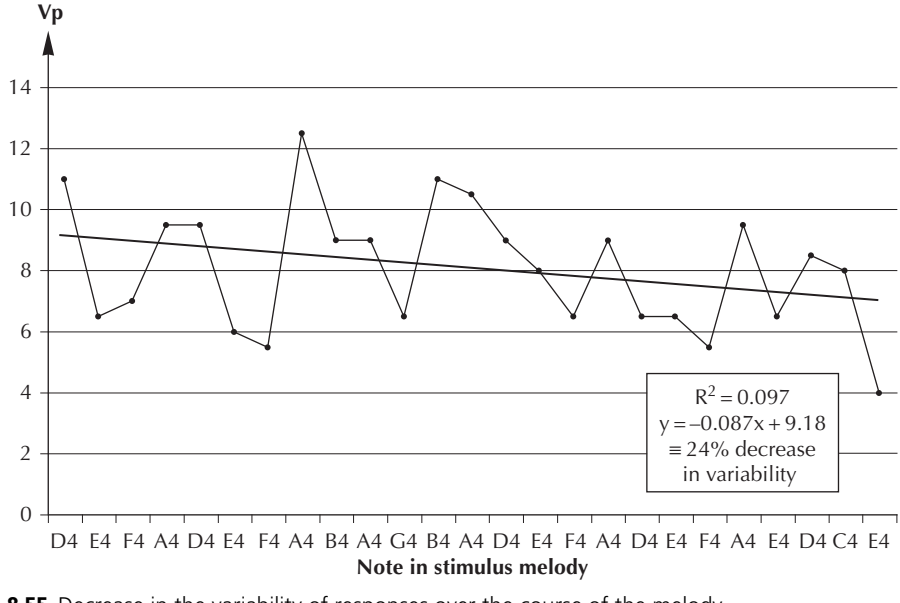


Fig. 8.55 Decrease in the variability of responses over the course of the melody.

(which was intended to make prediction easier as the music progressed), there was a high degree of variability in listeners' predictions. Even the last note, which is signaled both intra-opusly (see Fig. 8.51) and schematically (as the tonic at the end of a tonally and thematically symmetrical melody, whose first section concluded on the dominant), was not anticipated by three listeners.

Table 8.8 Individual responses

Participant	*'Actual' note in melody versus* predicted note in melody																											Number of correct predictions	Gender	Age	Years of musical traning	Minutes per day spent listening to music
	E4	*F 4*	*A4*	*D4*	*E4*	*F 4*	*A4*	*B4*	*A4*	*G4*	*B4*	*A4*	*D4*	*E4*	*F 4*	*A4*	*D4*	*E4*	*F 4*	*A4*	*E4*	*D4*	*C 4*	*E4*	*D4*							
1	A3	**F 4**	**A4**	F 4	**E4**	**F 4**	**A4**	D4	**A4**	F 4	F 4	B4	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	E4	D4	**D4**			16	F	21	–	>60
2	F 4	G3	G4	G4	G3	E4	G4	G3	**A4**	C 4	A4	B4	A3	C 4	G3	G4	A3	A3	D4	**A4**	B4	B3	A3	G3	C 4			2	F	26	–	30-60
3	F 4	**F 4**	G4	G4	F 4	**F 4**	**A4**	D4	**A4**	**G4**	F 4	**A4**	G4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	G4	G4	**C 4**	F 4	**D4**			15	F	22	>8	30-60
4	**E4**	D4	G4	F 4	**E4**	**F 4**	C 4	C 4	**A4**	**G4**	F 4	F 4	A4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	**C 4**	C 4	**D4**			15	F	22	<2	>60
5	**E4**	**F 4**	G4	G4	**E4**	**F 4**	**A4**	D4	**A4**	A4	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	G4	B3	**E4**	**D4**			17	F	24	>8	>60
6	F 4	**F 4**	G4	B4	F 4	**F 4**	D4	D4	**A4**	D4	F 4	**A4**	G4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	E4	**E4**	**D4**			13	F	24	>8	30-60
7	**E4**	**F 4**	G4	G4	A3	A3	—	D4	G4	**G4**	F 4	**A4**	B3	**E4**	**F 4**	A3	**D4**	**E4**	**F 4**	**A4**	B4	F 4	B3	**E4**	**D4**			12	M	36	5-8	30-60
8	**E4**	**F 4**	G4	B4	C 4	D4	**A4**	D4	C 5	F 4	F 4	**A4**	B4	**E4**	**F 4**	G4	**D4**	G4	**F 4**	E4	G4	F 4	**C 4**	**E4**	**D4**			11	F	27	5-8	>60
9	D4	—	—	G4	**E4**	**F 4**	—	D4	—	—	F 4	E4	—	D4	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	D4	D4	**D4**			10	F	24	<2	<30
10	F 4	**F 4**	G4	B4	**E4**	D4	D4	D4	**A4**	A4	F 4	**A4**	D5	D4	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	B3	D4	**D4**			11	M	50	–	<30
11	A4	**F 4**	G4	B4	A3	**F 4**	**A4**	B4	D5	F 4	F 4	**A4**	F 4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	B3	A3	**D4**			13	M	25	>8	>60
12	B3	E4	G4	E4	D4	D4	D4	E4	B4	B4	E4	**A4**	A4	D4	D4	**A4**	**D4**	**E4**	D4	**A4**	B4	**D4**	D4	D4	**D4**			7	F	31	–	30-60
13	**E4**	**F 4**	D4	F 4	**E4**	**F 4**	D4	D5	**A4**	**G4**	F 4	D4	G4	A4	**F 4**	D4	**D4**	**E4**	**F 4**	**A4**	B4	F 4	F 4	**E4**	**D4**			12	M	55	2-4	>60
14	B3	B3	F 4	A4	B3	**F 4**	**A4**	B3	**A4**	A4	E4	**A4**	G4	D4	D4	G4	A3	D4	B3	G4	A4	E4	B3	C 4	C 4			4	F	23	–	>60
15	B3	E4	D4	A3	A3	B3	E4	F 3	B3	F 3	B3	B3	A3	A3	C 4	E4	E3	G3	A3	B3	E3	C 4	B3	B3	F 3			0	F	30	–	>60
16	D4	**F 4**	G4	G4	D4	**F 4**	**A4**	D4	**A4**	**G4**	E4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	E4	B3	D4	**D4**			15	M	60	–	>60
17	**E4**	**F 4**	G4	**D4**	**E4**	**F 4**	D4	D4	C 5	F 4	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	A4	E4	F 4	**D4**			15	M	27	–	30-60
18	**E4**	**F 4**	G4	**D4**	**E4**	**F 4**	**A4**	D4	**A4**	F 4	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	**C 4**	B3	**D4**			19	M	30	2-4	30-60
19	**E4**	**F 4**	G4	D5	**E4**	**F 4**	E4	D4	**A4**	F 4	E4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	G4	G4	F 4	C 4	**D4**			15	F	27	5-8	30-60
20	**E4**	**F 4**	D4	B4	**E4**	**F 4**	**A4**	D4	**A4**	**G4**	F 4	B4	**D4**	D4	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	**C 4**	D4	**D4**			17	F	24	–	>60
21	**E4**	**F 4**	G4	G4	C 4	**F 4**	**A4**	G4	G4	**G4**	F 4	**A4**	G4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	**C 4**	**E4**	**D4**			16	F	24	>8	30-60
22	D4	**F 4**	F 4	A4	D4	D4	E4	D4	B4	F 4	**B4**	F 4	G4	D4	**F 4**	**A4**	**D4**	D4	E4	**A4**	B4	E4	D4	A4	**D4**			7	F	23	5-8	<30
23	G3	**F 4**	D4	C 5	D4	**F 4**	D4	D4	B4	F 4	D4	G4	C 4	D4	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	D4	**E4**	**D4**			11	F	29	2-4	<30
24	**E4**	**F 4**	G4	**D4**	**E4**	**F 4**	D4	D4	**A4**	**G4**	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	E4	**E4**	**D4**			18	M	28	<2	>60
25	**E4**	**F 4**	**A4**	G4	C 4	**F 4**	**A4**	**B4**	**A4**	F 4	F 4	**A4**	F 4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	G4	F 4	**C 4**	**E4**	**D4**			18	M	40	>8	>60
26	F 4	C 4	D4	B4	C 4	**F 4**	E4	**B4**	B4	F 4	F 4	**A4**	B4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	**C 4**	**E4**	**D4**			14	M	58	5-8	30-60
27	**E4**	**F 4**	G4	B4	C 4	**F 4**	**A4**	D4	**A4**	A4	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	B3	D4	**D4**			16	M	22	5-8	<30
28	**E4**	**F 4**	G4	B4	**E4**	**F 4**	**A4**	**B4**	**A4**	**G4**	F 4	B4	G4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	E4	B3	**D4**			16	M	59	5-8	30-60
29	**E4**	**F 4**	G4	A3	—	A3	G4	A3	**A4**	F 4	F 4	**A4**	G4	**E4**	A4	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	**C 4**	**E4**	**D4**			13	M	32	2-4	30-60
30	**E4**	C 4	A3	**D4**	F 3	D4	F 4	E3	E4	D4	D4	E3	G3	C 4	E4	E4	B3	B3	D4	F 4	A4	**D4**	F 3	C 4	**D4**			4	F	33	<2	30-60
31	D4	E4	D4	A4	D4	E4	**A4**	D4	**A4**	E4	F 4	G4	**D4**	D4	**F 4**	**A4**	A4	D4	A4	**A4**	D4	**D4**	D4	D4	**D4**			8	F	27	–	30-60
32	G4	**F 4**	**A4**	**D4**	A4	D4	D4	D4	**A4**	F 4	D4	B4	**D4**	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	**D4**	**C 4**	**E4**	**D4**			16	M	30	2-4	30-60
33	A4	A3	G4	E4	A4	D4	**A4**	**B4**	D4	A4	F 4	D5	A4	D5	A4	**A4**	**D4**	**E4**	**F 4**	**A4**	D5	A4	D4	D4	**D4**			8	F	73	–	30-60
34	A3	E4	F 4	A3	D4	A3	**A4**	A3	F 4	C 4	F 4	D4	C 4	D4	E4	F 4	A4	D4	E4	F 4	G4	**D4**	D4	D4	**D4**			3	F	21	2-4	30-60
35	**E4**	**F 4**	G4	B4	C 4	**F 4**	**A4**	D4	**A4**	**G4**	F 4	**A4**	**D4**	**E4**	**F 4**	**A4**	C 4	**E4**	**F 4**	**A4**	B4	G4	**C 4**	**E4**	**D4**			17	F	25	>8	>60
36	D4	**F 4**	**A4**	F 4	D4	E4	G4	G4	**A4**	F 4	F 4	**A4**	G4	F 4	G4	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	E4	**C 4**	B3	**D4**			11	F	76	<2	30-60
37	E4	**F 4**	G4	G4	**E4**	D4	D4	D4	B4	F 4	E4	**A4**	G4	D4	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	D4	D4	**D4**			10	M	27	>8	>60
38	D5	B3	B4	A3	C 4	**F 4**	**A4**	C 4	C 5	F 4	F 4	**A4**	G4	**E4**	A3	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	F 4	**C 4**	B3	**D4**			11	M	37	>8	>60
39	D4	A3	G4	G4	G4	G4	G4	D5	**A4**	B4	A4	**A4**	D4	G4	**F 4**	G4	B4	G4	**F 4**	F 4	B4	**D4**	A4	D4	**D4**			6	F	22	5-8	<30
40	**E4**	**F 4**	G4	F 4	**E4**	**F 4**	D4	F 4	G4	F 4	E4	**A4**	G4	**E4**	**F 4**	**A4**	**D4**	**E4**	**F 4**	**A4**	B4	G4	E4	D4	**D4**			13	F	65	5-8	30-60

The results show high intersubject variability too (see Table 8.8). With a potential maximum of 25, the number of correct predictions ranged from 0 to 19 ($M = 11.9$, $SD = 4.84$). There were no significant effects for age, years of musical training, or the time reportedly spent listening to music. Gender, however, did appear to be important, with a significant difference between men's ($n = 16$, $M = 14.3$, $SD = 2.75$) and women's ($n = 24$, M = 10.3, $SD = 5.28$) success in anticipating what came next: $t(38) = 2.83$, $P = 0.0075$. As the groups of male and female subjects did not differ significantly in terms of age, musical training, or the time spent listening to music, we had to look for other explanations. Clearly, the relatively small numbers of men and women involved may have resulted in unrepresentative samples (an issue that could only be resolved through larger-scale replication). Then, there was an experimental difference between the two groups, whereby the octave in which responses were elicited was different for men and women (Constraint 7; see Fig. 8.52). Had tessitura been a significant factor in the formation of expectations, there would have been a difference in the frequencies with which intervals of different polarities were predicted (up, down, or neutral), according to where the stimulus was pitched, since, other things being equal, the lower a given note, the greater the probability that the one following will be higher, and vice versa (Huron, 2006, pp. 80ff.). Following this reasoning, women's predictions (whose stimulus was higher) should have contained a greater proportion of descending intervals, while men's should have been more likely to ascend. Our analysis by intervallic polarity did indeed show a difference in the patterns of response by gender, but these were not straightforward (see Table 8.9).

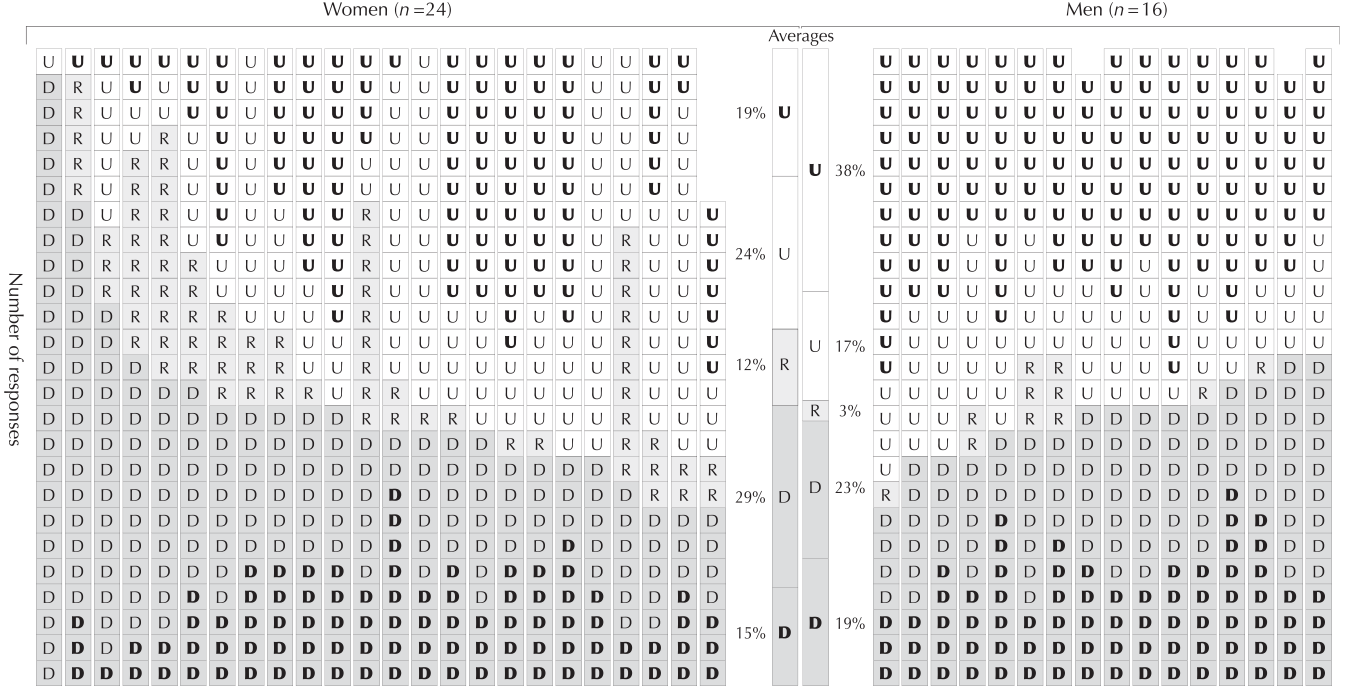
With regard to descending intervals, the proportions predicted by women ($M = 11$, $SD = 3.8$) and men ($M = 10.6$, $SD = 1.6$) were very similar (44% and 42%, respectively), which suggested no effect of tessitura. The data pertaining to ascending intervals painted a different picture, though: women's predictions ($M = 10.7$, $SD = 4.88$; 43%) and men's ($M = 13.6$, $SD = 1.71$; 55%) differed significantly, $t(38) = 2.28$, $P = 0.029$, supporting the tessitura hypothesis. Moreover, as the proportion of ascending intervals to descending was 3:2, this could potentially have explained men's greater success in prediction.

There were two confounding factors, however. First, men's *proportion* of successful ascending predictions (150 out of 218, or 69%) was significantly greater than women's (114 out of 256, or 44%), $\chi^2(1, n = 474) = 28.12$, $P < 0.0001$. (Men's proportion of successful *descending* predictions, being 77 out of 169, or 45%, was also greater, at 90 out of 264, or 34%, although here the difference was less marked, $\chi^2(1, n = 453) = 8.76$, $P = 0.003$.) Second, the different proportion of ascending predictions could largely be accounted for by women's tendency to expect pitches to be repeated (although none in fact was) ($M = 3.1$, $SD = 3.20$; 12%), which was significantly greater than that for men ($M = 0.7$, $SD = 1.08$; 3%): $t(38) = 2.88$, $P = 0.007$.

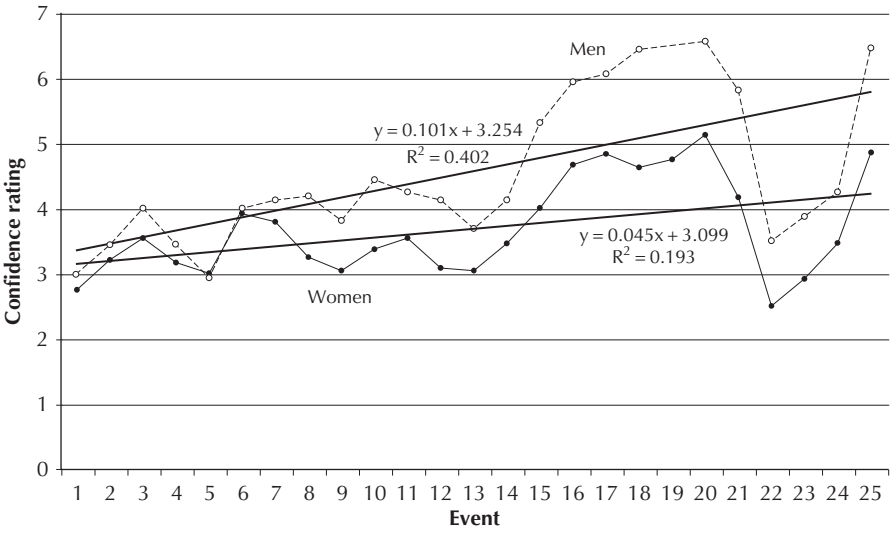
The *confidence* with which men and women made their predictions differed significantly too. On a scale of 1 (low) to 7 (high), women's confidence ratings were $M = 3.68$, $SD = 1.42$, while men's were both higher and more consistent, with $M = 4.57$, $SD = 0.96$: $t(38) = 2.19$, $P = 0.035$. Although men were almost invariably more confident than women (after only one event, note 5, were men less so, and then by just 0.07 of a point), and while the confidence of both sexes grew through the tests, men increased in confidence almost twice as much as women: by around two points on the Likert scale as opposed to one (see Fig. 8.56). It could be that, as men's early predictions proved to be correct more often than women's, their confidence grew more strongly.

In summary, while tessitura may have explained some of the differences in men's and women's expectancy profiles, it was not the only factor—and it could be that the results reflected a difference in the way that men and women process and predict musical structure. This possibility

Table 8.9 Intervallic polarity of responses



Key: D = downward interval (incorrect); **D** = downward interval (correct); R = repetition of same note (invariably incorrect); U = upward interval (incorrect); **R** = upward interval (correct).



women	2.75	3.21	3.54	3.17	3.00	3.92	3.79	3.25	3.04	3.38	3.54	3.08	3.04	3.46	4.00	4.67	4.83	4.63	4.75	5.13	4.17	2.50	2.92	3.46	4.83
men	3.00	3.44	4.00	3.44	2.93	4.00	4.13	4.19	3.81	4.44	4.25	4.13	3.69	4.13	5.31	5.94	6.06	6.44	6.50	6.56	5.81	3.50	3.88	4.25	6.44
difference	**0.25**	**0.23**	**0.46**	**0.27**	**–0.07**	**0.08**	**0.33**	**0.94**	**0.77**	**1.06**	**0.71**	**1.04**	**0.65**	**0.67**	**1.31**	**1.27**	**1.23**	**1.81**	**1.75**	**1.44**	**1.65**	**1.00**	**0.96**	**0.79**	**1.60**

Fig. 8.56 The changes in confidence ratings of predictions for men and women.

had some neuropsychological support: Koelsch *et al.* (2003), for example, found that an electrophysiological correlate of music-syntactic processing is generated bilaterally in women, with right hemispheric predominance in men. There appeared to be attitudinal differences too, and the confidence with which predictions were made may have had an impact on expectational "success." For example, women's lower levels of predictive conviction may have resulted in the greater frequency with which they anticipated repetition (which never actually occurred) rather than change. It is possible that such differences may have arisen from opposing personality traits, stereotyped as "male" and "female" in Western culture. We felt that these were intriguing areas for future research.

The range and variability of data across all subjects (particularly in the case of women, whose patterns of expectation were more varied, as the differences in standard deviation show) raised two phenomenological issues. First, the variation in responses could be held to argue against a common mechanism of expectation. Second, as over half the predictions (52%) were incorrect, we wondered whether expectation of this kind could be part of the "typical" listening experience (Ockelford, 2006a, p. 135), or was it rather a feature of musical metacognition that had been induced experimentally?

The zygonic model of expectation (Fig. 8.47), versions Z1 and Z2, could potentially accommodate both these concerns. First, in relation to Thorpe's first research question, it predicted that materials pertaining to "current structures, within groups" and "previous structures, schematically encoded" interact to produce a *general* sense of what may follow. Hence, one would *expect* listeners' responses to differ, and would anticipate that, taken together, they would reflect the probabilistic nature of the model. Moreover, by hypothesizing that listeners' expectations usually occur non-consciously (notwithstanding our capacity to draw these into conscious awareness), then the second, esthetic, issue could potentially be resolved (although this would require further

Table 8.10 Predicted and observed responses

Note in stimulus melody

	D4	E4	F 4	A4	D4	E4	F 4	A4	B4	A4	G4	B4	A4	D4	E4	F 4	A4	D4	E4	F 4	A4	E4	D4	C 4	E4
MODEL Z1 – adjacency																									
B5									.02			.02													
A5				.02				.02	.01	.02		.01	.02				.02				.02				
G5				.01				.01	.01	.01	.02	.01	.01				.01				.01				
F 5			.02	.01			.02	.01	.02	.01	.01	.02	.01			.02	.01			.02	.01				
E5		.02	.01	.02		.02	.01	.02	.05	.02	.01	.05	.02		.02	.01	.02		.02	.01	.02	.02			.02
D5	.02	.01	.01	.05	.02	.01	.01	.05	.10	.05	.02	.10	.05	.02	.01	.01	.05	.02	.01	.01	.02	.01	.02		.01
C 5	.01	.01	.02	.10	.01	.01	.02	.10	.24	.10	.05	.24	.10	.01	.01	.02	.10	.01	.01	.02	.10	.01	.01	.02	.01
B4	.01	.02	.05	.24	.01	.02	.05	.24	.14	.24	.10	.14	.24	.01	.02	.05	.24	.01	.02	.05	.24	.02	.01	.01	.02
A4	.02	.05	.10	.14	.02	.05	.10	.14	.24	.14	.24	.24	.14	.02	.05	.10	.14	.02	.05	.10	.14	.05	.02	.01	.05
G4	.05	.10	.24	.24	.05	.10	.24	.24	.10	.24	.14	.10	.24	.05	.10	.24	.24	.05	.10	.24	.24	.10	.05	.02	.10
F 4	.10	.24	.14	.10	.10	.24	.14	.24	.05	.10	.24	.05	.10	.10	.24	.14	.10	.10	.24	.14	.10	.24	.10	.05	.24
E4	.24	.14	.24	.05	.24	.14	.24	.05	.02	.05	.10	.02	.05	.24	.14	.24	.05	.24	.14	.24	.05	.14	.24	.10	.14
D4	.14	.24	.10	.02	.14	.24	.10	.02	.01	.02	.05	.01	.02	.14	.24	.10	.02	.14	.24	.10	.02	.24	.14	.24	.24
C 4	.24	.10	.05	.01	.24	.10	.05	.01	.01	.01	.02	.01	.01	.24	.10	.05	.01	.24	.10	.05	.01	.10	.24	.14	.10
B3	.10	.05	.02	.01	.10	.05	.02	.01	.02	.01	.01	.02	.01	.10	.05	.02	.01	.10	.05	.02	.01	.05	.10	.24	.05
A3	.05	.02	.01	.02	.05	.02	.01	.02		.02	.01		.02	.05	.02	.01	.02	.05	.02	.01	.02	.02	.05	.10	.02
G3	.02	.01	.01		.02	.01	.01				.02			.02	.01	.01		.02	.01	.01		.01	.02	.05	.01
F 3	.01	.01	.02		.01	.01	.02							.01	.01	.02		.01	.01	.02		.01	.02	.01	.01
E3	.01	.02			.01	.02								.01	.02			.01	.02			.02	.01	.01	.02
D3	.02				.02									.02				.02					.02	.01	
C 3																								.02	
MODEL Z2 – adjacency + recency																									
B5									.01	.01	.00	.01	.01	.00	.00										
A5				.01	.01	.00	.00	.01	.01	.01	.01	.01	.01	.01	.00			.01	.01	.00	.00	.01	.01	.00	.00
G5				.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.00			.00	.00	.00	.00	.00	.00	.00	.00
F 5			.01	.01	.01	.00	.01	.01	.01	.01	.01	.01	.01	.01	.00			.01	.01	.00	.00	.01	.01	.00	.00
E5		.01	.01	.01	.01	.01	.01	.01	.03	.02	.02	.03	.02	.02	.01			.01	.01	.01	.01	.01	.01	.01	.01
D5	.02	.01	.01	.02	.02	.02	.01	.02	.06	.06	.04	.06	.06	.04	.03			.01	.02	.02	.01	.02	.02	.02	.01
C 5	.01	.01	.01	.04	.04	.03	.02	.05	.13	.13	.10	.15	.13	.08	.05			.02	.05	.04	.03	.05	.04	.03	.02
B4	.01	.02	.03	.09	.09	.06	.05	.11	.14	.19	.16	.14	.18	.11	.07	.05	.11	.09	.06	.05	.11	.09	.06	.03	.01
A4	.02	.04	.07	.19	.07	.06	.07	.09	.16	.16	.20	.22	.19	.12	.07	.07	.09	.07	.06	.07	.09	.08	.06	.03	.01
G4	.05	.08	.16	.14	.15	.12	.16	.19	.17	.20	.17	.14	.18	.12	.11	.16	.19	.15	.12	.16	.19	.17	.12	.06	.06
F 4	.10	.19	.16	.14	.12	.16	.16	.14	.10	.09	.14	.11	.11	.10	.15	.16	.14	.12	.16	.16	.14	.18	.14	.10	.15
E4	.24	.17	.20	.14	.17	.16	.19	.14	.08	.06	.06	.05	.05	.12	.14	.19	.14	.17	.16	.19	.14	.13	.17	.14	.14
D4	.14	.20	.15	.10	.10	.15	.14	.10	.05	.02	.03	.02	.02	.07	.14	.14	.10	.10	.15	.14	.10	.14	.14	.19	.22
C 4	.24	.14	.10	.06	.12	.12	.10	.06	.02	.01	.01	.01	.01	.10	.11	.10	.06	.12	.12	.10	.06	.06	.13	.15	.14
B3	.10	.06	.04	.03	.05	.05	.04	.03	.02	.01	.01	.01	.01	.04	.05	.04	.03	.05	.05	.04	.03	.03	.06	.13	.11
A3	.05	.03	.02	.02	.03	.03	.02	.02	.01	.01	.01	.01	.01	.02	.02	.02	.02	.03	.03	.02	.02	.02	.03	.06	.05
G3	.02	.01	.01	.01	.01	.01	.01	.01	.00	.00	.01	.01	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.03	.02
F 3	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.01	.01	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
E3	.01	.01	.01	.00	.01	.01	.01	.00	.00		.01	.01		.00	.01	.01	.01	.01	.01	.00	.01	.01	.01	.01	.01
D3	.02	.01	.00	.00	.01	.01	.00	.00			.01	.01		.01	.01	.00	.00	.00	.01	.01	.00	.00	.01	.01	.01
C 3																								.01	.01
MODEL Z3 – adjacency + recency + between-groups																									
B5									.01	.01	.00	.01	.01	.00	.00										
A5				.01	.00	.00	.00	.00	.01	.01	.01	.01	.01	.00	.00			.00	.00	.00	.00	.00	.01	.00	.00
G5				.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.00	.00			.00	.00	.00	.00	.00	.00	.00	.00
F 5			.01	.01	.00	.00	.00	.00	.01	.01	.01	.01	.01	.00	.00			.00	.00	.00	.00	.00	.01	.00	.00
E5		.01	.01	.01	.00	.00	.00	.00	.03	.02	.02	.03	.02	.01	.00			.00	.00	.00	.00	.00	.01	.00	.00
D5	.02	.01	.01	.02	.01	.00	.00	.00	.06	.06	.04	.06	.06	.02	.01			.00	.00	.00	.00	.00	.02	.01	.00
C 5	.01	.01	.01	.05	.02	.01	.00	.00	.13	.13	.10	.15	.13	.04	.01			.00	.00	.00	.00	.00	.04	.01	.00
B4	.01	.02	.03	.11	.04	.02	.01	.01	.14	.19	.16	.14	.18	.06	.02	.01	.01	.00	.00	.00	.00	.00	.09	.03	.01
A4	.02	.04	.07	.09	.04	.04	**.88**	.01	.16	.16	.20	.22	.19	.06	.02	**.88**	.01	.00	.00	**.99**	.00	.00	.08	.03	.01
G4	.05	.08	.16	.19	.07	.03	.02	.01	.17	.20	.17	.14	.18	.06	.03	.02	.01	.00	.00	.00	.00	.00	.17	.06	.01
F 4	.10	.19	.16	.14	.06	**.79**	.02	.01	.10	.09	.14	.11	.11	.05	**.79**	.02	.01	.00	**.99**	.00	.00	.00	.18	.06	.02
E4	.24	.17	.20	.14	.59	.04	.02	.01	.08	.06	.06	.05	.05	.56	.03	.02	.01	**.97**	.00	.00	.00	.00	.13	.08	**.79**
D4	.14	.20	.15	.10	.05	.04	.02	**.94**	.05	.02	.03	.02	.02	.03	.04	.02	.01	.00	**.94**	.00	.00	**1.00**	.14	.07	.05
C 4	.24	.14	.10	.06	.06	.03	.01	.00	.02	.01	.01	.01	.01	.05	.03	.01	.01	.00	.00	.00	.00	.00	.06	.57	.04
B3	.10	.06	.04	.03	.02	.01	.01	.00	.02	.01	.01	.01	.01	.02	.01	.01	.00	.00	.00	.00	.00	.00	.03	.03	.01
A3	.05	.03	.02	.02	.01	.01	.00	.00	.01	.01	.01	.01	.00	.01	.01	.00	.00	.00	.00	.00	.00	.00	.02	.01	.01
G3	.02	.03	.01	.01	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00
F 3	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00
E3	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00
D3	.02	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C 3																								.00	.00
OBSERVED																									
B5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
A5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
F 5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
E5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
D5	.03	.00	.00	.03	.00	.00	.00	.05	.03	.00	.00	.03	.03	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00
C 5	.00	.00	.00	.03	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
B4	.00	.00	.03	.23	.00	.00	.00	.13	.13	.05	.03	.13	.05	.00	.00	.00	.03	.00	.00	.00	**.75**	.00	.00	.00	.00
A4	.05	.00	.10	.08	.05	.00	.47	.00	.59	.13	.05	.63	.08	.03	.05	**.78**	.05	.00	.03	**.85**	.05	.05	.03	.03	.00
G4	.03	.00	.62	.25	.03	.03	.11	.05	.08	.26	.00	.05	.31	.03	.03	.10	.00	.05	.00	.03	.13	.13	.00	.00	.00
F 4	.10	.69	.08	.13	.05	.60	.03	.03	.03	.41	.68	.05	.05	.03	**.75**	.03	.00	.00	**.80**	.08	.00	.33	.05	.05	.00
E4	.48	.10	.00	.05	.36	.08	.11	.03	.03	.03	.15	.03	.00	.58	.05	.05	.00	**.78**	.05	.03	.00	.10	.15	.33	.00
D4	.15	.03	.15	.13	.18	.20	.26	.53	.03	.05	.08	.05	.33	.25	.05	.03	**.80**	.10	.08	.00	.03	.35	.20	.33	**.93**
C 4	.00	.05	.00	.00	.18	.00	.03	.05	.00	.05	.00	.00	.05	.05	.03	.00	.03	.00	.00	.00	.00	.03	.33	.10	.05
B3	.08	.05	.00	.00	.03	.03	.00	.03	.03	.00	.03	.03	.03	.00	.00	.00	.03	.03	.03	.03	.00	.03	.20	.13	.00
A3	.05	.05	.03	.10	.08	.08	.00	.05	.00	.00	.00	.00	.05	.03	.03	.03	.05	.03	.03	.00	.00	.00	.03	.03	.00
G3	.03	.03	.00	.00	.03	.00	.00	.03	.00	.00	.00	.00	.03	.00	.03	.00	.00	.03	.00	.00	.00	.00	.00	.03	.00
F 3	.00	.00	.00	.00	.03	.00	.00	.03	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.00	.03
E3	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.03	.00	.00	.00	.00	.03	.00	.00	.00	.03	.00	.00	.00	.00
D3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C 3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Proportions of expectancies

Proportions of expectancies

Proportions of expectancies

Proportions of expectancies

empirical work). Therefore, the key question was how well Z1 and Z2 fit the observed data. The predictions of all three models and subjects' responses are summarized in Table 8.10.

It was evident that version Z1 of the model produced broader spans of values than those of subjects' expectations, though since, at the extremes, the figures were small, the impact on similarity was modest and the mean difference of predicted and observed values was only 0.065 ($SD = 0.022$). With version Z2, the mean difference of predicted and observed values was 0.059 ($SD = 0.015$). The difference between the two was significant: $t(24) = 2.58$, $P = 0.017$. This suggested that acknowledging the potential influence of the four most recent pitches (where they exist) provided a more accurate model of listeners' expectations than the effect of the most recent value alone. And it provided support for the hypothesis postulated in research question (a) at the very beginning of this section that, ceteris paribus, expectations arising from "current structures, within groups" (the four preceding notes) and "previous structures, schematically encoded" interact to produce a *general* sense of what may follow.

Research question (b) asked whether there was support for the hypothesis that expectations arising from "current structures, between groups" produce a *specific* sense of what is to come. We sought evidence for this by comparing the coefficients of variability (V_P) of those pitches that the zygonic analysis shown in Fig. 8.52 indicated could be predicted through between-group relationships and those that could not, and the data set out in Fig. 8.57 indicating that

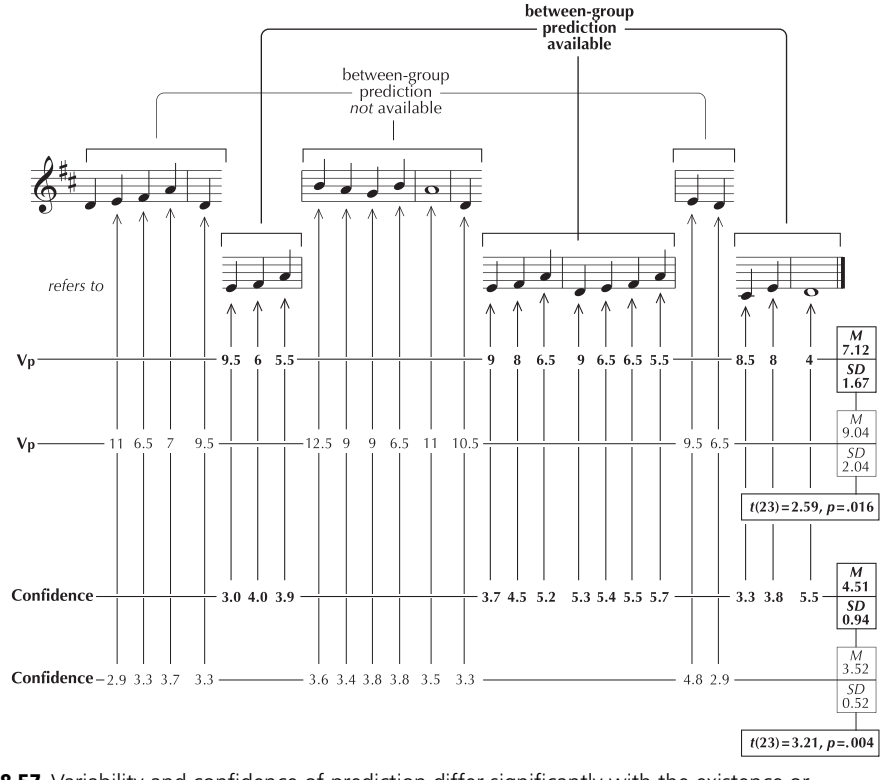


Fig. 8.57 Variability and confidence of prediction differ significantly with the existence or non-existence of between-group structure.

there was indeed a significant difference in the average V_P values pertaining to each category, $t(23) = 2.59$, $P = 0.016$. This finding was supported by the differences in confidence with which subjects reported that their predictions had been made: where between-group structures were available, anticipation was significantly more assured than where they were not, $t(23) = 3.21$, $P = 0.004$.

Thorpe's research question (c) asked whether there was evidence to support the notion that expectations arising from (a) "current structures, within groups" and "previous structures, schematically encoded" interact with (b) "current structures, between groups", such that (b) lends greater specificity to (a), and (a) grounds (b) in a local context. Version Z3 of the zygonic model was constructed to test this hypothesis, fusing all three anticipatory elements; therefore, the degree to which the predictions of Z3 and the observed responses corresponded would reflect the extent to which the theory was supported.

Analysis of the data shown in Table 8.10 indicated that the average difference between predicted and observed responses in Z3 was only $M = 0.039$, $SD = 0.019$, and that this differed significantly from version Z2: $t(24) = 3.79$, $P = 0.0009$. Hence the data supported aspects A1, A3, and B2 of the zygonic model. The graphs shown in Fig. 8.58 provide a compelling visual metaphor of the changing nature of people's expectations as they responded to the melody over time, and compares them with the outputs of Z3.

Taking grand averages of these results revealed a high degree of correlation between the model and subjects' responses (Fig. 8.59). There were differences, however, which indicated limitations of the model and suggested potential modifications, as well as suggesting possible improvements in the experimental design. In relation to the first three events, Z3 predicted a broad spread of values centered on the pitches that were heard—a consequence of the primary zygonic relationships upon which it was based. While subjects also anticipated a range of values, there was a bias towards expecting a pitch that was one scale degree higher than the one heard. Why? With regard to the first event, we felt that two factors may have played a part. First, some listeners may have internalized the tendency of melodies to begin by ascending (Huron, 1996, 2006, pp. 86ff.), creating a schema that they intuitively brought to bear. We took the view that this could feature in future models as an additional factor in B2.

Furthermore, it seemed to us that this tendency may have been reinforced by the introductory material, which began with a rising scale. Although the subsequent descent was intended to counter any such effect, the introductory gesture may have reinforced the sense of an "arch" contour typical of many melodies (Huron, 2006). We concluded that future experiments could use introductory materials that gave an unambiguous sense of key without incurring melodic movement.

The second stimulus pitch (a scale step higher than the first) would have supported the expectations of the 49% of subjects who anticipated the ascent, and suggested to all listeners that the melodic opening was based on stepwise upward movement. There were three possible sources of such a projection: the schema of initial melodic ascent, the introductory material, and, most immediately, the opening interval—each reliant on secondary zygonic relationships (see Fig. 8.60). However, in relation to A1 ("current structures encoded in working memory") secondary relationships were not tested (see Constraint 8), as we had no evidence as to how primary and secondary relationships arising from current structures may have interacted. Given our findings, however, we thought that it may be possible to include this element in future empirical work. The fact that listeners recognized the pattern of ascent was shown by their tendency (62%) to

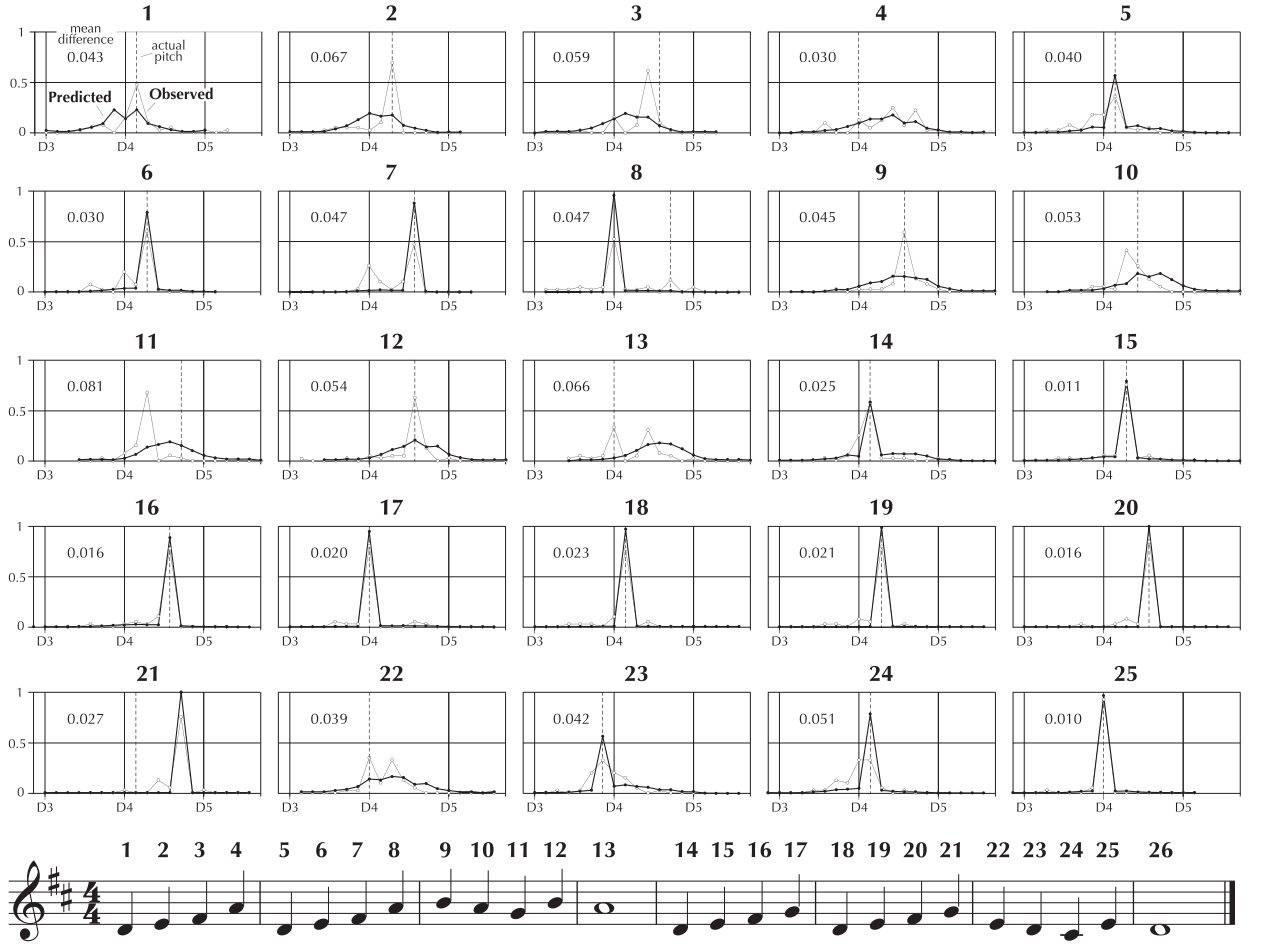


Fig. 8.58 Correlations between Z3 outputs and observed responses, event by event.

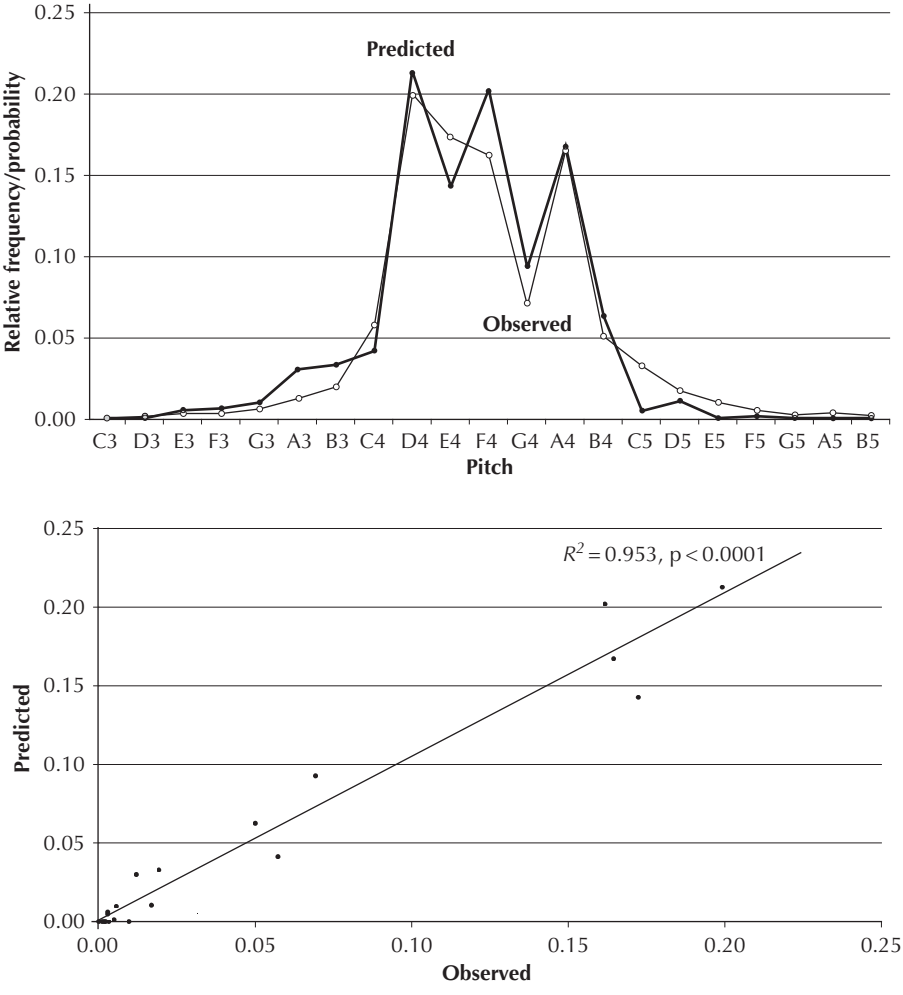


Fig. 8.59 Correlation between the means of all Z3 outputs and observed responses, note by note.

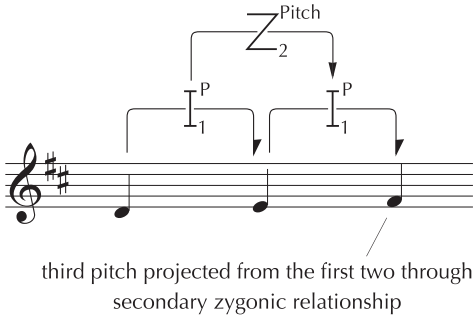


Fig. 8.60 Anticipation through secondary zygonic structure not factored in to Z3.

anticipate G4 as the 4th event. However, the A4 that actually occurred broke the pattern, and at this stage subjects projected a range of values, whose profile was close to that predicted by Z3.

From Event 5 (see Fig. 8.58), evidence emerged of between-group expectation, reflected in the peak shared by subjects' responses and Z3, although the effect in the zygonic model was stronger (58% as opposed to 36%), with a consequent underestimate of the probabilities assigned to other pitches. That is, in the zygonic model, the balance between projections based on adjacency and recency and on between-group relationships moved in too pronounced a fashion towards the latter. This was affirmed in differences between the subjects' and Z3's projections that follow Events 6 and 7. We felt that, in future models, the ratio between the competing forms of expectation could be adjusted (cf. Table 8.5).

After the second A4 (Event 8), both the subjects and Z3 predicted a continuation of the pattern (a further D4), though the melody actually took a different course, rising to B4. This caused a collapse (at Event 9) of specificity in the model and, to a certain extent, in the responses, although most subjects anticipated A4, providing further evidence of secondary zygonic relationships being used in anticipation—here through inversion.

After Event 10, with no between-group relationships in play, the model predicted a broad range of values—partly matched by the profile of subjects' responses, although a clear majority (41%) anticipated F♯4. It was unclear why this prediction dominated, since the secondary zygonic structural logic in evidence up to this point would have projected G4 (although this was the second most common expectation at 26%).

At Event 11, secondary zygonic structure reasserts itself, and the majority of subjects (68%) anticipated F♯4 as a continuation of the descent from B4, A4, and G4 (Fig. 8.61), while Z3 offered a general profile of expectation. At Event 12, A4 was accurately anticipated by most listeners (63%), explicable through a combination of primary and secondary zygonic projection from notes 10 and 11. Z3 also predicted A4 as the most likely successor, though here the effect was more muted, perhaps because only primary relationships were taken into account.

At Event 13, Z3 projected a spread of values centered on A4, whereas around a third of subjects anticipated a continuation of the descent from B4 and A4 to G4 (implying further secondary zygonic organization) and a third expected a return to D4, presumably a schematic response

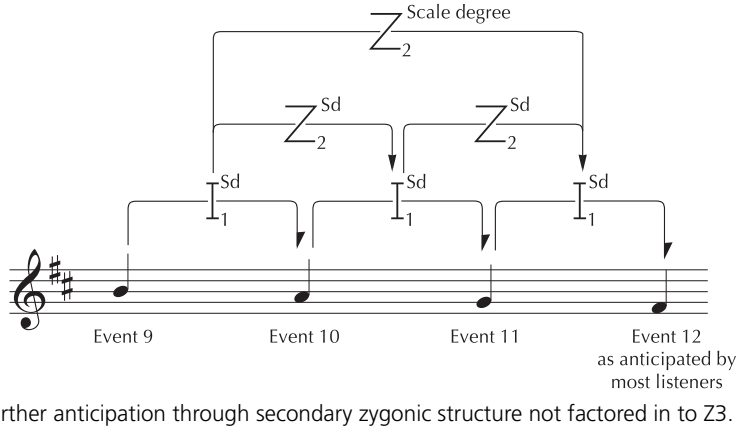


Fig. 8.61 Further anticipation through secondary zygonic structure not factored in to Z3.

to the implied half cadence (ending on the dominant), which often presages a return to the tonic. We were of the view that this potential characteristic of B2 could be captured in future modeling.

At Event 14, between-group structures feature again, whose effects on expectation gradually gained in strength among listeners and Z3: the longer the repetition of the opening phrase continued, the surer its continuation was felt to be, although the zygonic model again predicted individual values more strongly than the subjects, suggesting that some modification to the interagency/between-group ratio was required.

At Event 21, both listeners and Z3 projected B3, but the melody deviates from its previous course, and the relative certainties of between-group anticipation again dissipate into generality at Event 22. At Event 23, the transposition of the motif first heard in bar 3 was acknowledged by subjects and the zygonic model alike, a recognition that grew more assured at Event 24, though, once more, Z3 was firmer in its between-group prediction. At Event 25 (the penultimate note), there was the strongest correlation of all as A1, B2, and C3 acted together to predict an unambiguous return to the tonic.

In summary, the evidence suggested that Z3 was broadly effective in modeling subjects' expectations in the context of the single melody that was used, though the results indicated three areas where refinements could be made. First, we felt that the ratio between A1 and A3 should be adjusted, so that the impact of between-group relationships was less pronounced, particularly at the beginning of groups. Second, the potential effect of within-group secondary zygonic relationships (A1) needed to be included. Third, the effects of schemata pertaining to melodic contour and symmetry (B2) should be recognized. How these features interact with the adjacency and recency in relation to primary relationships, and links between groups, could be determined by future empirical work.

Of course, our study had limitations, not least the fact that the responses of only 40 listeners were tested in relation to one melody, whose design would inevitably have influenced the results. The findings confirmed that humans *can* project what is coming next when listening to music, but provided no evidence that they usually *do*. Indeed, the fact that most projections made in the absence of inter-group information subsequently proved to be incorrect throws into doubt whether, beyond having a general sense of what is coming next, listeners actively seek to anticipate the future in first-time hearings, since this would presumably have a negative esthetic impact. The proposition that specific projections are enabled by repeated hearings was not tested. However, initial evidence that this might be the case was provided by a further study by a fellow student of Thorpe's, Hayley Trower.

The study by Hayley Trower

As part of her MSc in applied music psychology at the University of Roehampton, Hayley Trower undertook an exploratory investigation into the effect of tonality on memory for melodies (Trower, 2011) using Lerdahl's theory of "tonal pitch space" (Lerdahl, 2001). Her 14 research subjects comprised nine women and five men, aged between 25 and 34, with differing levels of music education and a wide range of musical experiences within Western mainstream traditions. Nationalities included British, British-Indian, American, and Japanese.

Subjects were presented with 16 pairs of slow-moving melodic sequences that used the framework of the major scale. Each consisted of five pitches of equal length, lasting 15 seconds, to

enable ratings of expectedness to be made and to minimize the potential impact of rhythm on the perception of expectancy (Schmuckler and Boltz, 1994). Eight pairs of melodies were the same, and eight differed in their final pitch, allowing every scale degree to appear once in a cadential function (with the tonic repeated at the higher and lower octaves). In each case, the first four notes formed a different, stylistically conventional pattern. The stimuli were created using Sibelius music notation software, and converted from MIDI to audio files, using Logic Pro, to sound like a Steinway piano, rich in tone and with some reverberation. The order of sequences was randomized by subject. A distracter was played between each pair of sequences, comprising eight random tones of equal duration, lasting approximately 7 seconds.

Trower's experiment comprised two conditions—"listening" and "rating"—and seven subjects were randomly allocated to each. The rating condition required subjects continuously to evaluate the perceived predictability of each note in the sequence, using a proprietary device known as the Continuous Response Measurement Apparatus or CReMA (Himonides, 2011), whilst the melody was played to them at a comfortable level through speakers. After 15 seconds (of which 7 were taken up with the distracter), the second stimulus of the pair was presented, and the rating task repeated. In both listening and rating conditions, after each trial, subjects had to judge whether the pair of sequences they had just heard was the same or different. Trower's hypotheses were that there may be correlations between tonal stability (as calculated using Lerdahl's model) and melodic memory, and expectancy ratings and memory. In the event, the data were inconclusive, but those from the subjects who provided continuous ratings did provide a fascinating insight into how perceived melodic expectancies change with repeated hearings.

To understand how the data were gathered, it is important to know how the CReMA functions. It takes the form of a fixed ribbon, around 40 cm long, presented to subjects laterally. They place a finger on the ribbon, and move it left or right to rate what they are perceiving, in accordance with given instructions. In Trower's case, the center was said to represent a "neutral" position with regard to melodic expectancy, with positions further to the left intended to indicate that a given pitch was perceived to be increasingly "unexpected" or "surprising" and locations further to the right showing a note pitch was more "expected" or "predictable". The CReMA data are outputted in MIDI format, with a linear relationship between a subject's changing finger position and an assigned number. In Trower's experiment, the higher the number, the more expected a pitch was reckoned to be.

Since Trower was interested in relative (rather than absolute) pitch expectancies, only responses provided after the second note in each sequence were taken into account. Thereafter, the responses of longest duration were taken to be the subjects' definitive responses. In cases where no single, unequivocal response was apparent, the mean of the ratings following the event (up until the next one) was taken as the subject's response. Since half the stimulus pairs (each comprising five pitches) had different final notes, only the ratings pertaining to pitches 2, 3, and 4 will be considered for expectancy analysis here.

So in summary, we have seven subjects' ratings of how expected or unexpected they found pitches to be in retrospect in relation to 16 (identical) stimulus pairs (see Fig. 8.62).

What would the zygonic model (illustrated in Fig 8.47) predict in relation to these data? It would suggest that, on a first hearing, when the material is unfamiliar, *general* implications (and therefore expectations) would tend to dominate, with *specific* implications (and expectations) being limited to immediate or otherwise memorable repetition. During further hearings,

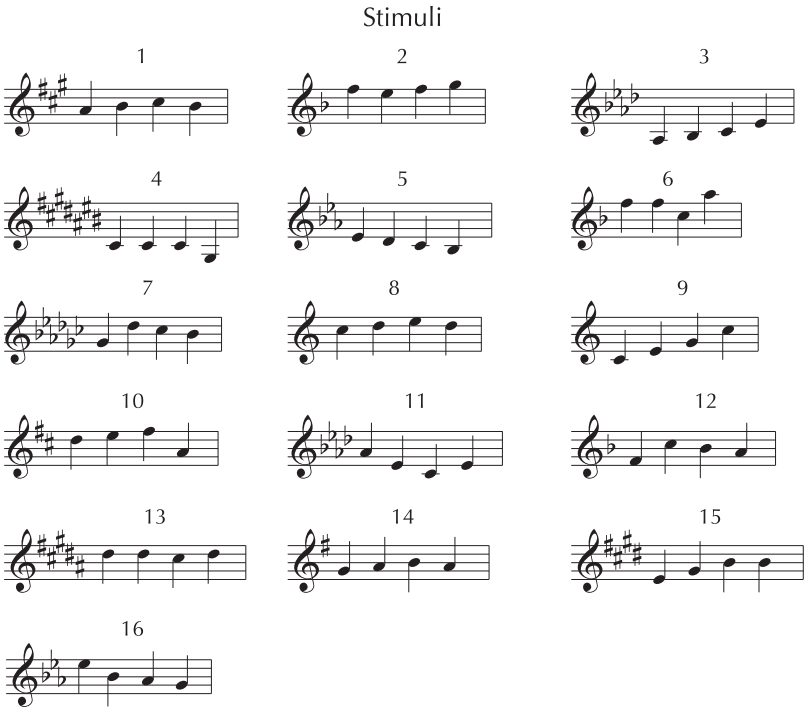


Fig. 8.62 Elements of the melodic stimuli Trower (2011) used for analysis.

as the material became more familiar, it would predict that the former would become less dominant and the latter would come to dominate more. What is this likely to mean for the perception of expectancy in relation to repeated hearings of short melodies of the sort used by Trower?

Let us take a hypothetical four-note motif (see Fig. 8.63), and assume that the average "degrees of expectedness" as gauged by a group of listeners retrospectively pertaining to pitches 2, 3, and 4 were 0.65, 0.72, and 0.58, respectively, where 0 represents "completely unexpected" and 1 corresponds to "wholly expected." Now let us assume that, following the intercalation of other material, the motif is presented again (Fig. 8.64). The listener has some memory of it, though this, in tandem with a lack of contextual information, means that it is not entirely clear (particularly in the first instance) whether this is "the same thing again" or not. Hence, we would expect the expectancy values to rise, though still retain the basic properties of expectancy gleaned statistically and from internal forces. We would also expect the difference to increase through the motif as the certainty in the listener's mind increased that this was indeed "the same thing again."

Are these two hypotheses supported by Trower's data? Figure 8.65 shows the mean degrees of expectation relating to the each of the 16 melodic fragments in Fig. 8.62. In relation to the first hypothesis, there is a statistically significant tendency for the second set of expectancies to be higher than the first: $t(47) = 7.53$, $P < 0.0001$ (see Fig. 8.66). With regard to the second hypothesis, there is a tendency for the differences in expectancies between the

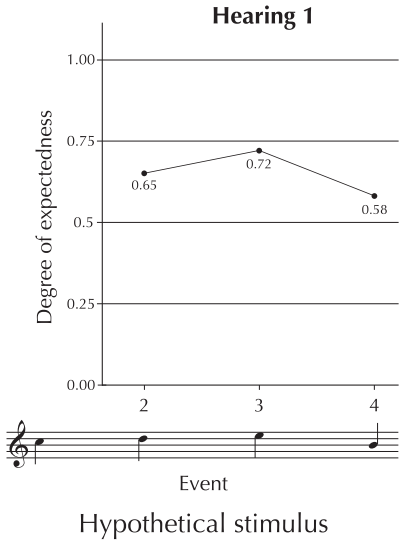


Fig. 8.63 Notional expectancies associated with hypothetical stimulus.

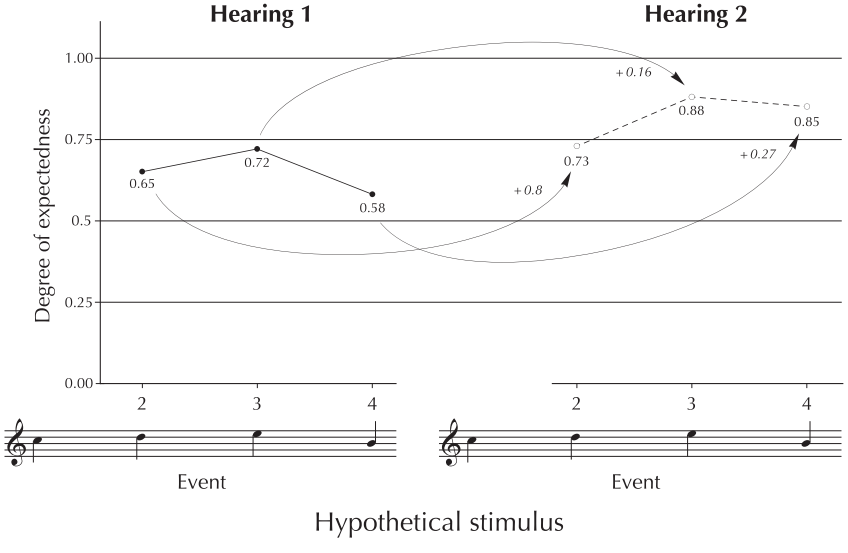


Fig. 8.64 Conjectured increases in expectancies associated with second hearing.

initial hearing and second hearing to increase through the course of each melodic fragment, although the relatively small number of data and wide standard deviations mean that this trend does not attain statistical significance (see Fig. 8.67). However, the results do offer preliminary support for that aspect of the zygonic model of expectation in music pertaining to repeated hearings.

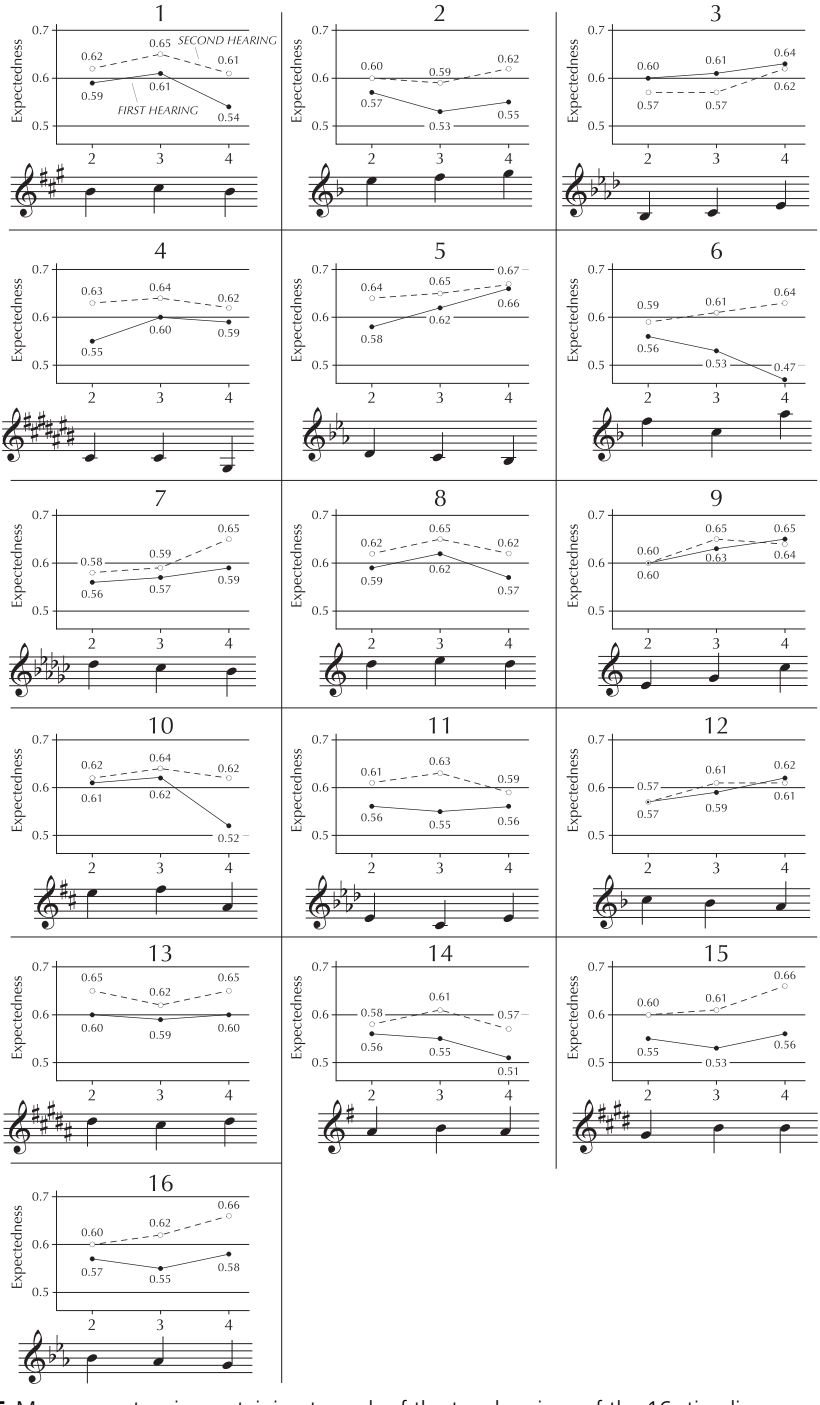


Fig. 8.65 Mean expectancies pertaining to each of the two hearings of the 16 stimuli.

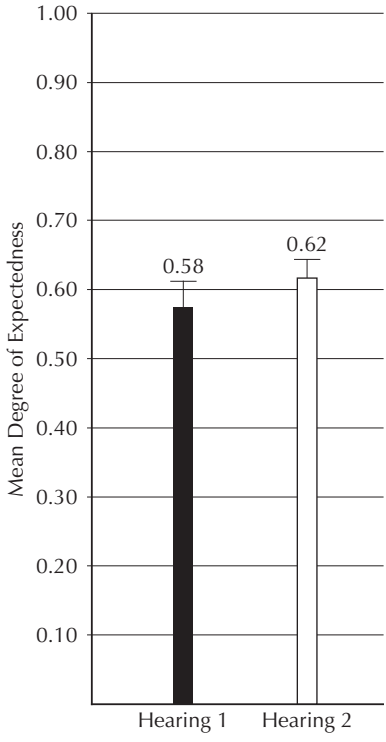


Fig. 8.66 Mean expectancies pertaining to hearings 1 and 2.

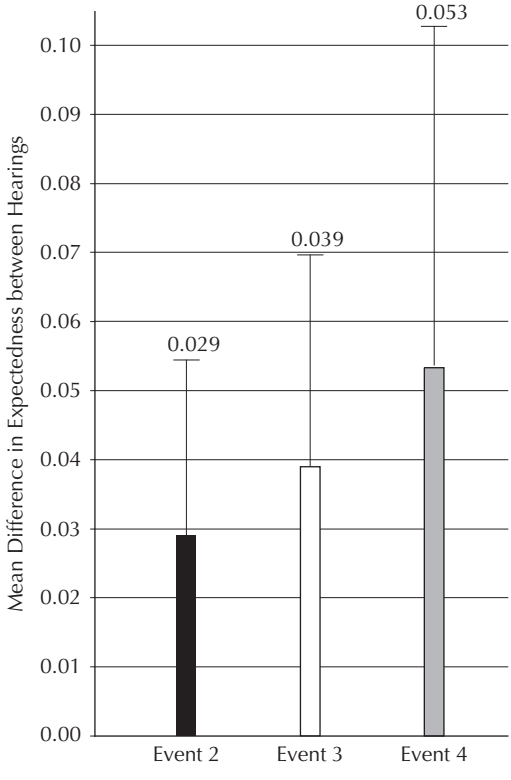


Fig. 8.67 Differences in expectancies pertaining to events 3, 4, and 5 between hearings 1 and 2.

Conclusion

In the first part of this chapter, the theory of expectation in music first mooted by Leonard Meyer and subsequently developed by Eugene Narmour, and the body of empirical work that derived from it, notably the research of Glenn Schellenberg and David Huron and his colleagues, were subject to zygonic meta-analysis. This resulted in a proposed simplification and consolidation of earlier thinking. In particular, it enabled expectations purported to arise from "within" groups of musical events and "between" them, as well as those deriving from the "statistical learning" associated with hearing many pieces in congeneric styles to be brought together in one model. With due regard to Ray Jackendoff's notion of a "closed parser," the model also enabled us to tackle the issue of how humans are both able to make perfectly good sense of a composition on its first hearing, as well as relishing works with which they are very familiar, having heard them literally hundreds of times before. Two research projects were reported that offered initial support for the zygonic model in Western tonal contexts. An exploration of its potential efficacy in predicting how listeners typically process the pitch structures in the atonal music of Schoenberg and his followers appears in Chapter 9.

Chapter 9

Can music survive without listening grammars? Studies in the perception of atonality

Introduction

This chapter uses zygonic theory to investigate how listeners respond to some forms of Western music written since the beginning of the 20th century that consciously eschew certain of the structural and expressive principles that composers had previously, more or less unthinkingly, adopted—in particular, the apparently universal notion of "tonality." Currently the preserve of a tiny minority of enthusiasts, has such "new" music the capacity ever to succeed in attracting wider, "non-specialist" audiences or will much of it ultimately represent little more than a stylistic cul-de-sac in the broad span of Western music's evolution? Conversely, are there strategies that the composers of atonal music could consider adopting to make their pieces more readily approachable by the majority of listeners, each of whom has a natural propensity to understand and enjoy the music to which he or she is exposed? These are among the key issues that are tackled in the analyses that follow.

The notion of "musical grammars"

Our starting point is Fred Lerdahl's notion of "musical grammars": limited sets of rules that can "generate indefinitely large sets of musical events and/or their structural descriptions" (Lerdahl, 1988, p. 233). In zygonic terms, it is held that such grammars—like all musical structures—derive ultimately from a sense of derivation through imitation (see Chapter 1). At the highest level, these may be "universal" (common to all types of music, including the use of recurring intervals in the domains of pitch and perceived time), while at lower levels, other structures may be bound by culture- or style-specific content (such as the habitual use of particular cadential formulae, for example) (cf. Meyer, 1989, pp. 3–37).

Lerdahl identifies two main forms of musical grammar, "listening" and "compositional," which correspond to the (typically non-conscious) ideation of "reactive" and "proactive" zygonic relationships (see p. 19). In the majority of cultures, most of the time, we can assume that listening and compositional grammars very largely overlap: the composer or improviser and his or her audience intuitively tapping into the same set of rules that they have learnt implicitly through exposure to a similar corpus of music. Here, communication is not a problem: there is enough redundancy for the burden of the musical message to be conveyed, even if, as we should expect, there are subtle shades of difference in the esthetic of the auditory information as it is created and received.

However, in some cultures (such as the West), composers of "art" music quite deliberately introduced additional, "conceptual" constraints. These "artificial" grammars worked alongside, or fused with, the "natural" grammars prevalent at the time (Lerdahl, 1988, p. 235). Again, effective

musical communication was not compromised provided that sufficient of the natural grammars was audible for the music to "make sense" in the ears of listeners (see Fig. 9.3). Take, for example, the countersubject in Bach's fugue XVI in G minor from Book 1 of *Das Wohltemperierte Klavier*, BWV 861 (Ockelford, 2009, p. 86). This extends seamlessly from the subject through a number of motivic threads. Of particular significance among these for the ensuing fugal texture is the link through inversion of the second half of the subject to the opening of the countersubject. That is, essentially the same material performs two functions, affording the musical fabric a taut logic that is so characteristic of Bach. *But*, even if a listener were to fail to pick up on this connection, the music would still make sense, since the countersubject meets the minimum requirement of harmonizing the "answer" while fulfilling the harmonic expectations set up by the subject (Fig. 9.1).

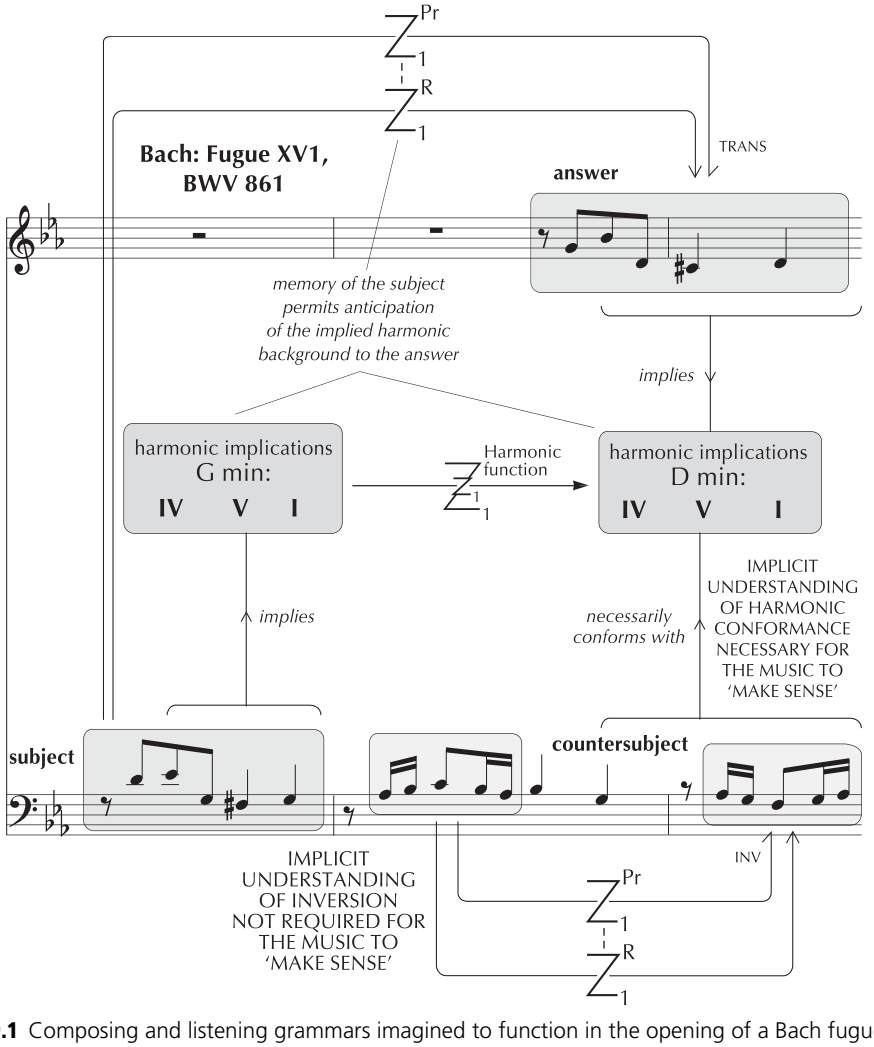


Fig. 9.1 Composing and listening grammars imagined to function in the opening of a Bach fugue.

This belt and braces approach to composition (see Chapter 2), of ensuring that compositional grammars are supported by the safety net of listening grammars, was characteristic of all Western composers, from Dufay, Palestrina, and Bach, for example, to Mozart, Schumann, and Brahms; that is, from the Middle Ages right up until the end of the 19th century. Indeed, there is evidence that composers themselves were aware of the relationship between the two forms of structure, and knew how to engineer it, so that both their artistic instincts as composers and the practical need to produce music with sufficient immediacy to please patrons and audiences could be satisfied. For example, in a letter to his father of 28 December 1782, Mozart wrote that he still had two more piano concertos to complete of the three that he was working on for his 1783 subscription concerts (K. 413–415):

> These concertos are a happy medium between what's too difficult and too easy—they are Brilliant—pleasing to the ear—Natural without becoming vacuous;—there are passages here and there that only connoisseurs can fully appreciate—yet the common listener will find them satisfying as well, although without knowing why (Spaethling, 2000, p. 336).

However, in the early 1900s Arnold Schoenberg and his associates, Alban Berg and Anton Webern, working together in what became known as the Second Viennese School, promoted a line of thinking that persisted throughout the 20th century, in which the principle of music having a natural grammar—a cognitive space that was tacitly shared between composers and listeners—was consciously abrogated. Indeed, the notion of general accessibility to art music became, in some circles, *infra dig.* As Schoenberg put it (1946/1975, p. 124), "if it is art, it is not for all, and if it is for all, it is not art," a sentiment echoed in Milton Babbitt's now notorious article of 1958, in which he contended that composers no longer live "in a unitary musical universe of 'common practice' ", and so, at best, "music would appear to be for, of, and by specialists" (Babbitt, 1958, p. 38).

This schism between some composers and "mainstream" classical music audiences began with Schoenberg's conscious eschewal of what had previously been regarded as an indispensable structural element in all music, tonality: the sense that, within a relative pitch framework, notes fulfill distinct functions in relation to one another, based on past patterns of idiosyncratic usage. "Atonality," as the fruits of Schoenberg's new approach became known,[1] is, in theoretical terms, something of an oddity, since it is the negation of a system of rules rather than their implementation: it stipulates the kinds of pitch relationships that are *not* admissible, but does not indicate which *are*. Hence, one could reasonably argue that atonality does not, on its own, constitute an artificial grammar. However, its immediate consequences for listeners can be somewhat the same, and musical communication is likely to be impaired, as audiences seek to make sense of the streams of notes that assail them. In relation to this, a number of different strategies have been adopted. For example:

1 Listeners may instinctively turn their attention to organization in domains other than pitch, particularly rhythm and timbre. Lerdahl, in reflecting on his response to Pierre Boulez's *Le Marteau sans Maître* (1954), for instance, asserts that its pitch structure is imperceptible, even

[1] The term "atonality" was not one that Schoenberg himself used, though he does refer to "renouncing a tonal centre" in works of his "second period" (which includes his Op. 11 piano pieces referred to below). He writes: "the overwhelming multitude of dissonances cannot be counterbalanced any longer by occasional returns to tonic triads as represent a key. It seemed inadequate to force a movement into the Procrustean bed of tonality without supporting it by harmonic progressions that pertain to it. This dilemma was my concern … That I was the first to venture the decisive step will not be considered universally a merit—a fact I regret but have to ignore" (Schoenberg, 1949/1975, p. 86).

after many hearings: rather, the effect is of a "smooth sheen of pretty sounds" flying by (Lerdahl, 1988, p. 232).

2 In the domain of pitch, composers may choose to fill the structural void left by the absence of tonality by utilizing non-tonal forms of organization, such as the serial techniques invented by Schoenberg, and adopted or extended by a number of others (including Boulez in *Le Marteau*). Depending on their constitution as natural (perceptual) or artificial (conceptual) grammars, listeners may or may not detect and come to understand such structures just by hearing them (Krumhansl *et al.*, 1987).

3 A third recourse for listeners, again in relation to pitch, are the "tonal flecks" that many ostensibly atonal pieces contain. These are residual intimations of tonality that may (but need not) have been intended to be interpreted in that way by the composer—for, as we shall see, irrespective of the composer's intentions, listeners have a tendency to "hear tonality in everything" (Piston and Westergaard, 1968, p. 15).

4 In similar vein, listeners may, to a greater or lesser extent, be able to assimilate some atonal passages by mentally mapping them onto known tonal structures, and accepting some pitches as "errors." This accords with listeners' anecdotal complaints that atonal pieces sound "discordant" or "wrong" and that they are difficult to remember (cf. Bernstein, 1976, p. 273; Rochberg, 2004, p. 95).

5 Fifth, and finally, we should note that music theorists such as Allen Forte claim to have unearthed structures in atonal music using "set theory." This uses and extends many of the principles of serialism, holding that one group of pitches can be regarded as equivalent to another irrespective of transposition or inversion, the octave in which pitches are sounded, whether or not they are repeated, and, additionally, the order in which they occur. The ontological status of analyses using set theory has been a matter of some debate (see, for example, Ockelford, 2005a; Mailman, 2007). There is no evidence that Schoenberg and his followers conceived of their atonal compositions as agglomerations of relative pitch-class sets, nor that listeners typically hear them in this way. However, this is an area that merits further investigation.

Here we will report on two studies that explore issues 2, 3, 4, and 5: those pertaining to pitch perception. The first investigation (previously reported in part in Ockelford, 2011) involves, once more, the musical savant Derek Paravicini, and explores how his capacity to learn and remember the opening bars of Schoenberg's *Klavierstück* Op. 11, No. 1, and the challenges this poses for him, shed light on his cognition of atonality. In particular, we will consider the part that Derek's intuitive preconceptions of musical structure as being tonal may play in his apprehension of the Op. 11, No. 1 (issue 4), and the extent to which its pitch classes may be heard as being organized in sets, in the absence of any explicit listening guidance (issue 5). The degree to which Derek's responses may be representative of listeners more widely is also considered.

Second, we examine issues 2 and 3 using probe-tone data gathered by Desmond Sergeant (see Ockelford and Sergeant, in press). Here, a group of Western classical musicians with advanced skills, including, in many cases, experience in performing 20th-century music, rated how convincing a continuation each of the 12 pitch-classes offered when heard at the end of a given tone row. Subjects' responses yield fascinating insights into the perception of the serial principle of repetition avoidance (termed here "antistructure") and of "tonal flecks."

Derek's encounter with the *Magical Kaleidoscope*

Audiences are often intrigued by Derek's capacity to learn, reproduce, and improvise on music in a wide range of styles, working entirely by ear. Occasionally I get asked "But what about *atonal* music? Can he learn pieces by Schoenberg, for example?" Until recently I could only respond with: "Almost certainly not without a huge amount of effort, though he's never tried." However, I had the opportunity to test this out when, a couple of years ago, I was asked to contribute something to a *Festschrift* for John Sloboda (Deliège and Davidson, 2011). I decided to build on Sloboda's seminal work with the savant Noel Patterson (Sloboda *et al.*, 1985), which explored memory in the context of a piece that used a familiar tonal system (Grieg's *Melodie* from his collection of *Lyric Pieces*, Op. 47, No. 3) and one that did not (Bartók's *Whole-Tone Scale* from *Mikrokosmos*, Book 5). Sloboda *et al.* discovered that Patterson found the former far easier to learn than the latter, and concluded that his learning, like non-savant experts, was "structurally based" (Sloboda *et al.*, 1985, p. 166).

With Derek, I decided to take this one stage further, and present him with a truly atonal piece of music to see what transpired. While, as we have seen, he is thoroughly conversant with the natural grammars of what may be termed the Western musical "vernacular," particularly the diatonic major and minor scale systems, he had been exposed to little 20th-century music that moves beyond these conventions, and he was not known to have attempted to play atonal music. Based on my extensive experience of working with him, I hypothesized that:

- *Prediction 1*: The lack of a tonal framework would have a negative impact on his capacity to learn and remember the piece, since an important source of information about musical events—their perceived functionality in relation to one another—would be missing, which, I believed, would make the perceptual input more impoverished and less easy to encode parsimoniously. This would be likely to lead to short-term memory overload, with asystematic patterns of error.
- *Prediction 2*: A tonal framework (or frameworks) would be *imposed*, more or less consistently, as Derek strove to "make sense" of the music: that is, new material would be modified to facilitate assimilation. This would be likely to be shown by the omission of pitches, or by their "migration" to conform to familiar structures, and through the same errors being made consistently.

A musically self-contained section of an authentic piece of atonal music was selected, the opening 11 bars of Schoenberg's Op. 11, No. 1 (see Fig. 9.2), with which I was as confident as it was possible to be that he had never heard before. This passage was deemed to be of sufficient length and complexity to demonstrate the cognitive principles involved in Derek's attempting to learn and remember atonal music, and yet be of a level of technical difficulty that would not impair his capacity to play back immediately what he had heard (so that issues of performability would not interfere with the results). Allen Forte (1981) described the Op. 11, No. 1 as "Schoenberg's first atonal masterpiece" and dubbed it the *Magical Kaleidoscope* on account of what he believed to be its cellular (rather than tonal) pitch structure. The title *Magical Kaleidoscope* was given to the piece in working with Derek, since it necessarily had to be distinct and memorable in his terms (and opus numbers are not).

A further, tonal, passage was required for the purposes of comparison. However, given the possible confusion of results pertaining to a subject's recollection of the pitch framework of a piece (cf. p. 141) with other aspects of its structure operating at more local level (motivic relationships,

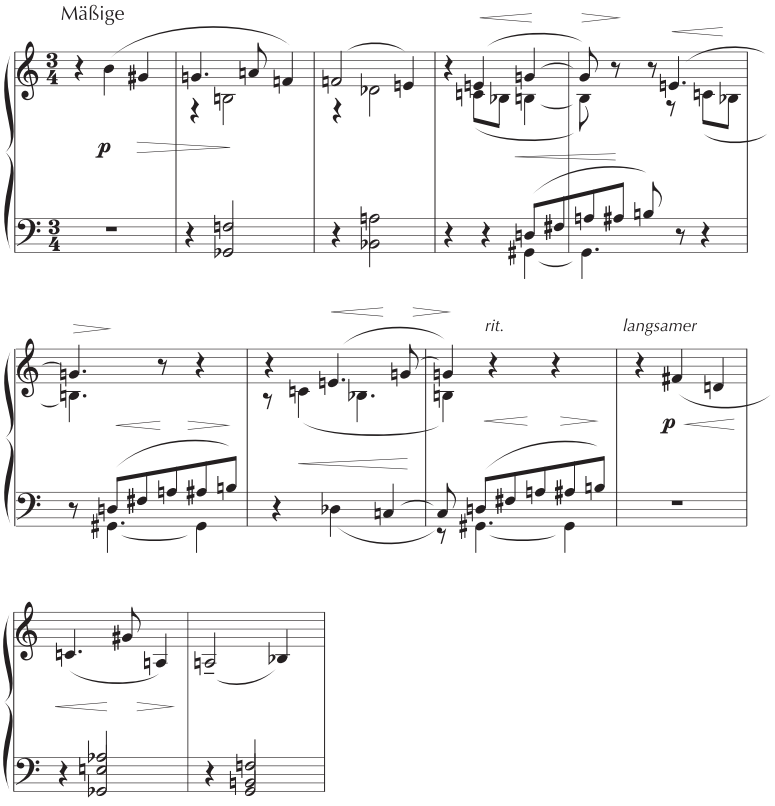



Fig. 9.2 Opening of Schoenberg's *Klavierstück*, Op. 11, No. 1, known as the *Magical Kaleidoscope*.

for example), it was necessary to create stimulus material that differed structurally from Op. 11, No. 1 *only* with respect to offering a sense of tonality. This was achieved through using a zygonic music-theoretical approach to inform the creation of the new piece, with the results described below. There were other constraints, of a more practical nature, too: it was essential that the tonal comparator should bear no thematic resemblance to existing works, for example, and technically it needed to be well within Derek's grasp. And it had to have a memorable title too, distinct from the *Magical Kaleidoscope*; the name chosen was *Kooky Minuet* (see Fig. 9.3).

Observe that this is the opposite of the approach adopted by Lalitte *et al.* (2009), who used specially constructed atonal versions of Beethoven piano sonatas to investigate the contribution of tonal relationships to the perception of musical ideas. Here, however, the structures were not controlled with the same rigor as in the work with Derek: comparative analyses of the *Magical Kaleidoscope* (*MK*) and *Kooky Minuet* (*KM*) show just how similar they are in many dimensions, despite the considerable perceptual difference engendered by the presence of consistent tonal relationships in *KM*. For example, both pieces map out the same variety of ternary form, comprising five segments (A_1 B_1 B_2 B_3 A_2), in which the middle ("B") section has three iterations (produced largely through rhythmic variation) and the initial ("A") section is modified somewhat on its reprise at the end of the passage. Both *MK* and *KM* have the same number of notes per segment, respectively 13, 11, 11, 13, and 13—a total of 61. These events extend over 45 seconds in the performance of *MK* that Derek heard and 40 seconds in the case of *KM*.

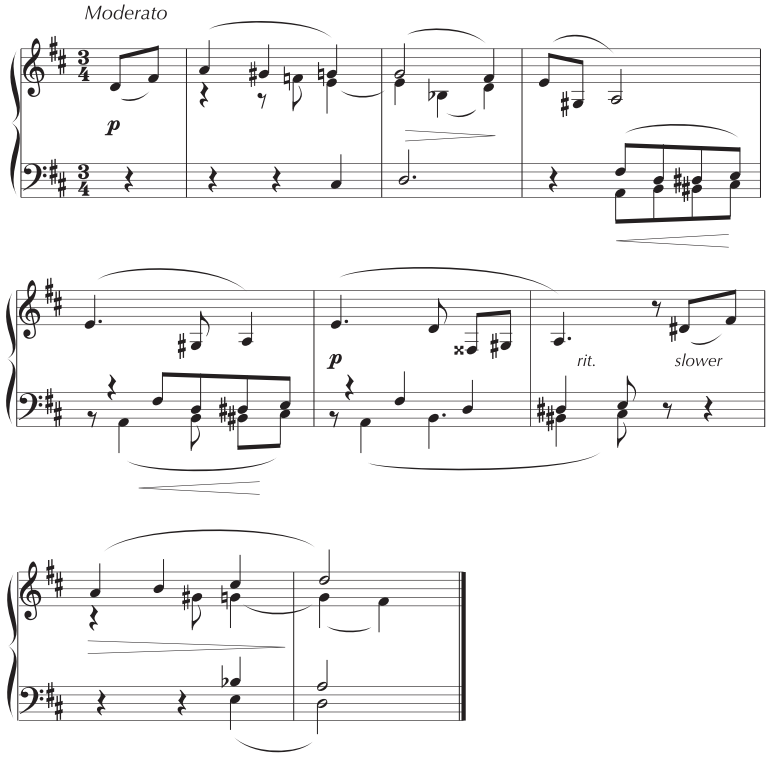



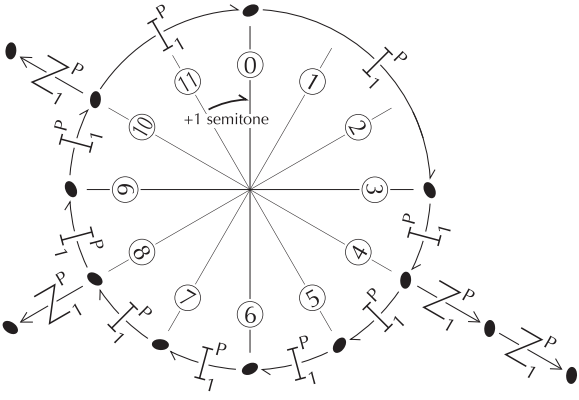
Fig. 9.3 Especially composed tonal equivalent of Schoenberg's Op. 11, No.1, known as the *Kooky Minuet*.

The moment-to-moment structure of *KM* necessarily differed somewhat from that of *MK*, since it is in the nature of transitions between successive pitches, the disposition of simultaneities, and, more broadly, the context-sensitive frequencies of occurrence of scale degrees and the intervals between them upon which a sense of tonality is founded. However, it was important that the overall *degree of structure* present should be maintained, segment by segment. That is to say, the set of relative pitches used in comparable segments of *MK* and *KM* should have equal zygonicity: that is the proportion of potential zygonic relationships to all relationships, here *within* a group (cf. Formula 7.4) (see Ockelford, 2005a, pp. 74, 75).

Take, for example, the opening phrases of *MK* and *KM*, which, as we have seen, each comprise 13 notes. The important thing, from the point of view of pitch-structural equivalence, is that they both express nine different pitch-classes that have the same pattern of distribution (see Fig. 9.4). Thus, they have the same complexity, which, as we have seen, is related to the parsimony with which they can theoretically be encoded (p. 256) or the ratio of repetition to difference. This measure is termed "zyg_1-seq" (since the sameness and difference are judged at the primary level between sequentially adjacent values in the relative pitch-class set; see Ockelford, 2005a, p. 94). Zygonicity (zyg_1-seq) is identical in the subsequent phrases too (Fig. 9.5).

Even in terms of the more exacting mode of comparison that assesses the distribution of melodic intervals between *successive* notes, using the similarity measure shown in Formula (2.1) (Ockelford, 2005, p. 41), the similarity between *KM* and *MK* is still high, at 78%. The majority of

Magical Kaleidoscope, Segment 1
Distribution of relative pitch-class set



relative pitch-class	0	1	2	3	4	5	6	7	8	9	10	11
frequency	1	0	0	1	3	1	1	1	2	1	2	0

Ordered intervallic content

interval (semitones)	Z	1	2	3
frequency	4	7	1	1

Zygonicity (zyg_1–seq) = 4÷13 = **0.308**

Kooky Minuet, Segment 1
Distribution of relative pitch-class set

relative pitch-class	0	1	2	3	4	5	6	7	8	9	10	11
frequency	1	0	0	1	3	1	1	1	2	1	2	0

Ordered intervallic content

interval (semitones)	Z	1	2	3
frequency	4	7	1	1

Zygonicity (zyg_1–seq) = 4÷13 = **0.308**

Fig. 9.4 Distribution of relative pitch-classes in the opening phrases of *Magical Kaleidoscope* and *Kooky Minuet*.

intervals are four semitones or smaller; over 90% in each case. Moreover, the pitch *range* of both pieces is identical—two octaves and five semitones—and sets of the pitch-classes are virtually identical (*KM* uses all 12, whereas *MK* omits E♭; see Fig. 9.13 and Ockelford, 2005a, p. 115).

It is in the domain of *harmonic* intervals that the main difference in the domain of pitch is to be found: something we should expect, as certain intervals and combinations thereof evoke percepts that are strongly associated with conventional Western tonality. Here the distributions are only 56% similar. Observe, in particular, the variation in the numbers of intervals comprising three semitones (equivalent to a minor 3rd), four semitones (a major 3rd) and seven semitones (a perfect 5th)—constituents of diatonic triads; and one semitone (a minor 2nd) and 11 semitones (a major 7th)—astringent discords (see Table 9.1).

In summary, then, the substantive difference between the passages in terms of pitch is that the structure pertaining to the *framework* that is used engenders in one case (*KM*) a clear sense of tonality and in the other (*MK*) it does not. Hence, in *KM*, it was hypothesized that Derek would be able to gauge pitches *functionally* in relation to others, whereas in *MK* he would not. As we have seen, it was anticipated that this would lead him either to experience overload in short-term

Magical Kaleidoscope, Segments 2 and 3
Kooky Minuet, Segments 2 and 3
Distributions of relative pitch-class sets

relative pitch-class	0	1	2	3	4	5	6	7	8	9	10	11
frequency	1	0	1	0	0	1	1	1	2	1	2	1

Ordered intervallic content

interval (semitones)	Z	1	2	3
frequency	2	6	3	0

Zygonicity (zyg_1–seq) = 2÷11 = **0.154**

Magical Kaleidoscope, Segment 4
Kooky Minuet, Segment 4
Distributions of relative pitch-class sets

relative pitch-class	0	1	2	3	4	5	6	7	8	9	10	11
frequency	1	0	1	0	1	1	1	1	2	2	2	1

Ordered intervallic content

interval (semitones)	Z	1	2	3
frequency	3	8	2	0

Zygonicity (zyg_1–seq) = 3÷13 = **0.231**

Magical Kaleidoscope, Segment 5
Kooky Minuet, Segment 5
Distributions of relative pitch-class sets

relative pitch-class	0	1	2	3	4	5	6	7	8	9	10	11
frequency	1	0	1	0	1	1	2	1	2	1	2	1

Ordered intervallic content

interval (semitones)	Z	1	2	3
frequency	3	8	2	0

Zygonicity (zyg_1–seq) = 3÷13 = **0.231**

Fig. 9.5 Distribution of relative pitch-classes in phrases 2, 3, 4 and 5 of *Magical Kaleidoscope* and *Kooky Minuet*.

memory, resulting in frequent and asystematic errors, or to *impose* frameworks on what he heard, leading to systematic inaccuracies in recall.

Learning and attempting to reproduce *MK* and *KM* were tasks undertaken by Derek as part of a day's other musical activities, including recording familiar repertoire and performing with a singer (a broadly typical schedule for him). Although the *MK* and *KM* tests occurred on the same day, the work was undertaken in different sessions, and no interference was evident at the time or revealed in subsequent analysis (see later). I had previously recorded the materials using a Yamaha digital stage piano, feeding MIDI data through an RME Fireface to an Apple MacBook Pro running Cakewalk's SONAR 6 (Producer Edition). Verification was achieved by subsequently notating the data via Sibelius 5 and cross-checking with the original score.

The session was organized as follows:

1 Listen to the whole piece (twice).
2 Listen to the first segment and then play (four times).
3 Listen to the second segment and then play (four times).
4 Listen to the third segment and then play (four times).

Table 9.1 Comparisons of melodic and harmonic intervals used in *Magic Kaleidoscope* (*MK*) and *Kooky Minuet* (*KM*)

		interval (semitones)	Z	1	2	3	4	5	6	7	8	9	10	11	12
melodic	*MK*	frequency	2	14	7	8	7	1	0	0	1	0	0	1	0
		relative frequency	5%	44.5%	17.5%	20%	17%	2%	0%	0%	2%	0%	0%	2%	0%
	KM	frequency	1	24	7	3	5	0	1	1	2	0	0	0	0
		relative frequency	2%	55%	16%	7%	11.5%	0%	2.5%	2.5%	4.5%	0%	0%	0%	0%
harmonic	*MK*	frequency	0	5	3	4	9	4	7	0	3	5	6	4	1
		relative frequency	0%	10%	6%	7.5%	17.5%	7.5%	14%	0%	6%	10%	12%	7.5%	2%
	KM	frequency	0	1	15	1	4	7	6	2	6	3	0	1	0
		relative frequency	0%	2%	33%	2%	9%	15%	13%	4.5%	13%	6.5%	0%	2%	0%

$$\text{Similarity (\%) } MK \text{ and } KM \text{ (melodic intervals)} = 100 - \sum \left(\frac{\sum \left| x_i - \left(\frac{\sum x_i}{x} \right) \right|}{x} \right) \% = \mathbf{78\%}$$

$$\text{Similarity (\%) } MK \text{ and } KM \text{ (harmonic intervals)} = \mathbf{56\%}$$

5 Listen to the fourth segment and then play (four times).

6 Listen to the fifth segment and then play (four times).

7 Listen to the whole piece and then play (twice).

Derek's responses were recorded on video and back through the same MIDI system (in unquantized form), which meant that the rhythms needed "tidying up" to accord with conventional notation. Generally, Derek's efforts were unambiguous in this respect. Occasionally, though, there were hesitations (uncharacteristic of his playing) and wherever these occurred, they are marked on the transcriptions that follow, and their potential significance is discussed below.

The segments were intended to be of such length as to lie just beyond the observed capacity of Derek's short-term memory, so that he would be likely to make some errors (that would give a fair indication of his coding strategies and their limitations), but not so many as to preclude meaningful analysis. (Attempting to recall the whole of *MK* or *KM* would occur only after it had been heard all through three times and each of its five segments had been played four times.) The replications within the experiment meant it would be possible to observe how Derek's recall evolved in the short term with repeated stimuli. Previous work (in which Derek had learnt a specially composed piece called *Chromatic Blues*, reported in Chapter 7) had shown that Derek's initial attempt to reproduce a passage became for him the most potent trace, even when the original was played again, and that the most substantial improvements occurred through the recruitment of long-term memory. The results of Derek's efforts are shown in Figs. 9.6 and 9.7.

In the research undertaken previously by Sloboda *et al.* (1985), Miller (1989), and Young and Nettelbeck (1995), different protocols were employed for measuring the fidelity of reproduction.

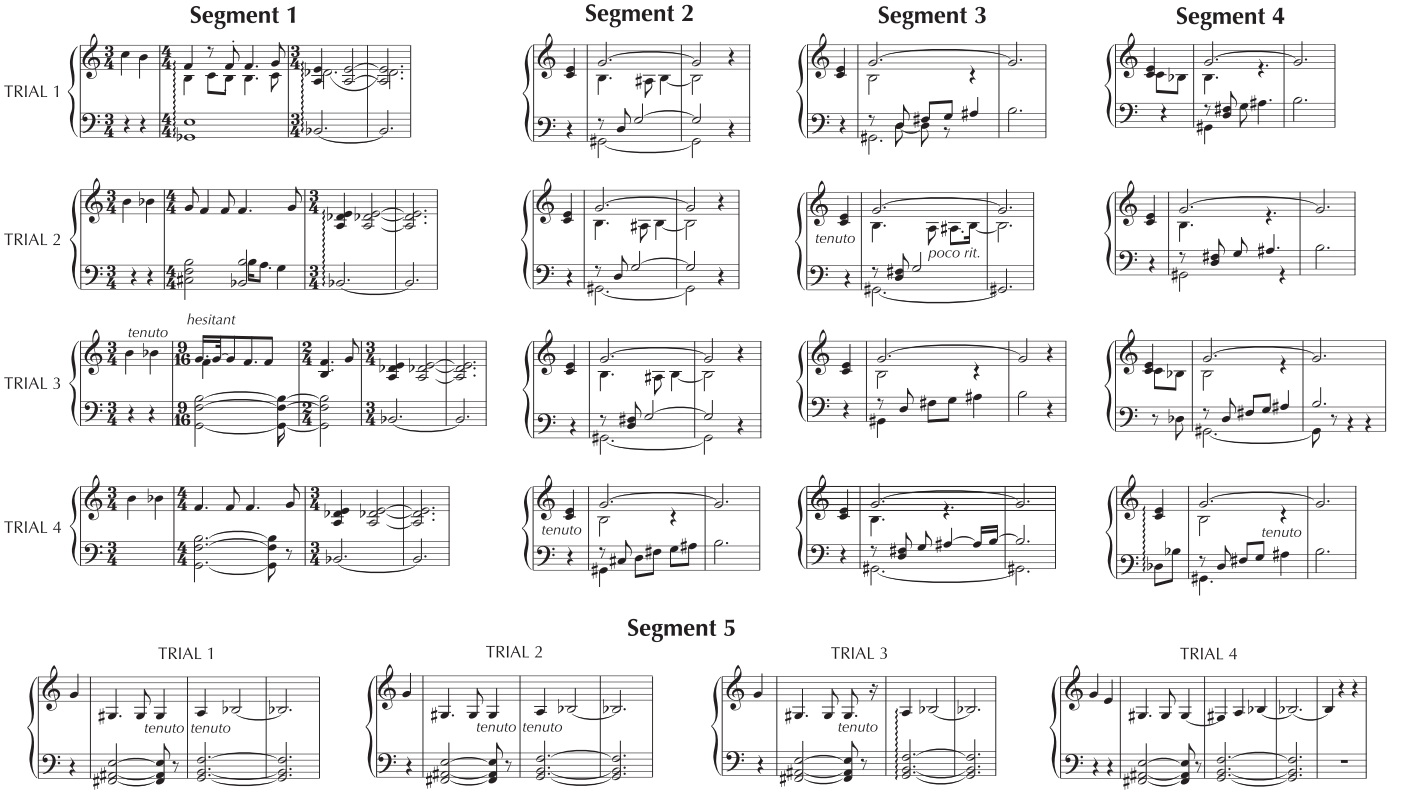


Fig. 9.6 Transcription of Derek's responses to the *Magical Kaleidoscope* materials.

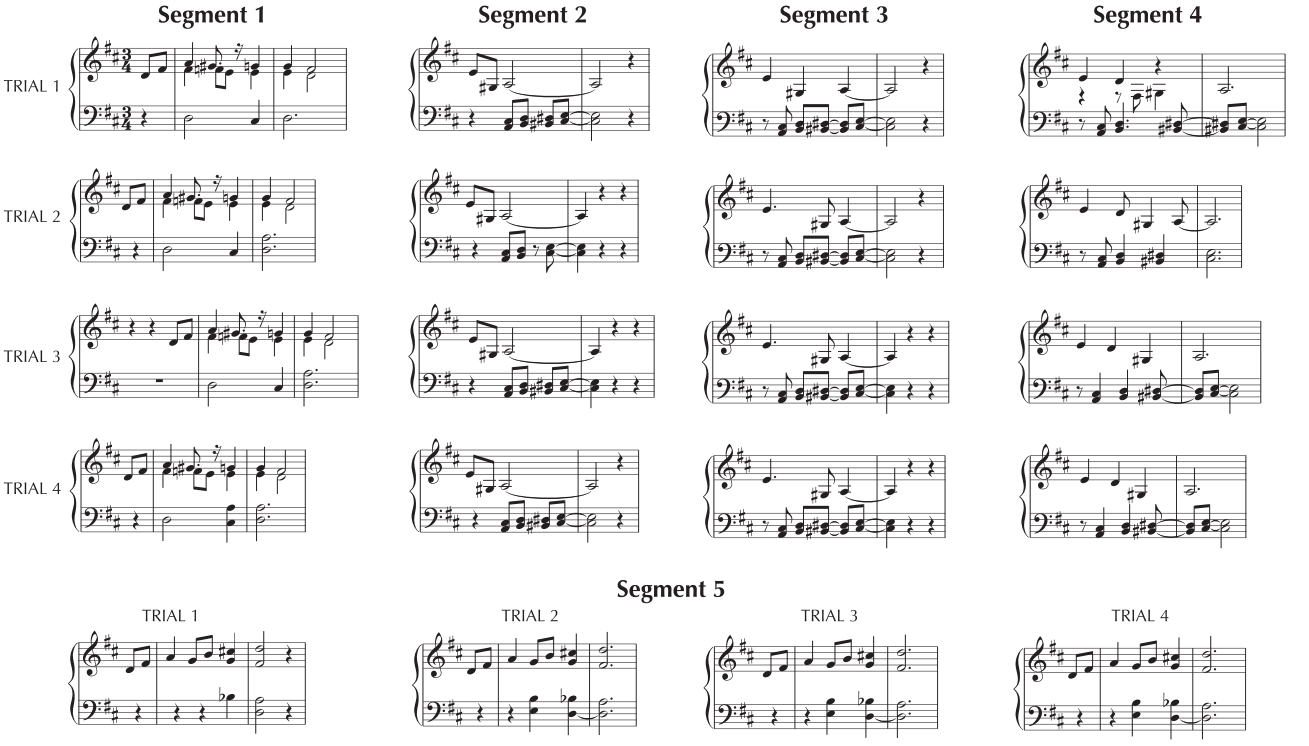


Fig. 9.7 Transcription of Derek's responses to *Kooky Minuet*.

Here, the notion of zygonicity (*between* groups of notes) is used to underpin the analyses that follow, since it arguably offers a more valid means of gauging how the material that Derek reproduced was related to what he had heard than simple note-matching. This is because measures of similarity alone, particularly in cases where the error rate is high, as we saw in Chapter 3, run the risk both of "false positives," since the constraints on music imposed by the use of frameworks in the domains of pitch and perceived time mean that there is a strong likelihood that some events or transitions will be the same by chance, and of "false negatives," as even perceptually straightforward transformations, through which one group of notes may be regarded intuitively as deriving from another, may involve high levels of surface variety. Most importantly, though, to restate a central assertion of this book, it is the question of musical *derivation* rather than *repetition* that is the appropriate proxy through which we can interrogate and seek to understand matters of recall.

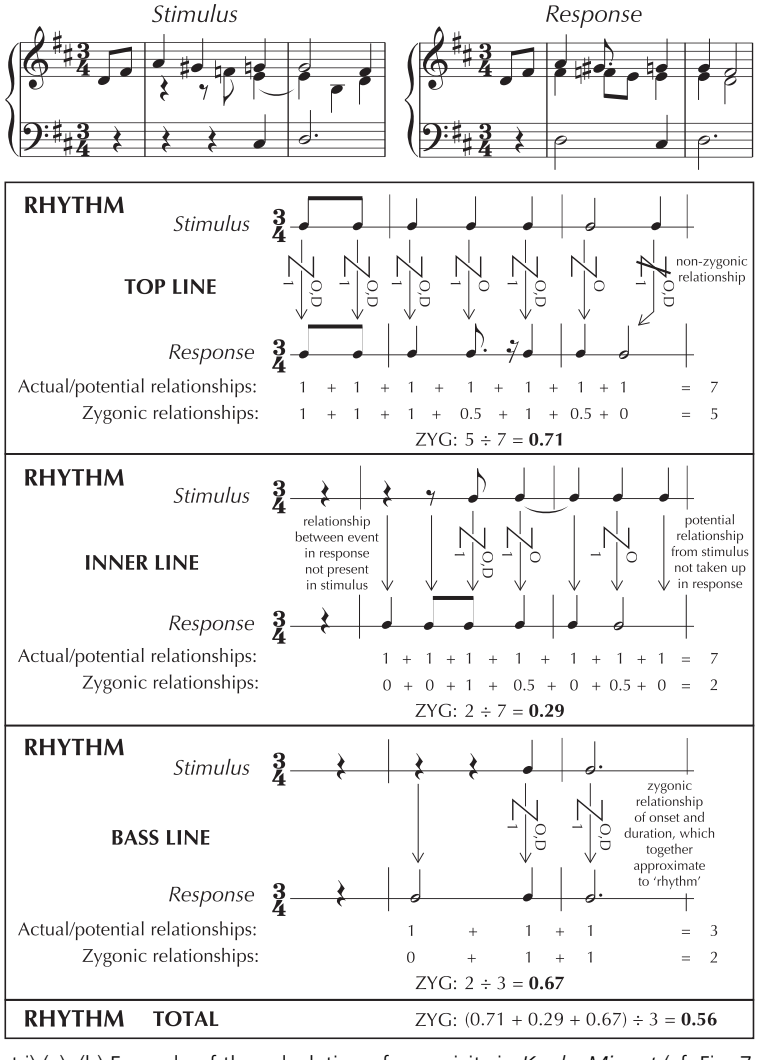


Fig. 9.8 (part i) (a), (b) Example of the calculation of zygonicity in *Kooky Minuet* (cf. Fig. 7.9).

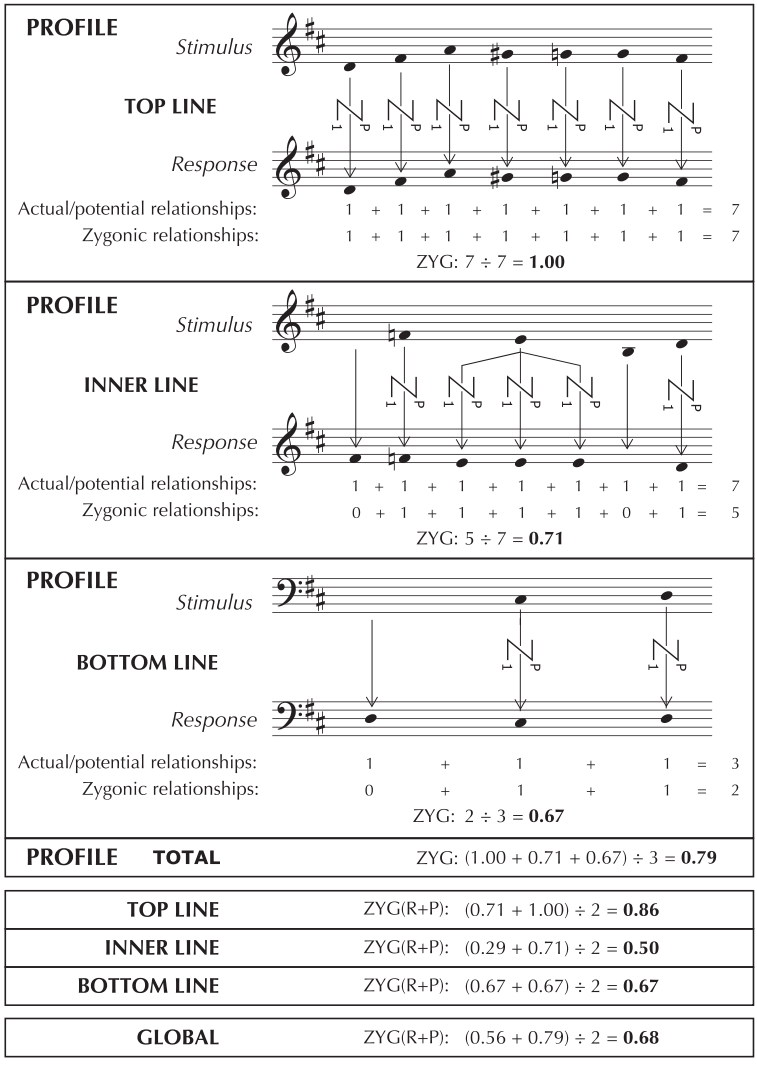


Fig. 9.8 (part ii) (continued).

Of course, similarity is an important element in the notion of derivation, but, as the potential for false positives and negatives shows, it does not make up the whole picture: as I argue in Chapter 3 and elsewhere (Ockelford, 2004) *context*, and in particular, *salience*, is also crucial in gauging whether one musical object can reasonably be deemed to derive from another. The algorithm for calculating zygonicity will be the same as that used in Chapter 7 (p. 257).

To give a further worked example of the algorithm in action, here is Segment 1 of *KM*, and Derek's initial response to it (see Fig. 9.8). Taking the top line first, there are seven events in both the stimulus and the response. In the domain of pitch, Derek's recall is entirely accurate (7 ÷ 7 events correct, ZYG = 1). With regard to rhythm, the first three events are identical, but the fourth has a different duration, and therefore scores 0.5. The fifth event is accurately reproduced, while

the sixth has the correct onset relative to the proceeding note but the wrong duration, giving a further score of 0.5. The seventh event scores 0. Hence the zygonicity of rhythm in the top part is $5 \div 7 = 0.71$. Although the middle part comprises only four events in the original, Derek's effort at reproduction yields six notes (with a total number of actual or potential relationships of seven), of which five are correct in the domain of pitch (ZYG = 0.71), and $1 + 0.5 + 0.5 = 2$ in the domain of perceived time (ZYG = 0.29). In the bottom part, two of the three notes that Derek plays are correct with respect to pitch and rhythm (ZYG = 0.67 in each case). Hence the zygonicity for pitch in the segment as a whole is $(1 + 0.71 + 0.67) \div 3 = 0.79$, and for rhythm is $(0.71 + 0.29 + 0.67) \div 3 = 0.56$. Global ZYG = $(0.79 + 0.56) \div 2 = 0.68$. The potential significance of these differences becomes apparent in the context of the other scores obtained for each trial in relation to *MK* and *KM*, which form the basis of the discussion that follows.

Derek's recall of the *Magical Kaleidoscope*, Segment 1 (bars 1–3)

Derek's first attempt to recall this segment was extraordinary to witness. Here was someone who, as we saw in Chapter 6, had shown that he could consistently disembed highly dissonant nine-note clusters with a striking immediacy and over 93% accuracy (see Fig. 6.14), and whose public piano performances were characterized by precision. Yet here, in an excerpt of textural and technical simplicity, Derek played the very first note incorrectly, substituting a fifth octave C for the original fourth octave B. I was listening to Derek's efforts at the time (rather than watching him play), and what I heard seemed so unlikely that I felt obliged to check that the keyboard had not somehow slipped into transposing mode.[2] But he really had made a mistake, and the errors continued, with ZYG(P) for the segment as a whole being only 0.34. This low figure suggests that the lack of a tonal framework had engendered a high level of confusion in Derek's mind (in accordance with Prediction 1), sufficient even to overwhelm his acute sense of AP: neither the individual percepts nor the relationships between them were spared. Admittedly, Derek's response does afford a sense of "atonality," though it is rather different from the one Schoenberg originally intended. Rhythm too is poorly reproduced (also with a ZYG(R) = 0.34), despite being seemingly straightforward at this early stage in the piece. Given that Derek's previous results in this domain were considerably more successful (see Chapter 7), one can only suppose that there was a cross-over effect, whereby difficulties in relation to pitch had a negative impact on the recall of rhythm.

Derek's confusion was confirmed as, in the course of the next two attempts, he tried different pitch combinations, apparently trying to square the circle of satisfying both the need for accurate reproduction of individual notes and conforming to tonal syntax.[3] His indecision is reflected in uncharacteristic hesitations and slips. These are particularly evident in his approach to the first chord (at the beginning of the second bar): in Trials 2 and 3 the preceding note is sustained, giving the impression that Derek was taking time to think what to do next. The chord itself evolves over the course of the first three trials, with changes particularly evident in the bass, where the

[2] My uncertainty was exacerbated by the fact that my own sense of AP has risen a semitone over the years (Ockelford, 2008a).

[3] The difficulties that Derek was having with the task at this point raised ethical concerns as to whether it was appropriate to expect him to continue, and he was asked whether he was comfortable to carry on (to which he replied in the affirmative). It is interesting to note that, when asked afterwards how similar his version of *MK* was to the original, he replied "not at all like it," a level of metacognition and verbal expression quite exceptional for him. Interestingly, John Sloboda has reported having similar concerns in relation to Noel Patterson in his 1985 study.

G♭ migrates via C♯ to a G, allowing the harmony to "resolve" to G^7 (the nearest available "tonal" option to Schoenberg's original sonority). Here, then, is evidence of Prediction 2, whereby atonal material is modified to conform to a familiar tonal framework. We shall now consider how this compares with Derek's recall of the opening of *KM*.

Derek's recall of *Kooky Minuet*, Segment 1 (bars 1 and 2)

One's immediate impression that Derek's first attempt at recalling this tonal excerpt is more successful than his efforts in relation to the opening of *MK* is borne out by the passage's zygonicity of 0.70, indicating a superiority over the latter of a little over 100%. Nonetheless, several errors do occur (which grow in number through Trials 2, 3, and 4). These inaccuracies are largely due to the increasing *addition* of material, whereby Derek "fills in" the implied harmonic gaps left by the open texture (such as the D and F♯ that he introduces beneath the melodic A), although there are *omissions* too (the B♭ in bar 2) and some material is *altered* (the rhythm of the cadential appoggiatura). Hence, all three logical mechanisms for the non-isometric transformation of musical material are utilized in the space of a few seconds, as Derek compensates for the limitations of his short-term recall (cf. Repp, 1997; Ockelford, 2009b). Given that errors could be made at the level of events, groups, or frameworks (see pp. 134–42 and Ockelford, 2011, p. 239), it is of interest to note that, if something has to "give," it is invariably the former rather than the latter—the tonal system constituting an accurately remembered backdrop upon which surface detail is reproduced with more or less fidelity.

Given the structural equivalence of the two opening segments from *MK* and *KM* in all respects apart from the presence or absence of a pitch framework deployed according to the "common practice" conventions of Western major tonality, it is reasonable to assume that it was Derek's recognition of this feature that accounted for his greater success in recalling the material from *KM*. Unpacking this assumption further, we can surmise that his superior performance in the "tonal" condition arose either because it permitted him to remember more of the stimulus by enabling him to encode the 13 events more efficiently, or because it allowed him to make coherent assumptions where his working memory capacity was exceeded, or both.

Segments 2, 3, and 4

Similar observations apply to the three segments that make up the "B" sections of each piece. In Segments 2 and 3 of *MK*, four events in particular contribute to the sense of atonality: the B♭ in the context of what is otherwise an initial C major harmony, and the G♯, F♯, and A framed within the G major triad that follows. Note that the non-harmonic A♯ can be heard tonally as ornamenting the succeeding B. Derek's approach is consistently to omit the B♭ and to transpose the A down to a G, despite hearing each eight times in the course of the trials pertaining to Segments 2 and 3. By replacing the A with a G, Derek also resolves the issue of the preceding F♯, enabling it to function like the following A♯—as a chromatic ornament—something that he consistently maintains. This way of hearing the ascending run of eighth notes in the middle of the texture, as chromatic–diatonic pairs, is reinforced in Trial 4 of Segment 2, when Derek completes the pattern by adding a C♯ before the D. Rhythmically, Derek's recall is poor across Segments 2 and 3, with an average ZYG(R) of only 0.39 (as opposed to 0.71 in the domain of pitch). This is largely due to his habit of sustaining the "harmony notes" to which their chromatic neighbors "resolve," bolstering his imposed sense of tonality. These changes all conform to Prediction 2; the one concession to atonality that remains is the G♯ in the bass, although to this listener, at least, the effect is of a residual "error" within an otherwise tonal passage.

In relation to the eight trials pertaining to Segments 2 and 3, it is evident that, having once regularized what he had heard, the cognitive urge to maintain the structures he had imposed was strong enough to overwhelm Derek's perception of individual events, despite the reinforcement offered by the multiple presentations of the original stimuli. This is reflected in the difference between the strength of derivation of Derek's responses from the source materials and the strength with which each of his attempts derives from the one that precedes: the average zygonicity of the former is 0.55, whereas that of the latter is 0.77. That is to say, Derek was far more influenced by his own versions of events than the stimuli from which they are drawn, despite the fact that these were repeatedly interpolated between his own reproductions. Again, this conforms to Prediction 2, with errors being repeated consistently.

Segment 4 of *MK* has two additional notes, D♭ and C, which appear at the outset in the bass. These are set against a more fragmented right-hand rhythm than used hitherto, in which the two parts move out of step. Interestingly, this change stimulates Derek to reproduce the B♭ for the first time in Trial 1, though this disappears again in Trial 2, only to reappear with the D♭ in different configurations in Trials 3 and 4. That is to say, each version of the opening bar is different, and all are incorrect—suggestive of the cognitive confusion envisaged in Prediction 1.

The net result of asystematic errors like these and the imposition on other occasions of a tonal framework is average global ZYG values across each set of four trials of Segments 2, 3, and 4 of *MK* of 0.48, 0.62, and 0.55. In contrast, Derek's recall of Segments 2, 3, and 4 of *KM* yields values of 0.86, 0.75, and 0.61 (an average 19% higher). Here, the given tonal framework is respected without exception, although there are *systematic* errors in the domains of pitch and perceived time. For example, the stylistically unusual (though syntactically plausible) F♯ with which the inner part kicks off is consistently replaced with a C♯ (forming a standard dominant harmony in root position rather than the submediant in first inversion implied by the F♯). And, as the rhythmic complexity of the segments grows through the use of a progressively more contrapuntal texture, so Derek increasingly "homophonizes" what he hears, chunking the "horizontal" lines into "vertical" sonorities. This tendency is almost entirely responsible for the decline in fidelity of reproduction across the three segments.

Segment 5

In *MK*, Segment 5 replicates the rhythm (though not the pitches) of Segment 1, and Derek appears to recognize this, since the first three trials end with the same rhythmic error that characterized his renditions of the opening phrase. There are a number of other inaccuracies too, including, for example, his systematic strengthening of the downbeats by shifting the left-hand chords forward by a quarter note—suggestive of Prediction 2 operating in the domain of perceived time.

In the domain of pitch, as before, Derek makes both erratic and structure-seeking errors. In Trial 1, for example, the opening F♯ and D are replaced with a G for no discernible music-structural reason, in accordance with Prediction 1. As the error is repeated in subsequent trials, however, it acquires a musical logic of its own (thereby supporting Prediction 2). The first chord, which does not conform to Western tonal conventions, is also subtly modified to become what is effectively a "dominant major 9th" chord, by omitting the C and subsequently the A (that are not compatible with this harmony) and adding an A♯ (that is), further corroborating Prediction 2. Derek ends the phrase in the same way as Schoenberg, on a G^7 chord with an added minor 3rd, which, in its original context supports the atonal feel, but in Derek's re-creation, has a tonal, "blues" effect.

Segment 5 of *KM* is, once more, reproduced considerably more accurately (with an average ZYG of 0.70, as opposed to 0.45 for Segment 5 of *MK*), and the errors that Derek does make are entirely structure-preserving in the realm of perceived time and, in the domain of pitch, serve to *simplify* things by reducing the level of chromaticism. For example, the initial D♯ becomes a more orthodox D♮, and the chromatic G♯ is omitted altogether. Through these means, the underlying harmonic progression of B, E, A, D is simplified to D, A, D.

Segments 1–5: quantitative comparison

The foregoing descriptions suggest qualitative differences in the way that Derek processes tonal and atonal music. In relation to the latter, when (we can assume) the capacity of his short-term memory is exceeded, he makes two types of error: asystematic, as in Prediction 1, and structure-enhancing, as in Prediction 2. With tonal music, in contrast, Derek's errors are purely systematic, *reinforcing* the prevailing tonality and meter through the addition of notes that accord with the frameworks provided, *simplifying* what is presented through the omission or material, or *making it more conventional* by replacing stylistically less usual relative values and transitions with ones that are encountered more frequently. These forms of assimilation are similar to those set out in Prediction 2 and may therefore be underpinned by the same types of cognitive manipulation. Derek's ability to infer tonal "grammars" from what is presented, with its concomitant absence of asystematic errors in memory, has a significant impact on his accuracy of recall. This is reflected in the different ZYG values pertaining to *KM* and *MK* (see Table 9.2). Average ZYG(P) values are as follows: *MK* ($M = 0.61$, $SD = 0.17$) and *KM* ($M = 0.83$, $SD = 0.10$). The difference between them is significant: $t(19) = 6.51$, $P < 0.0001$.

It is interesting to observe how Derek's performance varies across the textures of the two pieces. In *KM*, with regard to rhythm, he is, by some margin, most successful in reproducing the top part, followed by the bassline and then the inner voice—the same order of success that he showed in the attempting to learn and reproduce *Chromatic Blues* (see Table 7.6). In the domain of pitch, with respect to *KM*, the scores pertaining to melody and bass are virtually identical, with the inner part lagging some way behind. Again, this is similar to the position that obtains in the case of *Chromatic Blues,* suggesting that the way Derek stores and retrieves multistranded tonal musical material works consistently across both working and long-term memory. However, with *MK*, the zygonicity scores relating to pitch, which are strongest at the bottom of the texture and weakest at the top, more closely resemble Derek's approach to chordal perception (see Fig. 6.21), suggesting that his tendency to hear harmonies structurally, from the root up, was fully engaged as he strove to make sense of what he heard in a "vertical" rather than a "horizontal" way. This interpretation is supported by the very weak scores he achieved in relation to rhythm, indicating that he did not code lines horizontally, in relation to time. In this domain, he is most successful at reproducing the melody and least in recalling the bassline. It seems that the more attention he paid to pitch the less he was able to devote to relative inter-onset intervals and durations.

Derek's recall of *MK* and *KM* as a whole

In each case, having completed the trials pertaining to individual segments, Derek attempted to play *MK* and *KM* as a whole, having heard the piece or section in question right through. This procedure was repeated immediately. The results are shown in Fig. 9.9.

It is evident that Derek was overwhelmed by the task of trying to remember *MK*. As the transcription shows, his first attempt was remarkably brief, and was virtually identical to his response

Table 9.2 ZYG values pertaining to Derek's recall of *Magic Kaleidoscope* (*MK*) and *Kooky Minuet* (*KM*)

Derivation indices for Derek's recall of *MK*, trial by trial and segment by segment

	Segment 1			*Segment 2*			*Segment 3*			*Segment 4*			*Segment 5*		
	R	P	Global	R	P	Global	R	P	Global	R	P	Global	R	P	Global
							Trial 1								
Top	0.56	0.25	0.41	0.75	1.00	0.88	0.50	1.00	0.75	0.00	1.00	0.50	0.64	0.29	0.46
Inner	0.22	0.28	0.25	0.15	0.40	0.28	0.33	0.67	0.50	0.44	0.88	0.66	0.00	0.75	0.38
Bass	0.00	1.00	0.50	0.50	1.00	0.75	0.50	1.00	0.75	0.00	0.33	0.17	0.00	1.00	0.50
Total	**0.34**	**0.34**	**0.34**	**0.27**	**0.54**	**0.40**	**0.38**	**0.75**	**0.56**	**0.27**	**0.77**	**0.52**	**0.35**	**0.54**	**0.44**
							Trial 2								
Top	0.50	0.44	0.47	0.75	1.00	0.88	0.50	1.00	0.75	0.00	1.00	0.50	0.64	0.29	0.46
Inner	0.22	0.33	0.28	0.15	0.40	0.28	0.50	0.78	0.64	0.31	0.75	0.53	0.00	0.75	0.38
Bass	0.00	0.33	0.17	0.50	1.00	0.75	0.50	1.00	0.75	0.17	0.33	0.25	0.00	1.00	0.50
Total	**0.31**	**0.38**	**0.35**	**0.27**	**0.54**	**0.40**	**0.50**	**0.83**	**0.67**	**0.23**	**0.69**	**0.46**	**0.35**	**0.54**	**0.44**
							Trial 3								
Top	0.35	0.40	0.38	0.75	1.00	0.88	0.50	1.00	0.75	0.00	1.00	0.50	0.64	0.29	0.46
Inner	0.13	0.38	0.25	0.15	0.50	0.33	0.38	0.75	0.56	0.56	0.88	0.72	0.00	0.75	0.38
Bass	0.00	0.50	0.25	0.50	1.00	0.75	0.50	1.00	0.75	0.17	0.67	0.42	0.00	1.00	0.50
Total	**0.23**	**0.40**	**0.31**	**0.27**	**0.62**	**0.44**	**0.41**	**0.82**	**0.61**	**0.38**	**0.85**	**0.62**	**0.35**	**0.54**	**0.44**
							Trial 4								
Top	0.69	0.38	0.53	0.75	1.00	0.88	0.50	1.00	0.75	0.00	1.00	0.50	0.64	0.36	0.50
Inner	0.17	0.67	0.42	0.56	0.67	0.61	0.44	0.75	0.59	0.50	0.88	0.69	0.00	0.75	0.38
Bass	0.00	0.50	0.25	0.50	1.00	0.75	0.50	1.00	0.75	0.00	0.67	0.33	0.00	1.00	0.50
Total	**0.41**	**0.50**	**0.45**	**0.58**	**0.75**	**0.67**	**0.45**	**0.82**	**0.64**	**0.31**	**0.85**	**0.58**	**0.35**	**0.58**	**0.46**

Means across all segments and trials

Top	0.53	0.52	0.53
Inner	0.29	0.62	0.46
Bass	0.14	0.73	0.43
Total	**0.34**	**0.61**	**0.47**

Derivation indices for Derek's recall of *KM*, trial by trial and segment by segment

	Segment 1			*Segment 2*			*Segment 3*			*Segment 4*			*Segment 5*		
	R	P	Global	R	P	Global	R	P	Global	R	P	Global	R	P	Global
							Trial 1								
Top	0.71	1.00	0.86	0.83	1.00	0.92	0.33	1.00	0.67	0.40	0.80	0.60	0.79	0.71	0.75
Inner	0.29	0.71	0.50	0.88	0.75	0.81	0.50	0.75	0.63	0.00	0.75	0.38	0.60	0.80	0.70
Bass	0.67	0.67	0.67	0.88	1.00	0.94	0.63	1.00	0.81	0.38	1.00	0.75	0.50	0.50	0.50
Total	**0.56**	**0.79**	**0.68**	**0.86**	**0.91**	**0.89**	**0.50**	**0.91**	**0.70**	**0.38**	**0.85**	**0.62**	**0.68**	**0.71**	**0.70**
							Trial 2								
Top	0.71	1.00	0.86	0.83	1.00	0.92	0.83	1.00	0.92	0.30	0.80	0.55	0.79	0.71	0.75
Inner	0.29	0.43	0.36	0.63	0.50	0.56	0.50	0.75	0.63	0.38	0.75	0.56	0.60	0.80	0.70
Bass	0.67	0.67	0.67	0.63	0.75	0.69	0.63	1.00	0.81	0.50	1.00	0.75	0.50	1.00	0.75
Total	**0.53**	**0.71**	**0.62**	**0.68**	**0.73**	**0.70**	**0.50**	**0.91**	**0.77**	**0.38**	**0.85**	**0.62**	**0.68**	**0.79**	**0.73**
							Trial 3								
Top	0.71	1.00	0.86	0.83	1.00	0.92	0.83	1.00	0.92	0.20	0.80	0.50	0.79	0.79	0.79
Inner	0.29	0.43	0.36	0.88	1.00	0.94	0.50	0.75	0.63	0.38	0.75	0.56	0.60	0.60	0.60
Bass	0.67	0.67	0.67	0.88	1.00	0.94	0.63	1.00	0.81	0.63	1.00	0.81	0.50	0.50	0.50
Total	**0.53**	**0.71**	**0.62**	**0.86**	**1.00**	**0.93**	**0.64**	**0.91**	**0.77**	**0.38**	**0.85**	**0.62**	**0.68**	**0.68**	**0.68**
							Trial 4								
Top	0.71	1.00	0.86	0.83	1.00	0.92	0.83	1.00	0.92	0.20	0.80	0.50	0.79	0.79	0.79
Inner	0.25	0.38	0.31	0.88	1.00	0.94	0.50	0.75	0.63	0.38	0.75	0.56	0.60	0.60	0.60
Bass	0.67	0.67	0.67	0.88	1.00	0.94	0.63	1.00	0.81	0.63	1.00	0.81	0.50	0.50	0.50
Total	**0.50**	**0.67**	**0.58**	**0.86**	**1.00**	**0.93**	**0.64**	**0.91**	**0.77**	**0.38**	**0.85**	**0.62**	**0.68**	**0.68**	**0.68**

Means across all segments and trials

Top	0.66	0.89	0.78
Inner	0.47	0.66	0.57
Bass	0.64	0.88	0.76
Total	**0.60**	**0.83**	**0.70**

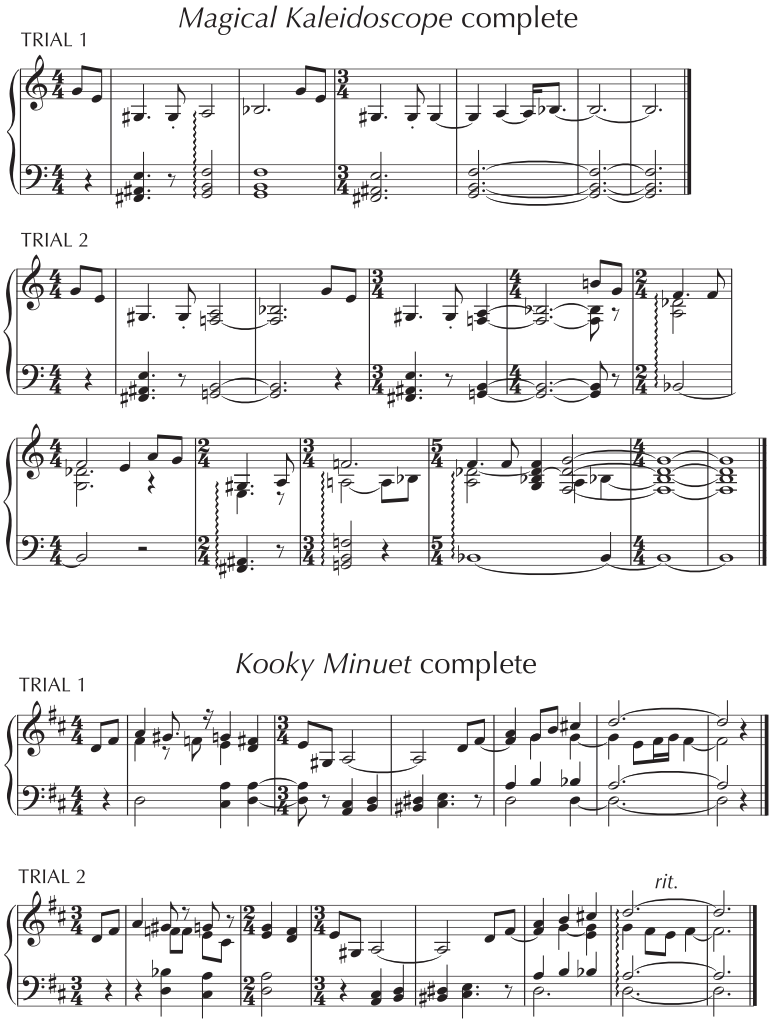



Fig. 9.9 Derek's recall of *Magical Kaleidoscope* and *Kooky Minuet*, complete.

to Segment 5, repeated. As a result, the level of derivation from *MK* as a whole is almost immeasurably low—estimated at ZYG = 0.08 (with ZYG(R) = 0.05 and ZYG(P) = 0.11). At his second attempt, Derek started in the same way (with his version of Segment 5, repeated), before moving on, in bars 5 and 6, to material that most closely resembles features of Segment 1. This was followed, in bars 7 and 8, by a further rendition of Segment 5, then, in conclusion, elements from the end of Segment 1. Hence, his account of *MK* was in the form A_1 A_2 B_1 A_3 B_2. So, again, there is little resemblance to the original in terms of global structure or detail, with an estimated ZYG of 0.17, with ZYG(R) = 0.11 and ZYG(P) = 0.23. It appears that the effect of atonality over time had a cumulatively negative impact on cognitive processing, with a catastrophic effect on memory.

Derek fared considerably better in relation to *KM*, which has a global zygonicity value of 0.44 at the first attempt (ZYG(R) = 0.39 and ZYG(P) = 0.49) and 0.42 at the second (ZYG(R) = 0.36 and ZYG(P) = 0.48). As these figures suggest, Derek's responses shared many similarities, with the

second deriving from the first with ZYG = 0.88 (ZYG(R) = 0.84 and ZYG(P) = 0.92). In both cases, the reproductions of Segments 1 and 5 were similar to those in the previous, individual trials, and Derek's main error was in conflating the three central segments (2, 3, and 4), which, in the stimulus, resemble each other closely. Hence, structurally, his account of *KM* can be represented as A_1 B_1 A_2. Note that if his single response to Segments 2, 3, and 4 is considered as a valid rendition of each, then the global ZYG values of his two attempts at *KM* rise to 0.68 on Trial 1 and 0.66 on Trial 2. These "structurally adjusted" figures show Derek achieving a relative accuracy of recall between four and eight times better than he attained in relation to *MK*. Given the controlled nature of the stimuli, which, as we have seen, were designed so that the tonal and metrical frameworks were the only aspects of structure that varied significantly—and given that, with one exception,[4] Derek's attempts respected the tonal and metrical frameworks—we can surmise that it was these that played a key role in facilitating his cognitive processing, memory, and recall.

Long-term recall—1 week and 1 year later

In order to ascertain what the long-term effects of the presence or absence of tonal and metrical frameworks (or the failure to recognize them) may have on memory, Derek agreed to take part in two further tests, respectively 1 week and 1 year after the learning phase. In the course of other recording sessions, and using the same equipment as previously, he was asked to reproduce whatever he could recall of *MK* and *KM*. Derek had not heard either stimulus in the intervening periods, nor, as far as the researchers could ascertain, had attempted to play them.[5] The results after 1 week are shown in Fig. 9.10.

Derek's version of *MK* after the 7-day break is startling. There is very little of the original material left (with an estimated global ZYG of 0.06). In music-analytical terms, it appears that Derek takes a tonalized and re-metricized version of the opening figure, which retains the notion of an unharmonized anacrusis moving to a discord in the next bar, and improvises on it. In his version, the first phrase is cast as a series of "dominant seventh" chords, which resolve onto one another in various ways in a manner reminiscent of Western late-Romantic harmonic sequences—the style from which Schoenberg's atonality evolved. It is as though Derek takes a stylistic step back to regain his tonal footing. In the course of his extemporization, two prominent atonal harmonies remain from Schoenberg's *MK*: the chord of B♭ minor with an added A that is originally heard at the conclusion of the first phrase in bar 3, and the final chord of G^7 with an added B♭. Derek resolves both these atonal aggregations, enabling them to function as chromatic harmonies: the A in the B♭ minor chord moves down to a G, and forms part of an $E♭^7$ harmony in second inversion (see bar 5 of Derek's rendition), and the B♭ in the G^7 chord moves up to its neighboring B♮ to form a "dominant seventh" chord (upon which Derek's version concludes). The derivation of this version from his previous attempt (ZYG = 0.22) is stronger than from the original stimulus, although a considerable degree of change has occurred nonetheless. It appears that the process of assimilation to tonal and metrical regularity has taken another step in the course of storage in and

[4] The two eighth notes that open bar 3, which Derek evidently hears as an anacrusis—implying a more conventional "harmonic rhythm," in which the dominant on the weak beat is resolved to the tonic on the strong.

[5] As we observed in relation to the *Chromatic Blues* experiment, Derek tends to connect particular pieces with certain people or occasions, and very rarely offers to play music that is outside the context or contexts with which he associates it.

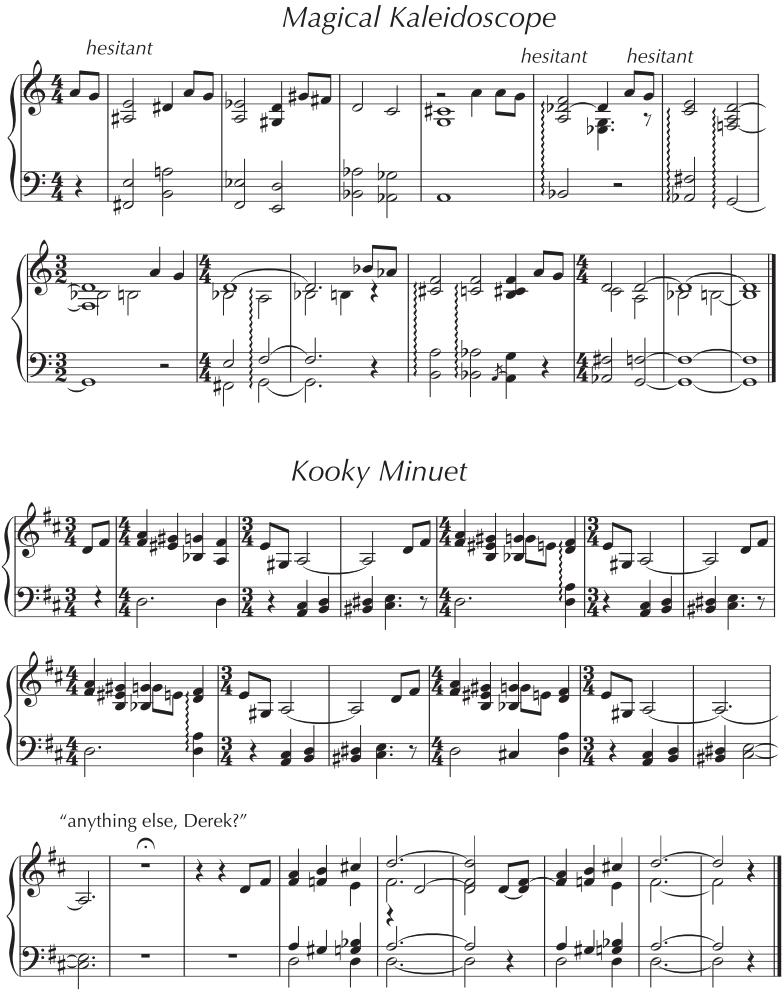



Fig. 9.10 Derek's recall of *Magical Kaleidoscope* and *Kooky Minuet* after 1 week.

retrieval from long-term memory. That is to say, there is evidence that Prediction 2 pertains not only to material being processed in the short term, but in long-term memory too.

In contrast, Derek's version of *KM* 1 week on strongly resembles the original, though his recollection of the global structure is eccentric. He plays his versions of the first two segments four times (A_1 B_1 A_1 B_1 A_1 B_1 A_1 B_1), followed by a period of silence, at which point he was prompted verbally with "anything else, Derek?," whereupon he played his rendition of the final segment twice. In terms of determining the zygonicity values, matching segment for segment yields a ZYG of 0.69 (ZYG(R) = 0.56 and ZYG(P) = 0.83). The ZYG from his previous attempt is 0.82 (ZYG(R) = 0.73 and ZYG(P) = 0.87). Once more the tonal and metrical frameworks of the original are broadly preserved (with the perseveration of the single metrical error noted above). When put alongside the *MK* data, these findings reinforce the hypothesis that the recognition of frameworks in pitch and perceived time, together with their probabilistic patterns of utilization, greatly facilitate the operation of Derek's long-term musical memory.

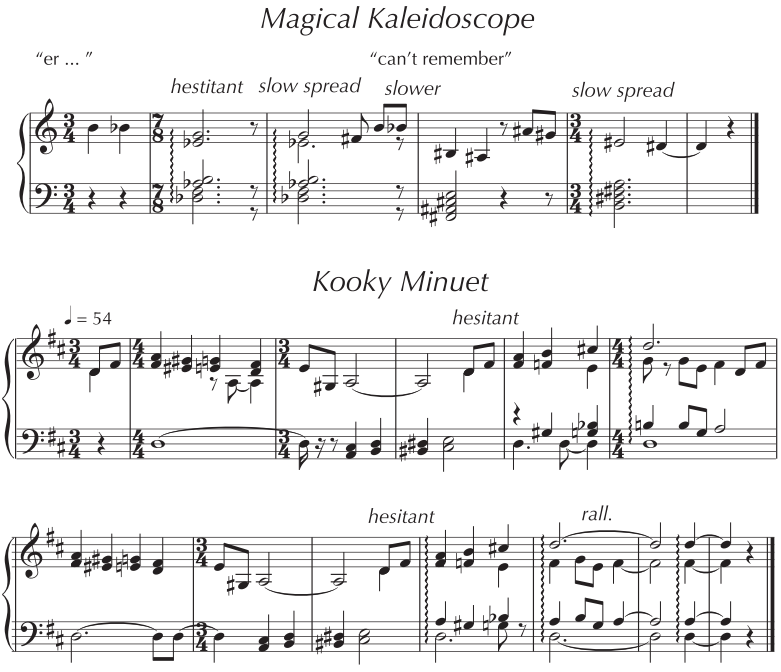



Fig. 9.11 Derek's recall of *Magical Kaleidoscope* and *Kooky Minuet* after 1 year.

Finally, Derek was asked, 1 year later, to play whatever he could remember of the two pieces. The results are shown in Fig. 9.11.

When asked to play *MK*, it is interesting to note that Derek paused and asked to hear the recording first—an unusually explicit indication from him that he did not feel he could recall the piece. Indeed, he articulated his uncertainty again during the course of the attempt, saying "Can't remember" after the first two phrases (although he did subsequently add two more). The transcription shows that, at this stage, the trace of *MK* has almost entirely decayed. All that remains is the opening pattern of a melodic anacrusis moving to a discord on a downbeat (in which the melody note functions as an appoggiatura). As before, Derek improvises on this, producing three versions of the same phrase, though with only a passing resemblance to *MK* proper (ZYG estimated at 0.08). The two atonal chords that were present after a week have now gone, and the only remaining suggestion of atonality is in the opening two notes (which appear to be taken from Derek's original responses in Trials 2, 3, and 4 to Segment 1)—although these are resolved with reference to the higher discord that follows ($D\flat^7$ with an added 9th and raised 11th)—and the F♯ that follows after a hesitation (in bar 3). This is left hanging awkwardly, out of line with an otherwise tonal framework. Metrically, Derek's hesitations make it difficult to discern any underlying regularity, and the overall effect is of temporal fragmentation. So there is evidence here of Predictions 1 and 2 working in the context of long-term memory: Derek seeks to impose tonal order on the fragment of *MK* that he can recall, but, seemingly aware that this is not the "right answer," he introduces a pitch (F♯) that he is aware lies outside the tonal system, in order to recreate something of the original effect of the Schoenberg. Meanwhile, and partly it appears as a consequence of his doubts pertaining to pitch, there are asystematic patterns of error in the domain of perceived time.

KM produces a very different result, however, which is now in the form $A_1\ B_1\ A_2\ A_1\ B_1\ A_2$. This has a structurally corrected global ZYG of 0.66 from the original, and 0.80 from his last attempt. That is to say, Derek's memory of *KM* seems hardly to have shifted in the course of 12 months. Again, given the structural equivalence of *KM* and *MK*, this provides further evidence that the presence of recognizable tonal and metrical frameworks is important to the successful functioning of Derek's musical memory.

So, in summary, the experiment with Derek supported the earlier anecdotal observation that, if the *probabilistic* way in which pitch frameworks are used to create a sense of "tonality" is destroyed, then his ability to process musical content and structure pertaining to individual notes and groups is seriously impaired too. We can further hypothesize that, for him, the probabilistic utilization of pitch frameworks facilitates cognitive encoding that is both rich yet parsimonious. The data presented here suggest, moreover, that comparable phenomena are at work in the domain of perceived time—in relation to *metrical* frameworks. And Derek's efforts at recalling music immediately, after a week, and then a year point to similar principles operating with respect to both working and long-term memory.

Of course, while these findings have intrinsic value—not least to those such as me who seek to support Derek in learning new repertoire—of more general interest is the extent to which they may be more broadly applicable. That is: what do the results suggest, if anything, about how neurotypical listeners process atonal pieces? It could be argued that to seek to generalize from Derek's research data would be inappropriate, since, as a savant, he is by definition an "atypical" musician; his acute sense of absolute pitch alone, for example, reported in Chapter 6, sets him apart from the great majority of other listeners. There is, however, evidence that militates against this view, one source of which is to be found in the precedents of other researchers having previously used savant data to consider the nature of neurotypical human abilities—to test issues of modularity in intelligence, for instance (see, for example, Smith and Tsimpli, 1995). Indeed, in their 1985 article, Sloboda *et al*. claim that Noel Patterson's cognitive architecture resembles that of a "typical" expert memorizer, and infer that even a moderate level of general intelligence is not necessary for the advanced development of certain musical skills (Sloboda *et al*., 1995, p. 166). That is to say, their findings both *contextualize* the specific in the general and use the specific to *inform our understanding* of the general.

A second source of evidence for the validity of generalizing from Derek's data lies in the fact that other musicians frequently learn and practice pieces alongside him, and engage with him in sophisticated improvisations, implying a commonality in the way that they and he are processing music. Arguably, then, Derek functions like most other people as a *listener* (a "super listener," perhaps, given his ability to recognize pitches and disaggregate chords) in that his musical understanding is implicit rather than explicit, perceptual rather than conceptual, intuitive rather than intellectual (see p. 7). However, where he differs from the vast majority is in his capacity to *reproduce what he hears* on the keyboard—entire, complex musical textures that amount to far more than the short vocal fragments that are all most people can manage to replicate (though even this capacity is far more limited than one may imagine; see Sloboda, 1985/2004). Inevitably then, most empirical work in the musical domain relies on indirect evidence obtained through verbal or other responses, whereas Derek offers us a privileged window direct into his musical mind, and perhaps into "the musical mind" more generally. He is by all accounts an ideal candidate for applied musicological research.

So let us consider how the findings pertaining to Derek's efforts at recall potentially illuminate the cognitive processing that may occur in most people in relation to atonal music. Anecdotally, listeners complain that atonal pieces sound "discordant" or "wrong" and that they are difficult

to remember (cf. Bernstein, 1976, p. 273; Rochberg, 2004, p. 95). Both these observations accord with Derek's attempts to reproduce *MK*, in that he "corrected" notes that were outside a traditional diatonic framework and found it difficult to remember the music in the short term—and impossible over extended periods of time. Does this mean that "typical" listeners are adopting strategies in line with Prediction 2: attempting to make sense of the music by imposing familiar frameworks (and hearing values outside these are "errors")? And does Prediction 1 hold true for them: that through failing to encode material parsimoniously they are unable to store or retrieve it? Both possibilities seem likely, although empirical verification would be difficult: limited evidence could be gained through vocal reproduction tasks or through using recognition paradigms, both areas of potential future research.

Finally, what, if anything, could composers glean from Derek's results? Is atonal music ever likely to succeed in attracting broadly based, non-specialist audiences who are not prepared or able to listen to music in other than in a non-conceptual (non-musicological) way? The answer must surely lie in providing alternative or supplementary structures that can be grasped quickly and intuitively: in Lerdahl's (1988) terms, to provide them with an accessible listening grammar. As Bartók (1920/1976, p. 458) writes: ". . . atonal music does not exclude certain exterior means of arrangement, certain repetitions (in a different position, with changes, and so forth), . . . refrain-like appearances of certain ideas, or the return to the starting point at the end." That is to say, if structure pertaining to tonal frameworks is absent, then other forms of organization will be required to make the music generally comprehensible, memorable, and, ultimately, enjoyable.

Two studies in the perception of serial music: the impact of "antistructure" and tonal flecks

I posited the notion of "antistructure" around 20 years ago, in my doctoral thesis, which set out the elements of zygonic theory fully for the first time (Ockelford, 1993). My assertion was this: just as a given musical event has the quality of being what it *is*, since in perceptual terms the event comprises a set of features that can exist in a number of potential states, it also has the quality of being what it *is not*. I postulated that this quality of *not being* may also be imitated, thereby forming antistructure (Ockelford, 1993, p. 101). This is not the *absence* of structure, but rather its *obverse*.

Straightforward examples in Western classical music, are to be found in the domain of timbre, in those concerti where composers have consciously omitted the soloist's sound from the main body of players. For instance, Richard Strauss's oboe concerto (1945) uses a small orchestra of two flutes, cor anglais, two clarinets in B♭, two bassoons, two horns in F, violins, violas, cellos, and basses. In the context of the concerto, the tone colors of these instruments are united in sharing the quality of *not being* an oboe. Hence they are linked *anti*structurally. This notion is represented schematically in Fig. 9.12, using a reversed "Z" to symbolize relationships that are antizygonic (cf. Ockelford, 1993, p. 49).

According to my analysis (Ockelford, 2005a), an example of antistructure in the domain of pitch occurs in the first of Schoenberg's *Drei Klavierstücke*, Op. 11 (used in the atonal experiment with Derek cited above). In the opening section ("Mäßige", bars 1–11), all pitch-classes are used except E♭. However, this value is particularly prominent in the first melodic gesture of the section that follows ("viel schneller", bars 12ff.), forming the lowest note in the texture up to that point, and providing the springboard from which a new, rapidly ascending, arpeggiated figure is launched. Arguably, then, this first appearance of the E♭ pitch-class adds to the sense that "here is something different" (see Fig. 9.13).

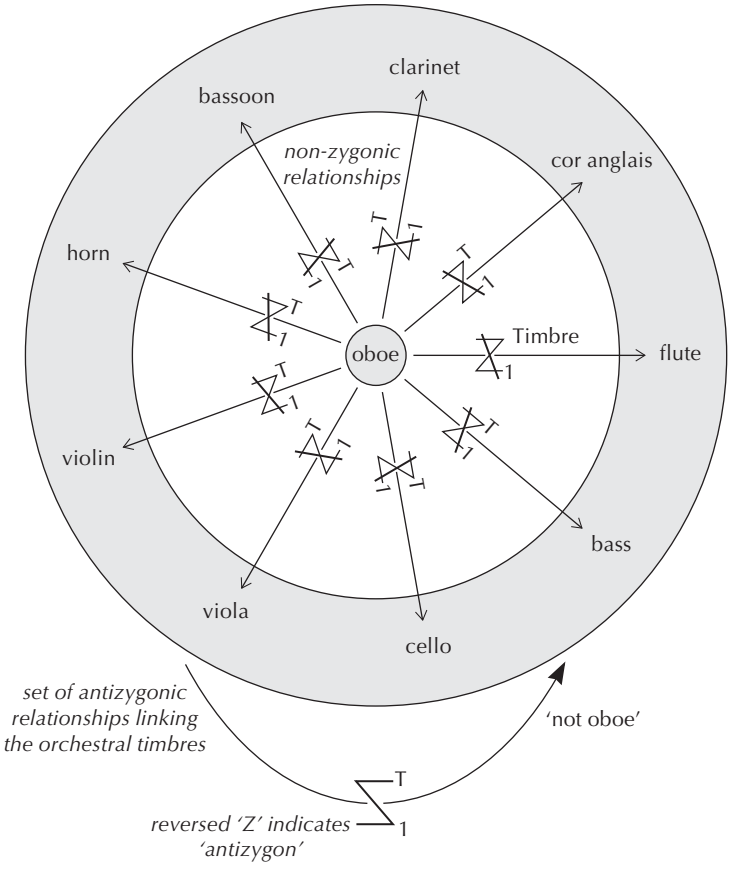


Fig. 9.12 Example of antistructure in the domain of timbre in Strauss's oboe concerto.

For music *theorists*, propositions such as these are, at least in principle, unproblematic. They would consider it reasonable to argue that the reading of the first *Klavierstück* shown in Fig. 9.13 may act as an "ear-opener" (Dubiel, 1999, p. 274), pointing listeners towards an antistructural feature (that is, pitch-classes in the first section sharing the quality of *not* being E♭) that subsequently assumes structural significance in Section 2 (through an E♭ in the second octave being repeated in the bass). That is, the antistructure is forms part of a listening grammar that specialists may appreciate (see p. 403).

For music *psychologists,* however, concerned more with "typical" listeners (rather than individuals with a high degree of expertise or score-specific knowledge; see, for example, Margulis, 2005b, pp. 334, 335), the value of observations like these is less clear. For them, the significant issue is likely to be whether the identified antistructure has any perceptual (albeit non-conscious) reality. The challenges of testing conjectures of this kind empirically lie at the heart of the study reported here, and are considered in some detail later.

There is a third perspective that *musicologists* may wish to take into account: that of the composer. What were Schoenberg's intentions in relation to this aspect of the piece? While there is no documentary evidence that he fashioned Op. 11, No. 1 with the initial omission of the E♭ in

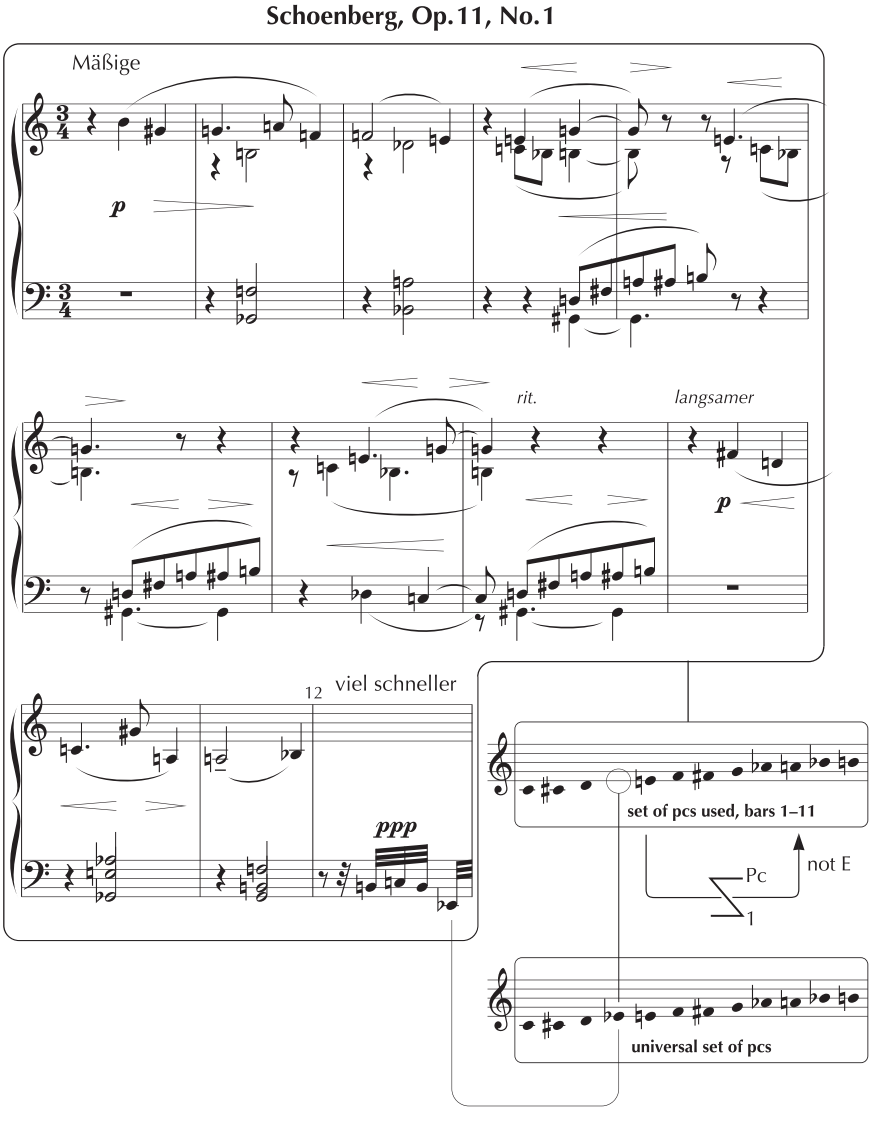



Fig. 9.13 Antistructure postulated to operate in the domain of pitch in Schoenberg's first *Klavierstück*, Op. 11.

mind, it may have been a feature of his thinking, though the antistructural procedure identified here arguably foreshadows the principle of avoiding of pitch-class recurrence that characterized the composer's subsequent "serial" writing (Schoenberg, 1948/1975, p. 247).

In summary, then, though the ontological status of the antistructure identified in the first *Klavierstück* is unclear (see Fig. 9.14), it is also non-contentious: my analysis (Ockelford, 2005a) highlights a feature that makes no general claim to be part of listeners' conceptual awareness (though it could conceivably exert a subliminal effect).

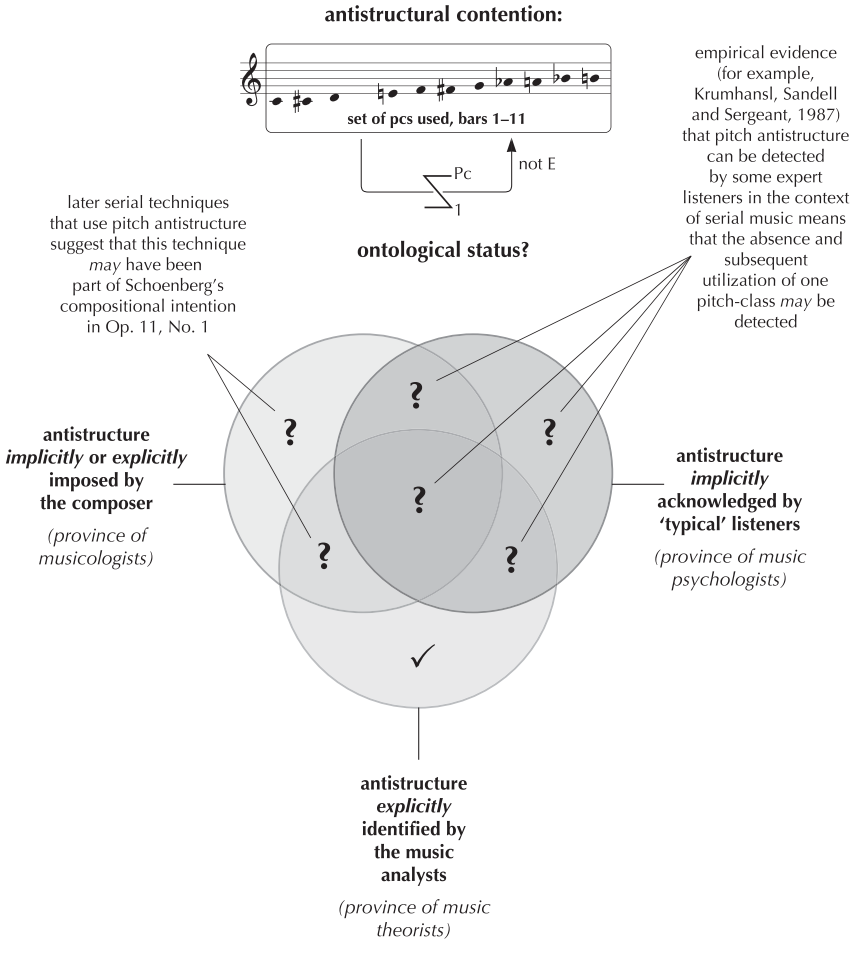


Fig. 9.14 The ontological status of the pitch-class antistructure postulated to exist in the opening section of Schoenberg's Op. 11, No. 1.

However, there are other instances of antistructure whose ontological status is a matter of some debate; for example, the property of tone rows that no pitch-class may be repeated until all 12 have been presented. Schoenberg's position is this (1948/1975, p. 246):

> The construction of a basic set of twelve tones derives from the intention to postpone the repetition of every tone as long as possible . . . [since] the emphasis given to a tone by a premature repetition is capable of heightening it to the rank of a tonic. But the regular application of a set of twelve tones emphasises all the other tones in the same manner, thus depriving one single tone of the privilege of supremacy.

From the *composer's* point of view, zygonic analysis shows how this antistructural rule unfolds as a row is (re)created (Fig. 9.15). There is a further implication in Schoenberg's remarks: that, by having a sequence of musical events that advances antistructurally—through avoiding the reiteration of any pitch-class—the impression of tonal hierarchy is avoided. As we shall see, though, this

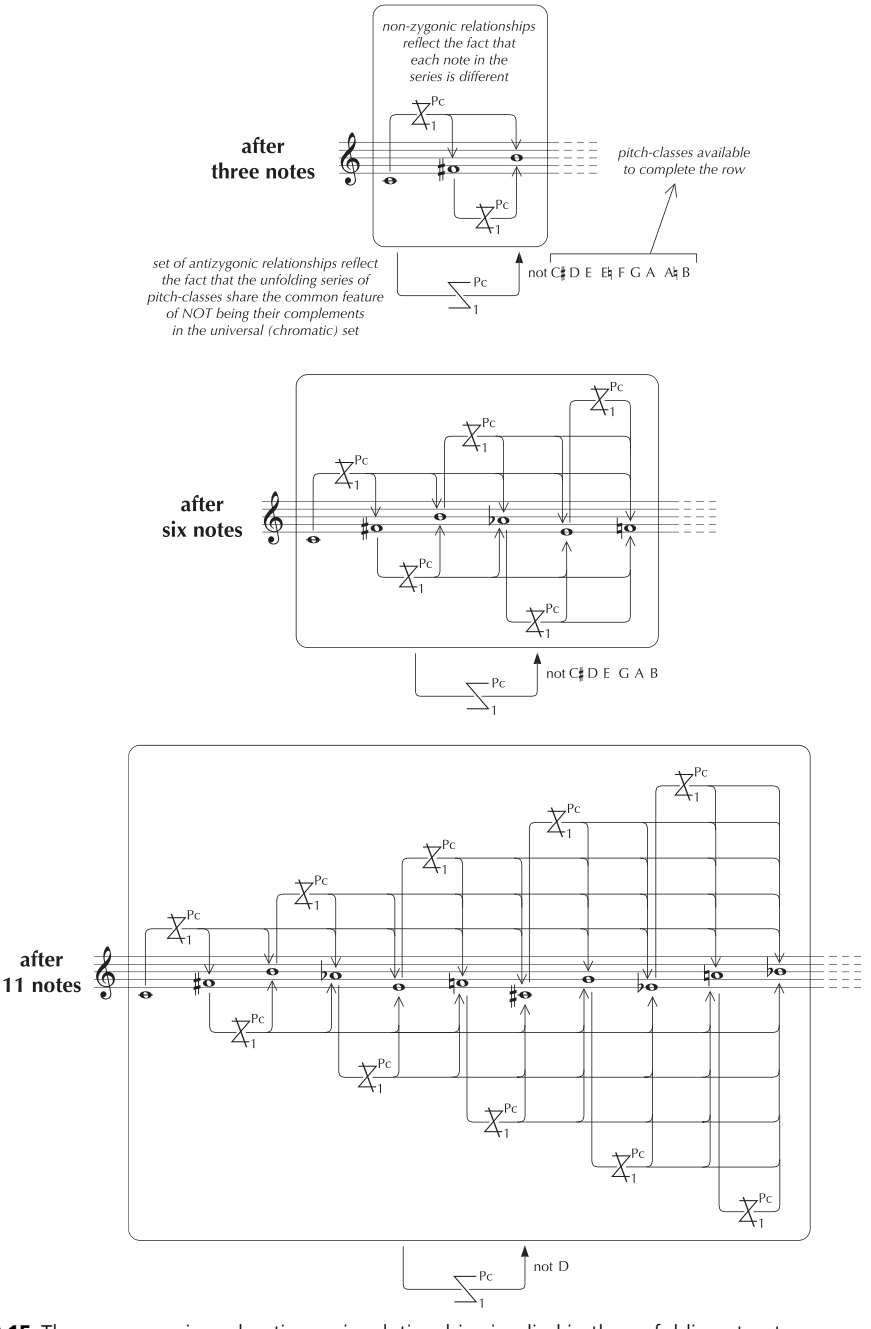


Fig. 9.15 The non-zygonic and antizygonic relationships implied in the unfolding structure of a 12-tone row.

is not actually the case: the repetition of notes is neither necessary nor sufficient for the tonally encultured ear to assign a series of pitches to a probabilistically weighted intervallic framework.

The verity of such assumptions aside, there can be little doubt that Schoenberg intended the compositional principles encapsulated in serialism to be detected by listeners; for example, two decades after the appearance of his first serial compositions, he endorsed the possibility of digression from the sequential order of a 12-tone series "in the later part of a work, *when the set had already become familiar to the ear*" (italics added; Schoenberg, 1941/1975, p. 226). His view of just what type of people such listeners were likely to be seemed to vary, however. For instance, in 1947, he wrote to the conductor Hans Rosbaud that an understanding of his music "*still* goes on suffering from the fact that the musicians do not regard me as a normal, common-or-garden composer . . . but as a modern dissonant twelve-note experimenter." However, "there is nothing I long for more intensely . . . than to be taken for a better sort of Tchaikovsky—for heaven's sake: a bit better, but really that's all. Or if anything more, then that people should know my tunes and whistle them" (Schoenberg, 1947/1987, p. 243). As we have seen, though (p. 405), on another occasion, he had said that his art could only be appreciated by an elite (Schoenberg, 1946/1975, p. 124).

Still, the principles of serialism were taken up—in distinctive ways—by a number of other composers, including Alban Berg, Anton Webern, Ernst Krenek, Luigi Dallapiccola, Luigi Nono, Roger Sessions, Milton Babbitt, Olivier Messiaen, Igor Stravinsky, Karlheinz Stockhausen, and Pierre Boulez. And, as we have seen (p. 406), through the work of academics such as Allen Forte (1973), Schoenberg's ideas gave rise to a new branch of music theory ("set-theoretical analysis"), whose initial aim was to describe and explain the pitch structures of atonal music (Dunsby, 1998). This mathematical approach borrowed several propositions from serialist thinking, and included the notion of "complementarity" (the idea that a privileged relationship exists between those pitch-classes present in a given set and those that are *not* members), which, in terms of the thinking presented in this book, offers a compelling instantiation of the antistructural principle.

In the late 1950s, Robert Francès (1958/1988, pp. 122–7) sought to ascertain whether listeners could continue to identify a series when it was subject to the isomorphic transformations characteristic of the 12-tone approach (inversion, retrogression, and retrograde inversion; see Schoenberg, 1941/1975, p. 225). His findings were clear, that "serial unity lies more on the conceptual than on the perceptual level," and that "when thwarted by melodic motion, rhythm, and the harmonic grouping of tones, it remains very difficult to hear" (Francès, 1958/1988, pp. 126, 127). That is, in Lerdahl's terms (1988, pp. 233–7), serialism constitutes an "artificial" compositional grammar rather than a "natural" one, which listeners of a shared culture can intuitively comprehend. Or, to extend the set analogy presented in Fig. 9.15, the connection between the *explicit* structures consciously imposed by composers and deciphered by analysts with the assistance of visual resources (scores), and the *implicit* musical organization that mere auditory exposure enables listeners to grasp, is fragile.

Other studies followed, including those by Christiaan de Lannoy (1972), which explored the detection and discrimination of dodecaphonic series, Cheryl Bruner (1984), which tested the perceptual reality of Robert Morris's (1979–1980) similarity index of pitch-class sets, and Don Gibson (1993), which examined the effects of pitch and pitch-class content on the aural perception of dissimilarity in complementary hexachords. None of these enquiries found that listeners—even those with a high level of music education—had the capacity to hear the theoretical structures concerned. However, an investigation by Krumhansl *et al.* (1987) *did* find evidence of antistructural perception in 12-tone rows among expert listeners who had received intensive training to become familiar with the materials that were used.

Listeners were exposed to sequences of three, six, nine, or twelve tones from Schoenberg's Op. 26 and Op. 37, and were asked to rate how well a "probe-tone" (Krumhansl and Shepard, 1979; Krumhansl and Kessler, 1982) fitted, "in the musical sense of the atonal idiom, with the series that preceded it" (Krumhansl *et al*., 1987, p. 41). Four experiments were conducted in total. The first used partial or complete statements of the rows in isometric form, presented as series of "Shepard" tones (Shepard, 1964). In the fourth study, the rows' original compositional properties were restored. The second and third tests, which employed the same two (artificial and natural) conditions, were designed to gauge listeners' ability to process row transformations (inversion, retrogression, and retrograde inversion). On the basis of the results that were obtained, the researchers classified their subjects into two groups, which exhibited diametrically opposed patterns of response. Within groups, however, there was strong intersubject agreement, which was taken as further justification of the binary categorization. Information from a questionnaire on musical background showed that the listeners in Group 1 "tended to have more academic training in music and more experience with atonal music, in particular, than Group 2" (Krumhansl *et al*., 1987, p. 49).

Two findings are of particular interest in the current context. First, is the sensitivity of listeners to recency effects—but in opposite ways. Group 1's probe-tone ratings favored pitch-classes that were *not* present in the stimulus, with particularly *low* ratings being assigned to those values that had just been heard. In contrast, Group 2's ratings showed a *preference* for the most recently sounded tones that were contextually prominent, through having been sounded more recently, for example. Second, is listeners' sensitivity to the possible tonal implications in the series. For example, Krumhansl *et al*. suggest that the prime form of the row that Schoenberg used in his fourth string quartet has the potential tonal trichords shown in Fig. 9.16. For Group 2, these local key implications had a positive effect on their ratings (albeit a weak one). In Group 1, listeners tended to respond systematically in a manner that may be termed "contra-tonal" (Huron, 1992), in that they preferred tones that were tonally remote from the implied key. That is to say, Group 1 perceived the antistructure implied in 12-tone rows (see Fig. 9.15), in which successive tones are constrained by non-recurrence. But they also seemed to *extend* this principle into the realm of atonality, by preferring continuations that were *other than* confirmatory of a tonal centre. Group 2, on the other hand, "missed the antistructural point" and perceived tonal "solutions" when these were available.

Following his collaboration with Krumhansl and Sandell, Sergeant designed and ran a subsequent series of nine experiments (Sergeant and Ockelford, forthcoming), which again used the probe-tone approach to test the perceptibility of various aspects of Schoenberg's serial techniques further, including the "verticalization" of "horizontal" lines (and vice versa), the notion of

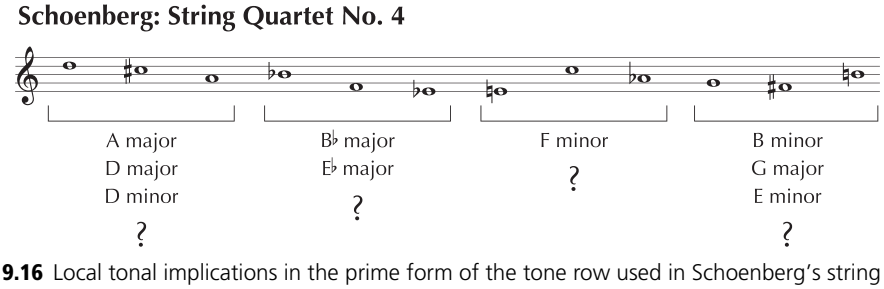


Fig. 9.16 Local tonal implications in the prime form of the tone row used in Schoenberg's string quartet No. 1 (after Krumhansl *et al*., 1987).

"octave equivalence," and the effects of the cyclical rotation of pitch series against repetition of rhythmic features. As well as providing additional evidence of the perceptual challenges that these procedures pose for listeners, the experiments also offer more empirical data that potentially shed light on the apprehension of antistructure—both in relation to the avoidance of pitch repetition ("not R", written "¬R" and the absence of implied tonal function "not T", written "¬T".[6] It is these two effects that are analyzed here.

First we consider the ways in which listeners may have reacted in relation to ¬R and ¬T. In this regard, their expectations "*e*", as gauged via the probe-tone technique, would have derived from the way in which these two elements were cognized "*c*". That is to say, if a listener detected both forms of antistructure in judging which pitch was likely to follow next, and given that "∗" represents an undetermined interrelational function, then:

$$e(\mathrm{S}) \leftarrow c(\neg \mathrm{R} * \neg \mathrm{T}). \tag{9.1}$$

This reads, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition (*c*) of NOT pitch repetition (¬R) and NOT implied tonal function (¬T)." This scenario is not the only possibility, however, as the listeners in Group 2 of Krumhansl *et al.*'s study indicate. Here, expectations were based on repetition "R" and tonal implication "T" as structural forces. That is:

$$e(\mathrm{S}) \leftarrow c(\mathrm{R} * \mathrm{T}). \tag{9.2}$$

This reads, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition (*c*) of pitch repetition (R) and implied tonal function (T)."

Extending this principle, it is theoretically conceivable that a listener may detect antistructure of one type but not another—that is, tonal function but not repetition:

$$e(\mathrm{S}) \leftarrow c(\neg \mathrm{R} * \mathrm{T}) \tag{9.3}$$

or repetition but not tonal function:

$$e(\mathrm{S}) \leftarrow c(\mathrm{R} * \neg \mathrm{T}). \tag{9.4}$$

Hence, given a set of probe-tone data from a 12-tone series, we postulate that

$$e(\mathrm{S}) \leftarrow c[(\neg \mathrm{R} \text{ or } \mathrm{R}) * (\neg \mathrm{T} \text{ or } \mathrm{T})] \tag{9.5}$$

or, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition (*c*) of NOT pitch repetition (¬R) or repetition (R) or NOT implied tonal function (¬T) or tonal function (T)."

But how can we disaggregate the potential influence of the four factors *c*(R), *c*(¬R), *c*(T), and *c*(¬T), since the nature of any interaction between them is unknown? To put it another way: given a set of expectational data pertaining to a series, it would not be possible to assign cause and effect to the separate antistructural elements, as a single outcome may result from different combinations of R, ¬R, T, and ¬T (see, for example, the hypothetical examples shown in Fig. 9.17).

[6] These are taken to be variables in the sense of being logical sets of perceived attributes. They can also be manipulated mathematically and algebraically, as will become apparent.

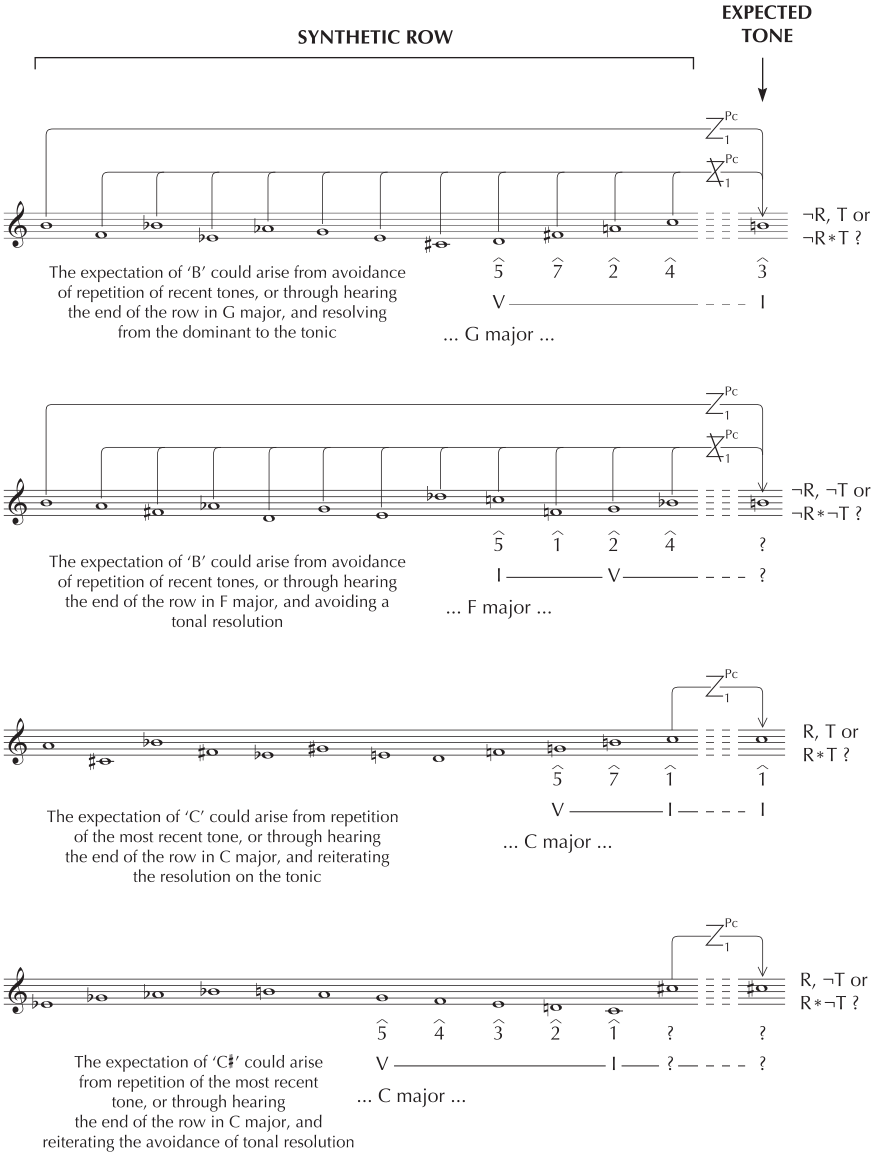


Fig. 9.17 Ambiguity in the structural (R or T) or antistructual (¬R or ¬T) derivation of tones following a 12-tone row.

However, given data from a number of different rows, it may be possible to gauge the distinct impact of R, ¬R, T, and ¬T, since, it is suggested, the avoidance of pitch repetition in some sense represents a "deeper structure" that operates consistently throughout all series, whereas implied tonal functions tend to exist as fleeting and idiosyncratic "surface perturbations." That is to say, as far as expectation is concerned, in relation to each tonal center, there are many different potential "inputs" (means through which a given key can be signaled) that correspond to a range of possible "outputs" (musically logical ways in which the suggested tonality can be reinforced) (see Fig. 9.18).

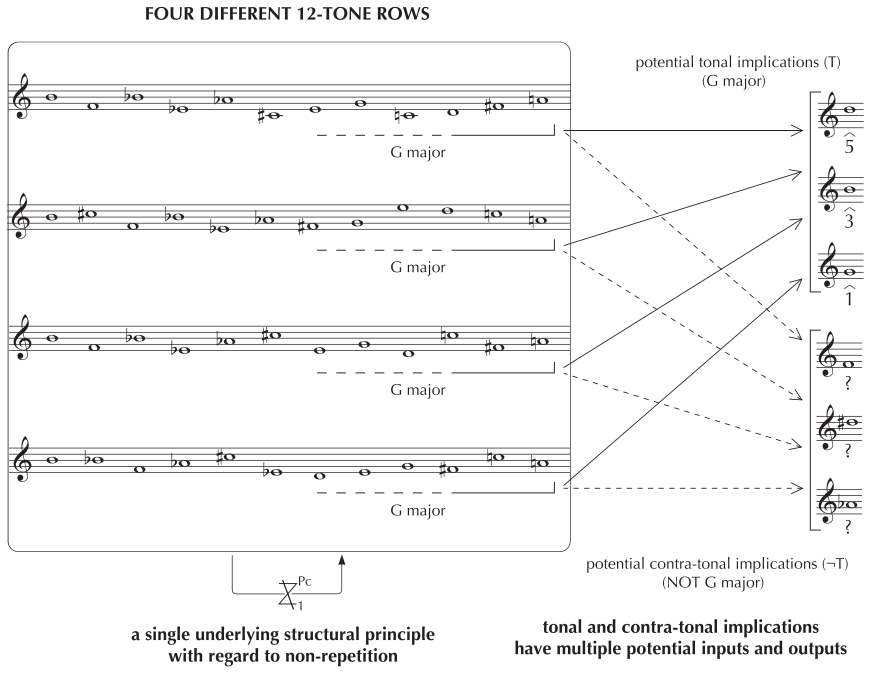


Fig. 9.18 Non-repetition functions as a "deeper" structural principle in 12-tone rows than tonality and non-tonality.

Hence it is axiomatic that, in relation to a number (n) of 12-tone series, the means of ¬R or R (symbolized respectively as $\neg\overline{\mathrm{R}}$ and $\overline{\mathrm{R}}$) will tend to what may be termed "general" values of NOT repetition or repetition ($\neg\mathbb{R}$ or $\mathbb{R}$), whereas the means of ¬T or T (symbolized as $\neg\overline{\mathrm{T}}$ and $\overline{\mathrm{T}}$) will tend to 0. That is:[7]

$$\neg\overline{\mathrm{R}} = \frac{1}{n}\sum_{i=1}^{n}\neg\mathrm{R}_i \rightarrow \neg\mathbb{R} \quad \text{and} \quad \overline{\mathrm{R}} = \frac{1}{n}\sum_{i=1}^{n}\mathrm{R}_i \rightarrow \mathbb{R} \tag{9.6}$$

whereas

$$\neg\overline{\mathrm{T}} = \frac{1}{n}\sum_{i=1}^{n}\neg\mathrm{T}_i \rightarrow 0 \quad \text{and} \quad \overline{\mathrm{T}} = \frac{1}{n}\sum_{i=1}^{n}\mathrm{T}_i \rightarrow 0. \tag{9.7}$$

This implies that expectations (e) occurring in relation to n 12-tone series (S) will tend to the cognition (c) of $\neg\mathbb{R}$ or $\mathbb{R}$ alone:

$$e\,(\mathrm{S}_{1\ldots n}) \leftarrow c(\neg\mathbb{R} \text{ or } \mathbb{R}). \tag{9.8}$$

In order to use this expression to gauge the import of Sergeant's data, it is necessary to make it function predictively, so that comparisons can be drawn between the values forecast by the

[7] By way of explanation, the first of these formulae reads: "the mean of 'NOT R,' which equals the sum of individual values of 'NOT R,' tends to a general value of 'NOT R.' "

model and listeners' actual expectations. If the predicted and actual figures are found to be similar or the same, this could be taken as evidence that the underlying assumptions used to the build the model are correct. Conversely, differences between expected and observed responses would suggest that changes may need to be made (and may indicate the nature of the modifications required). To quantify $e(S_{1\ldots n}) \leftarrow c$ ($\neg\mathbb{R}$ or $\mathbb{R}$), we will adapt the zygonic model of expectation and associated methodology set out in Chapter 8.

While there is a limited amount of evidence (for example, Ortmann, 1926; Huron, 2001b) to indicate that certain refinements to the basic model can improve its predictive capacity in tonal contexts (for example, the fact that exact repetition tends to be used less frequently than intervals of a major or minor second, and the tendency for the octave to arise more often than major or minor sixths and sevenths; see Table 8.3), there are no such empirical data pertaining to expectancies that may function in atonal music. Hence, in the absence of evidence to the contrary, a version of the model that is linear with respect to both adjacency and recency will be used here. With regard to adjacency, given a chromatic intervallic range extending over an octave (up or down) from a given pitch p_{n-1} (a span that suffices to encompass the empirical data reported below), the predicted probability P of a further given pitch p_n being expected to occur can be taken to diminish in a linear fashion in proportion to the size of the interval between pitch p_{n-1} and pitch p_n. Since the sum of the probabilities of all values must equal 1, this can be expressed as follows:

$$P(p_n) = \frac{13 - |p_n - p_{n-1}|}{13 + 2\sum_{i=1}^{12} i} = \frac{13 - |p_n - p_{n-1}|}{13^2} \tag{9.9}$$

where $|p_n - p_{n-1}|$ is the difference in semitones between the two notes concerned. This yields the set of probabilities shown in Table 9.3.

Apropos recency, for the "structural" listener, the predicted probability of an nth pitch, p_n, occurring after $n-1$ events, is given by the equation

$$\begin{aligned} P(p_n) = (n-1)\left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_{n-1}) + (n-2)\left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_{n-2}) \\ + \ldots \left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_1). \end{aligned} \tag{9.10}$$

However, for a listener processing a 12-tone row antistructurally (see Fig. 9.15) this effect is reversed, so that the most recent pitch exerts the least effect, the next most recent more influence, and so on:

$$\begin{aligned} P(p_n) = \left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_{n-1}) + 2\left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_{n-2}) \\ + \ldots (n-1)\left(\sum_{i=1}^{n}(i-1)\right)^{-1} P(p_1). \end{aligned} \tag{9.11}$$

Clearly, an important factor in applying this formula to model cognition is the number of pitches a listener can be assumed to hold in working memory. Although there are currently no

Table 9.3 Anticipated probabilities modeled through adjacency

Interval (semitones)		Predicted probability
12	up/down	0.0059
11	up/down	0.0118
10	up/down	0.0178
9	up/down	0.0237
8	up/down	0.0296
7	up/down	0.0355
6	up/down	0.0414
5	up/down	0.0473
4	up/down	0.0533
3	up/down	0.0592
2	up/down	0.0651
1	up/down	0.0710
0	—	0.0769

relevant empirical data pertaining directly to atonal series of notes, other evidence is available that suggests listeners' capacity for storage and recall in the domain of pitch in the absence of structure (which would have permitted more economical encoding) may be very limited. For example, re-analysis of Diana Deutsch's (1980) findings of listeners' capacity to process sequences of pitches shows an average accuracy of recall of unstructured 12-note sequences (each comprising an average of just five different pitch-classes) of only 52%. And it is important to bear in mind that Deutsch's stimuli were cast within a tonal framework (G major), providing coding cues in terms of scale degree not available from 12-tone rows.

Given this cognitive constraint, it seemed prudent, at least as a first step, to model the antistructure pertaining only to portions of 12-tone series—short enough to be manageable in working memory—and it was decided initially to work with the last six notes of each row (a number that also corresponds to the number of different pitch categories that a listener without absolute pitch can store in working memory; see Miller, 1956, after Pollack, 1952; Krumhansl, 1987, p. 34). It was felt that this figure could in subsequent studies be increased or reduced or left unchanged in the light of the preliminary findings reported next. Anticipated probabilities of probe-tone responses pertaining to notes 7, 8, 9, 10, 11, and 12 were calculated using Formulae (9.9) and (9.11), and are shown in Table 9.4 and Fig. 9.19. The method of utilizing these data is shown Fig. 9.21.

Study 1—the cognition of "antistructure"

Thirteen of the rows were selected from Sergeant's original materials (which he had taken or adapted from the serial repertoire), which fulfilled the following three criteria: that they should be isometric (comprising notes equally spaced in time and of equal duration), contain no octave

Table 9.4 Anticipated probabilities modeled through adjacency + recency = 'interagency'

			'Recency' factor ...					
	Interval (semitones)		Pitch 7 **0.2857**	Pitch 8 **0.2381**	Pitch 9 **0.1905**	Pitch 10 **0.1429**	Pitch 11 **0.0952**	Pitch 12 **0.0476**
'Adjacency' factor ...	12	up/down	0.0017	0.0014	0.0011	0.0008	0.0006	0.0003
	11	up/down	0.0034	0.0028	0.0023	0.0017	0.0011	0.0006
	10	up/down	0.0051	0.0042	0.0034	0.0025	0.0017	0.0008
	9	up/down	0.0068	0.0056	0.0045	0.0034	0.0023	0.0011
	8	up/down	0.0085	0.0070	0.0056	0.0042	0.0028	0.0014
	7	up/down	0.0101	0.0085	0.0068	0.0051	0.0034	0.0017
	6	up/down	0.0118	0.0099	0.0079	0.0059	0.0039	0.0020
	5	up/down	0.0135	0.0113	0.0090	0.0068	0.0045	0.0023
	4	up/down	0.0152	0.0127	0.0101	0.0076	0.0051	0.0025
	3	up/down	0.0169	0.0141	0.0113	0.0085	0.0056	0.0028
	2	up/down	0.0186	0.0155	0.0124	0.0093	0.0062	0.0031
	1	up/down	0.0203	0.0169	0.0135	0.0101	0.0068	0.0034
	0	—	0.0220	0.0183	0.0147	0.0110	0.0073	0.0037

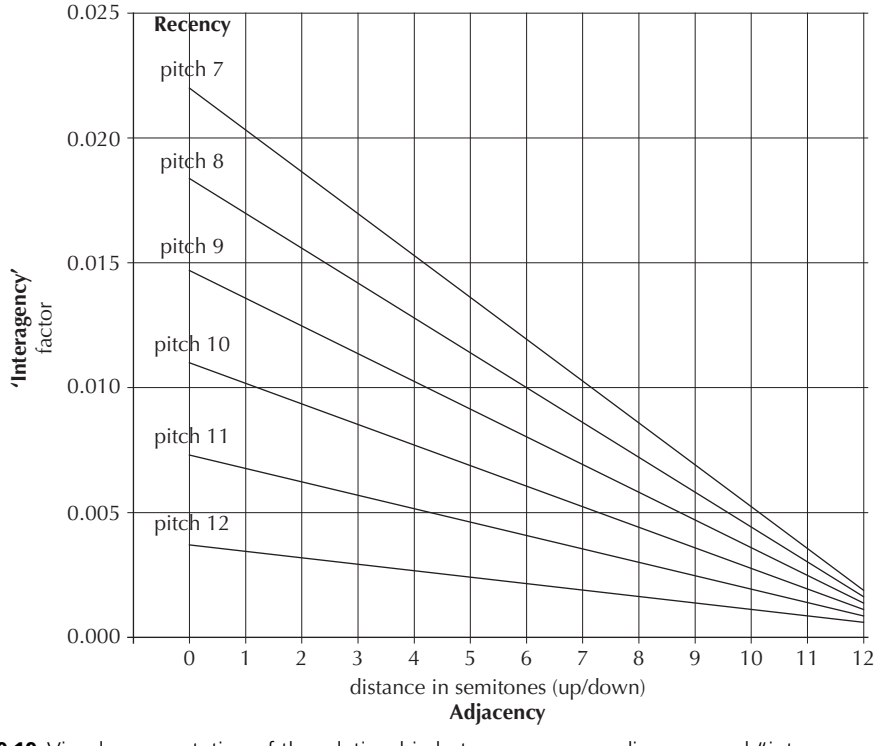


Fig. 9.19 Visual representation of the relationship between recency, adjacency, and "interagency."

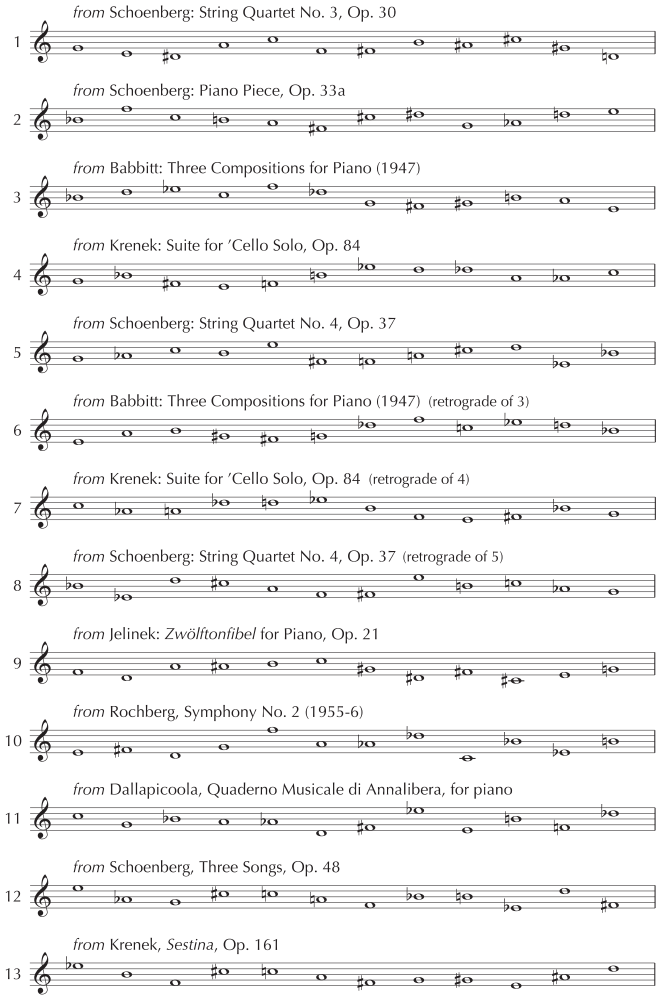



Fig. 9.20 The rows used in Sergeant's study.

displacement, and have no deliberately constructed "tonal" endings (see Fig. 9.20). Sergeant presented the rows to his listeners using a Synclavier synthesizer; tones were 500 ms in duration, with a symmetrical spectral envelope, providing similar rise and decay times. The tones were harmonically rich—each approximating to a quiet diapason pipe sound.

Fourteen musicians participated in Sergeant's study, of whom not less than 12 took part in any one task. All had undertaken advanced musical study, either at a conservatoire or university. They included people who were eminent in their sphere of musical endeavor (for example, principal chairs in established UK orchestras, the conductor of a national choral festival, and a member of a professional string quartet). Some had extended experience of 20th-century music.[8]

[8] Five subjects had AP, although the responses of these listeners did not differ significantly from those of the other musicians.

The study procedure was as follows. Subjects heard a 12-tone context sequence, followed after a 2-second interval by a probe-tone. Probe-tones randomly and exhaustively sampled each of the pitches heard in the context sequence. The task was to rate "how well the probe-tone followed, or blended, with the preceding sequence" using a seven-point scale ranging from 1 (fits poorly) to 7 (fits well). Subjects were given the advice that "some listeners have found it helpful to listen to the whole sequence, then judge how surprising the following probe-tone sounded—a tone that was surprising would have a low rating; one that was unsurprising a high rating." To prevent over-learning, leading to practice effects and listener boredom, series were arranged in blocks of either three or four presentations. Rest intervals were provided after each block of 18 test items.

The probabilities of each of the last six tones in the series occurring again, as predicted (1) through zygonic modeling of antistructure (using Formula 9.11) and (2) through probe-tone responses, are compared in the following tables and graphs. Differences of over 10% are noted for further discussion.

In Fig. 9.21, the method of calculating the predicted probabilities of responses is shown in detail in relation to Row 1. The results are scaled up (by a factor of 65.3) to ensure equality of means, and facilitate comparison with listeners' probe-tone judgments. Figure 9.22 summarizes the remaining findings, in relation to Rows 2–13.

Formula (9.11) provided a means of predicting antistructural cognition through a combination of adjacency and recency effects, while Formula (9.8) expressed the hypothesis that the *means* of expectations would tend to $\neg\mathbb{R}$ or $\mathbb{R}$ alone. Hence the degree to which the mean probe-tone results correlate with the mean predicted results is a measure of the strength with which listeners cognized antistructure in the manner predicted by the zygonic model. The two series of data are shown in Fig. 9.23.

The degree to which the two series of values (observed and predicted) correspond can be assessed statistically in a number of ways, of which two will be used here. One approach is to calculate by how many standard deviations the observed values depart from the mean of the predicted population. The data in Fig. 9.23 show that, in every case, the "*z*-score"[9] for the observed value falls within one standard deviation of the mean of the predicted value, and, with one exception, lie very close to it. Therefore, it is reasonable to argue that the observed values conform to those that are predicted. The second method is to run a multiple regression by treating the mean predicted values as the dependent variable and the observed values for pitches 7–12 of the series as six independent variables. The results are $F(6, 6) = 23.41$, $P < 0.001$, with $R = 0.98$, and $R^2 = 0.96$, showing the model to account for 96% of the total variance, with only 4% remaining unexplained.

But what of the discrepancies pertaining to individual rows? Formulae (9.1) and (9.2) suggest that differences could be ascribable to the impact of tonal or "anti-tonal" cognition. Specifically, with a cognitive approach that recognized and respected the conventions of tonality, one would expect pitches that accorded with the prevailing tonal context to be enhanced in terms of their probe-tone ratings (implying that they would be higher than the zygonic model predicted), while those that were incompatible would be rated lower. Conversely, given a cognitive style functioning *anti*-tonally, one would anticipate that pitches that did not conform to the current tonal frame of reference would receive elevated ratings, in contrast to those that presented a good tonal fit, whose scores would be relatively depressed (see Table 9.5).[10] But, as the same difference between a given

[9] That is, a standard score showing how many standard deviations an observation is above or below the mean.

[10] Observe that the ratings for listeners who disregard potential tonal implications in the series—who approach the task with an "atonal" mind-set—should accord with the model.

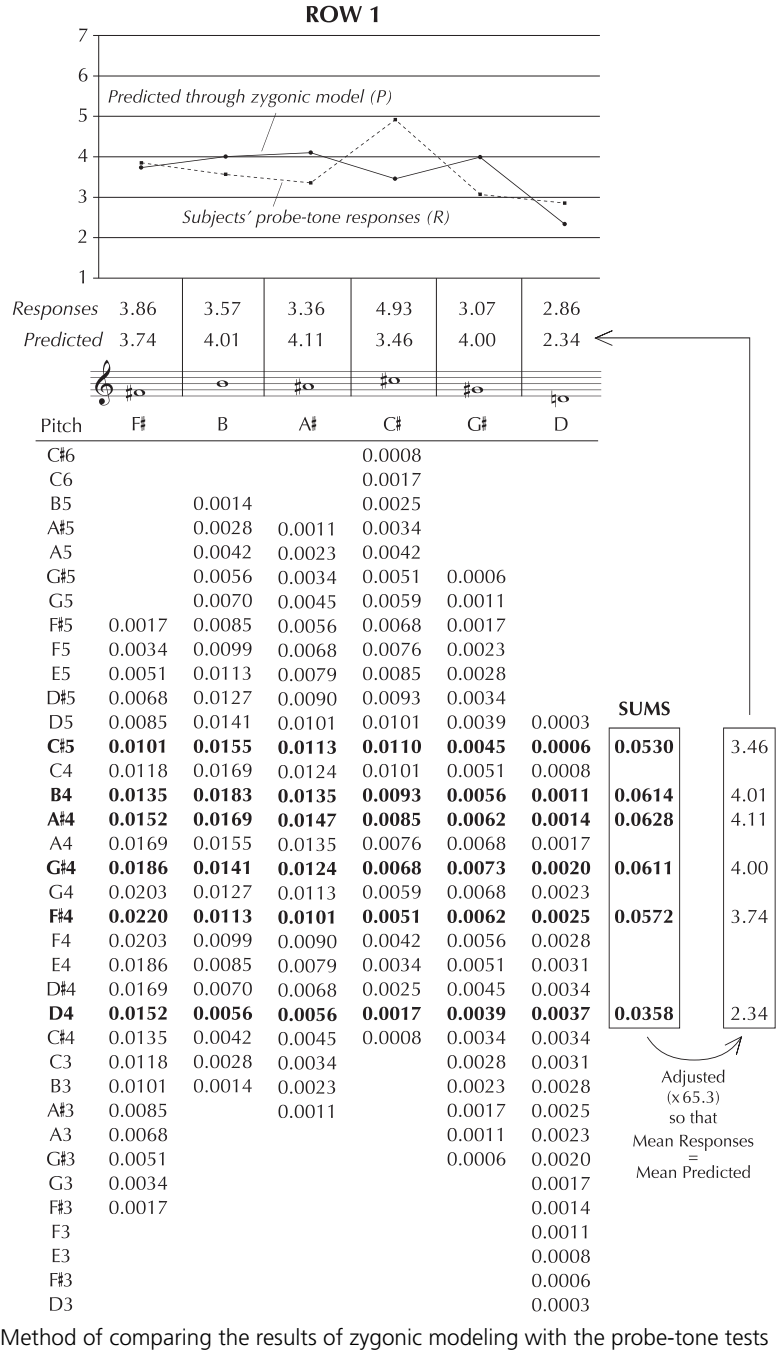


Fig. 9.21 Method of comparing the results of zygonic modeling with the probe-tone tests for the last six notes of Row 1.

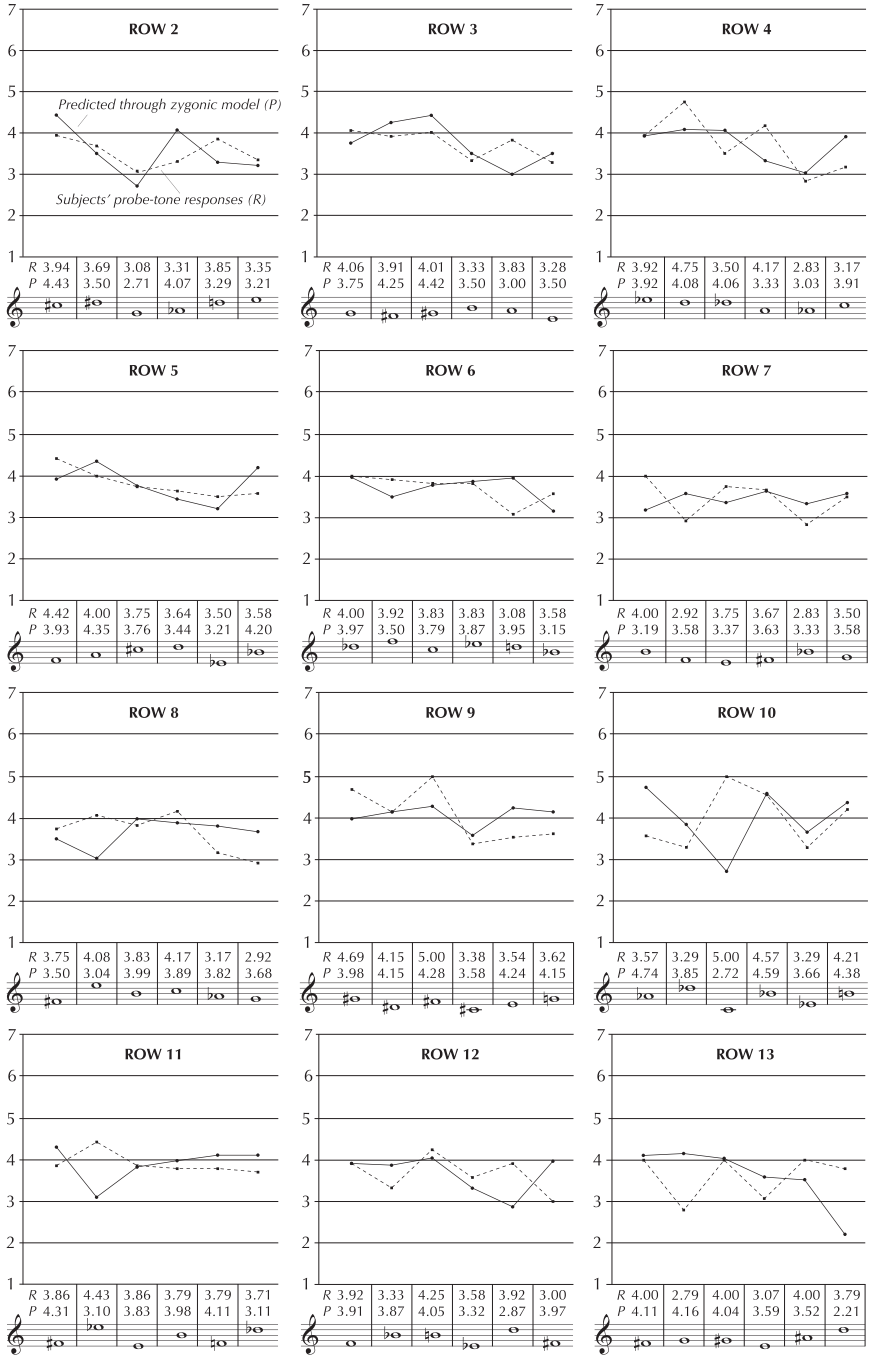
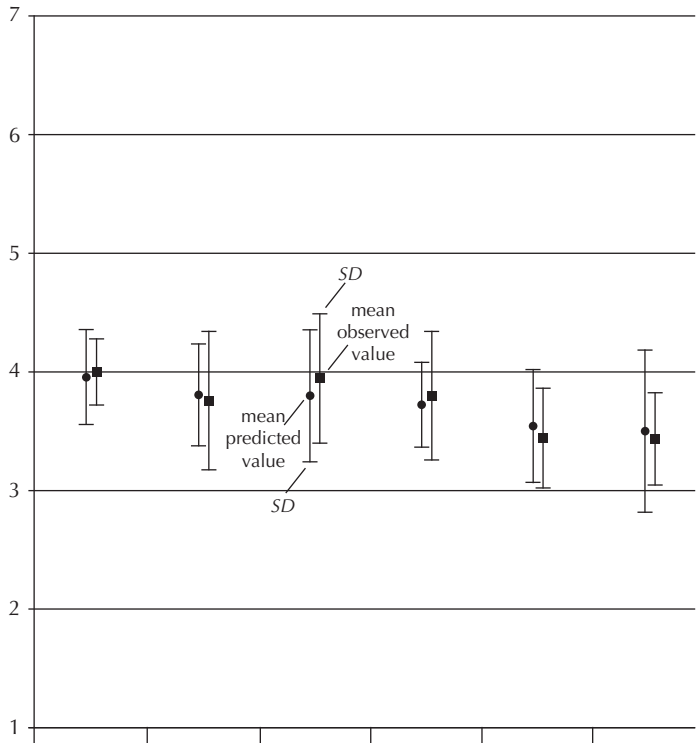


Fig. 9.22 Results from zygonic modeling and the probe-tone tests for Rows 2–13.



position of note in row		7	8	9	10	11	12
observed ■	*mean*	4.00	3.76	3.94	3.80	3.44	3.43
	SD	0.28	0.57	0.56	0.53	0.42	0.38
	z-score	0.10	0.09	0.19	0.25	0.22	0.09
predicted ●	*mean*	3.96	3.80	3.78	3.71	3.54	3.49
	SD	0.40	0.43	0.54	0.36	0.46	0.68

Fig. 9.23 Means and standard deviations of predicted values and observed responses.

Table 9.5 How the differences in responses and modeled ratings relate to 'tonal' and 'anti-tonal' listening strategies

Pitch-class categorized as 'tonal' or 'anti-tonal'	Probe-tone rating higher or lower than modeled	Expected of 'tonal' listening strategy?	Expected of 'anti-tonal' listening strategy?
Tonal ('T')	Higher	Yes	No
Tonal ('T')	Lower	No	Yes
Anti-tonal ('A')	Higher	No	Yes
Anti-tonal ('A')	Lower	Yes	No

probe-tone rating and its corresponding score predicted by the zygonic model could arise from opposing cognitive strategies (see Fig. 9.18) how is one to know which approach the listener was taking, and, therefore, how to analyze the data?

Desmond Sergeant and I devised a second study in an initial attempt to answer this question that was frankly more speculative in nature. Nonetheless it sets out a line of theoretical thinking that may be further developed in the future through a range of empirical work.

Study 2—the cognition of "tonal flecks"

A short series of notes (such as those at the end of a tone row) can be deemed to exist in one of three states with regard to tonality: the fragment may evoke one key, more or less unambiguously; it may suggest two tonal regions or more (although the ear will probably be able to focus on only one at once); or it may induce no impression of tonality at all. In order to get a sense of the tonality perceived to be in play at the ends of Sergeant's rows (the points at which listeners were asked to rate probe-tones), 15 musicians—all advanced performers or experienced teachers, who were familiar with tonal and post-tonal Western classical music and had a good grasp of music theory, but who had not participated as listeners in Sergeant's study—were asked to undertake a further rating task. They were emailed a copy of the second halves of the 13 rows explored in Study 1 (see Fig. 9.24), and asked what key or keys (if any) they heard each of the passages as ending in. They were told to assume enharmonic equivalence if necessary (whereby notes that sound the same within the system of equal temperament can be labeled differently according to tonal function: A♭ and G♯, for example). They were also asked to rate how secure they felt each of their judgments to be, on a scale of 1–10, where 1 was "very unsure" and 10 was "certain". The underlying methodological assumption was that the results would give a reasonable indication of how professional Western musicians in general—including Sergeant's subjects—perceive the (often unintended) interaction between tone rows and the perception of tonality.

The participants appeared to have taken considerable care with the task for which they volunteered: their answers were often supplemented with comments and, in one case, complete harmonizations. The results are summarized in Table 9.6.

As the data show, subjects occasionally gave alternative responses as to the key in which they considered some of the segments to end; commonly two, sometimes three options or more were provided. Segment 8 had most alternatives (six), while Segments 2, 6, 11, and 12 had only one response per listener. The reaction "no recognizable key" was given by six subjects on one to four occasions, amounting to a total of 14 out of the 216 responses, which equates to a little under 6.5%. Segment 2 engendered a sense of atonality most often (four times). Different listeners frequently expressed distinct ideas as to the key in which they thought a segment ended. The smallest number of keys was four (pertaining to Segment 11), and the largest, in the case of Segments 1 and 9, was eight ($M = 6$, $SD = 1.5$). Frequently, choices spanned the "circle of fifths," with contrasting tonalities chosen as "solutions": C major and G♯ minor in the case of Segment 2, for example, and C minor and G♯ minor for Segment 8. The highest number of ratings the same was 12, made in relation to Segment 6, which was felt by the majority of listeners to end in B♭ major; the next highest was 10, which pertained to A major for Segment 3 and G minor for Segment 7. By far the most frequent scenario, however, was for unique judgments to be made (36), with a dual rating occurring 17 times. The confidence scores varied widely from subject to subject, ranging between means of 3 and 10. The segments attracting the lowest average score were 10 and 13 ($M = 6.1$), while the highest pertained to Segment 3 ($M = 7.9$). No correlation was found between confidence ratings and the distribution of tonality judgments.

Table 9.6 Musicians' assessments of the tonality of the 13 tone-row segments used in Study 1

Segment	C major	*A minor*	G major	*E minor*	D major	*B minor*	A major	*F♯ minor*	E major	*C♯ minor*	B major	*G♯ minor*	G♭ major	*E♭ minor*	D♭ major	*B♭ minor*	A♭ major	*F minor*	E♭ major	*C minor*	B♭ major	*G minor*	F major	*D minor*	No sense of key	Categories	Means	Sums	Mean confidence ratings
1	–	–	–	–	1	**4**	–	–	–	2	**5**	1	2	–	–	–	–	–	–	–	–	1	–	1	–	8	2	17	6.9
2	5	1	–	–	–	–	1	–	1	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	4	5	2	15	6.9
3	–	**4**	–	–	1	–	**10**	–	1	–	–	–	–	1	–	–	1	–	–	–	–	–	–	1	–	7	3	19	7.9
4	–	1	–	–	–	–	–	–	1	1	–	–	–	–	4	1	7	–	–	1	–	–	–	–	–	6	2	16	7.1
5	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	–	4	2	–	4	–	5	3	17	6.9
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	**12**	–	–	1	–	3	4	15	7.6
7	–	–	**3**	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**10**	–	–	1	7	4	16	7.0
8	**6**	–	3	2	–	–	–	1	–	–	–	–	–	–	–	–	1	–	1	**6**	–	–	–	–	1	7	3	21	6.2
9	1	–	–	2	4	2	–	–	2	1	–	3	–	–	1	–	–	–	–	–	–	–	–	–	1	8	2	17	7.2
10	–	–	–	–	–	–	–	–	2	2	2	5	–	–	1	–	2	–	–	–	–	–	–	–	2	6	2	16	6.1
11	–	–	–	–	–	2	–	–	–	–	5	–	6	–	1	–	–	–	–	–	–	–	–	–	1	4	4	15	7.4
12	–	–	1	–	–	4	–	–	2	–	4	–	–	–	1	–	–	–	–	–	–	2	–	–	1	6	2	15	6.8
13	2	–	–	–	–	6	–	–	2	–	2	–	–	–	–	1	–	–	–	–	1	–	–	–	3	5	2	17	6.1
																						Means				6	3	17	6.9
																						Sums		14				216	

$N = 15$

What are we to take from these results? First, it appears that fragments of tone rows can appear to emanate "tonal signals" to which musicians are sensitive, and which they are generally reasonably confident in interpreting. Evidently, though, some segments are more tonally ambiguous than others, depending on the clarity with which tonality-defining patterns of intervals are presented. Where there is ambiguity, multiple interpretations are likely to be engendered, sometimes within the same listener. It seems to be rare, however, for *no* key to be discernible.

Where does this leave the aim of being able to distinguish potential tonal from possible anti-tonal listening in Sergeant's probe-tone results? The only segments that are likely to be provide usable data are those that are heard as ending in a particular key with reasonable consistency. A criterion of >50% of ratings pertaining to one key yields 5 of the 13 excerpts: Segment 7 (87% G major/minor),[11] Segment 6 (80% B♭ major), Segment 3 (74% A major/minor), Segment 8 (57% C major/minor), and Segment 1 (53% B major/minor).

Determining the concluding keys of the five segments is an important stage in being able to allocate probe-tone responses to tonal or anti-tonal categories. However, it is not merely a question of assigning notes to the relevant diatonic pitch set, since (1) all 12 pitch-classes can fulfill distinct tonal functions in a given key (hence none could necessarily be excluded on the grounds of being intrinsically "anti-tonal"), and (2) tonality is defined through the different transition patterns with which relative pitches tend to succeed one another (from a listener's point of view, based

[11] Major and minor keys with the same tonic can be regarded as equivalent for the purposes of this essentially cadential analysis, since, in accordance with Western "common practice," minor passages often end in the major through the use of the device known as the *tierce de picardie*.

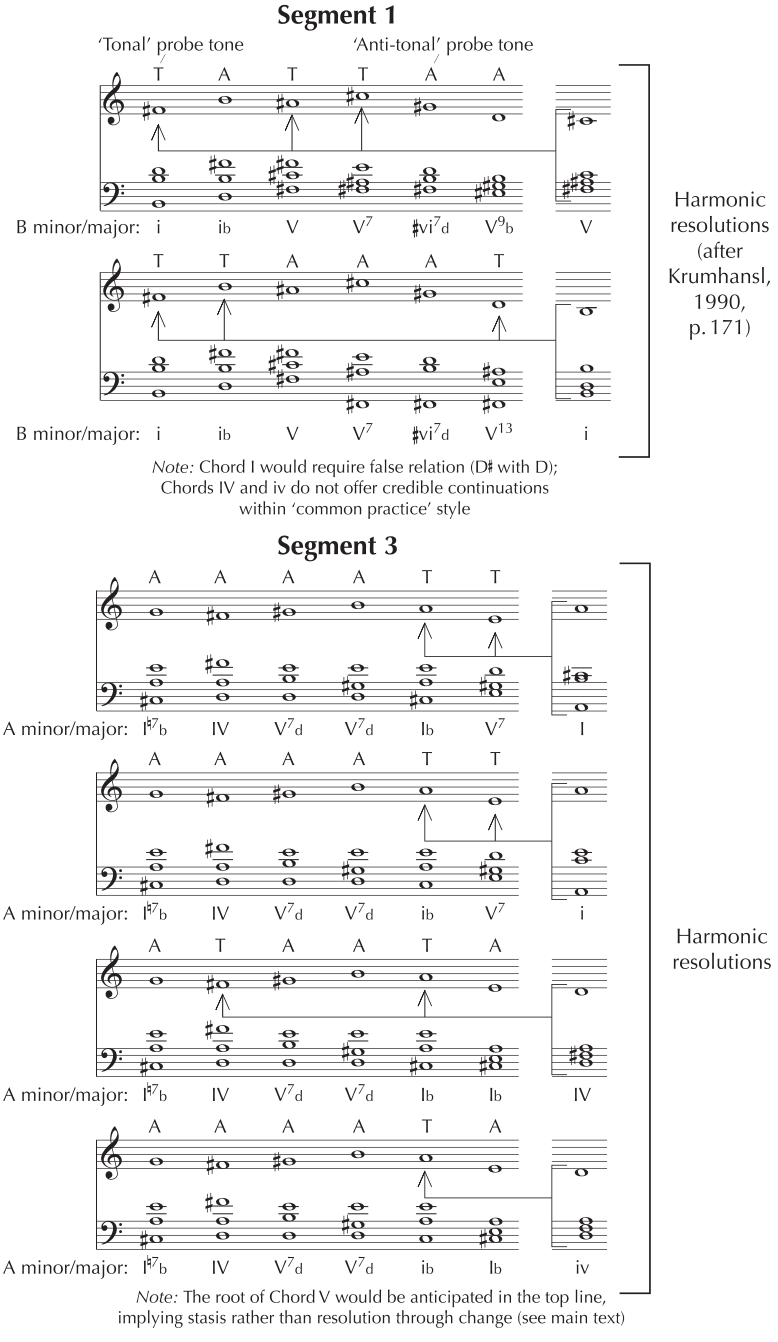


Fig. 9.24 (part i) Derivation of "tonal" and "anti-tonal" categories for probe-tones in (a) Segments 1 and 2, (b) Segments 6 and 7, and (c) Segment 8.

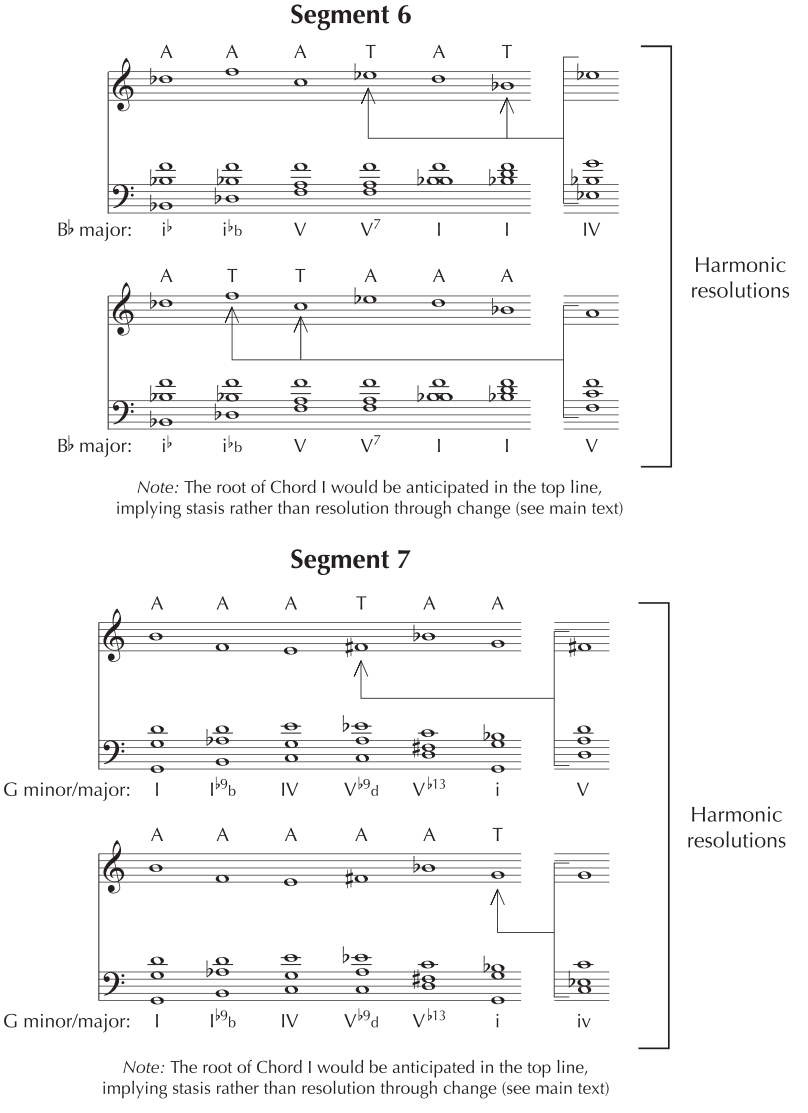


Fig. 9.24 (part ii) (continued).

on heuristics derived from the frequency of previous utilization; Huron, 2006). To put the matter simply: pitches may be defined as "tonal" if they provide a satisfactory resolution to the segment in question, within a defined key. Conversely, they may be regarded as "anti-tonal" to the extent that they are not heard as provide a fitting end to the sequence in the tonality concerned.

Judgments of melodic resolution within the common practice Western tonal system are invariably made in the context of *harmony*, sounded or implied (cf. Schenker, 1935/1979). The degree to which a given harmony provides a sense of closure depends in part on its perceived *stability* within a given key. Krumhansl (1990, p. 171), combining the results of two probe-tone experiments, found that, in a major modality, listeners regarded the most stable chord to be the tonic

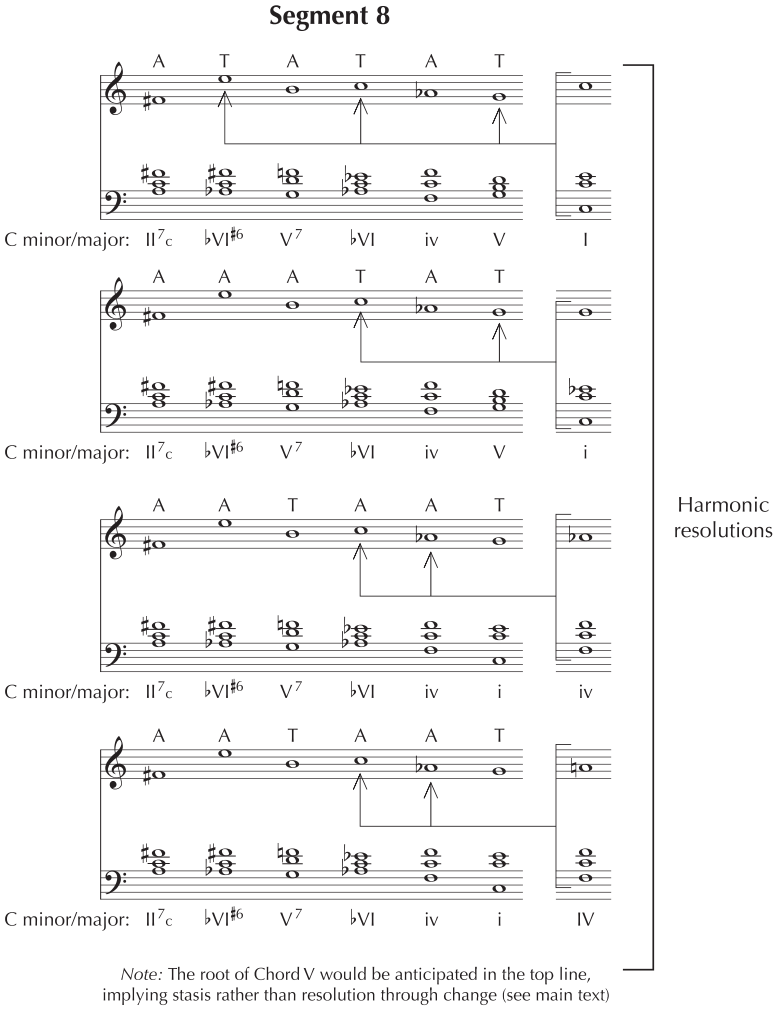


Fig. 9.24 (part iii) (continued).

(chord I, for example, C in C major), followed by the subdominant (chord IV, or F in C major) and then the dominant (chord V, or G in C major).[12] Resolution implies change; that is, movement within a part and from one chord to another. Hence, in order to undertake the tonal/anti-tonal analysis in relation to Segments 1, 3, 6, 7, and 8, it is necessary to identify in each case stylistically plausible cadential progressions that lead to one of these stable chords (according to Krumhansl's hierarchy). Harmonic "solutions" pertaining to each segment that respected these constraints were developed in consultation with two music theorists who were otherwise independent of the research. Given the need to end on chord I, IV, or V (or their minor equivalents) and the fact that

[12] For the purposes of this exercise, chords I, IV and V are treated as potential resolutions in minor keys as well as major.

resolution demands change (so the final note of each segment could not be repeated), the possibilities were in reality limited, and discussion centered around the one or two instances when progressions were theoretically possible but unlikely to occur within Western "common practice" style. In particular it was decided to omit chord I (B major) as a potential ending in Segment 1, as this would have implied a "false relation" (a semitonal clash) with the last note of the row; and the transition to a subdominant chord (IV or iv) was not deemed to be stylistically plausible. This yielded the harmonized segments (with an additional chord of resolution, corresponding to potential probe-tones) shown in Fig. 9.24.

These analyses enable us to categorize which notes can be regarded as "tonal" and which "anti-tonal" when heard as probe-tones. To reiterate: in respect of listeners who approach Sergeant's rating task with a tonality-seeking mind-set, we would expect those pitch-classes regarded as tonal to have scores higher than predicted by the zygonic model and those classed as anti-tonal to be lower, whereas those listening anti-tonally would be expected to suppress the ratings associated with tonal pitch-classes and elevate those pertaining to those that are categorized as anti-tonal. Hence there are four possibilities, which relate to the two different listening styles (see Table 9.7).

The higher and lower magnitudes pertaining to T and A are defined as the ratio between the *difference* between the probe-tone responses (R) and scaled predictions of the zygonic model (P) (see Fig. 9.11), and their *sum*:

$$\text{T or A} = (\text{R} - \text{P}) : (\text{R} + \text{P}). \tag{9.12}$$

To the extent that the mean of T ($\overline{\text{T}}$) across all respondents is greater than 0, and the mean of A ($\overline{\text{A}}$) is less than 0, we can say that they have a tendency to listen tonally. And where $\overline{\text{T}}$ is less than 0, and $\overline{\text{A}}$ is greater than 0, we can assume that listeners are adopting an anti-tonal approach. That is:

$$\text{if } \overline{\text{T}} > 0 \text{ and } \overline{\text{A}} < 0 \Rightarrow \text{tonal listening} \tag{9.13}$$

and

$$\text{if } \overline{\text{T}} < 0 \text{ and } \overline{\text{A}} > 0 \Rightarrow \text{anti-tonal listening.} \tag{9.14}$$

The range of results from Segments 1, 3, 6, 7, and 8, given the suggested chords of resolution set out in Fig. 9.24, are shown in Table 9.8. Consolidating these data (the means from each of the segments) produces the result in Fig. 9.25.

In Fig. 9.25 the mean tonal rating $\overline{\text{T}} = 0.051$, while the mean anti-tonal rating $\overline{\text{A}}$ is –0.032. Testing the directional tendencies of these two sets of values with a Mann–Whitney *U*-test shows

Table 9.7 How the differences in responses and modelled ratings relate to 'tonal' and 'anti-tonal' listening strategies

Pitch-class categorized as 'tonal' or 'anti-tonal'	Probe-tone rating higher or lower than modeled	Expected of 'tonal' listening strategy?	Expected of 'anti-tonal' listening strategy?
Tonal ('T')	Higher	Yes	No
Tonal ('T')	Lower	No	Yes
Anti-tonal ('A')	Higher	No	Yes
Anti-tonal ('A')	Lower	Yes	No

the difference to be statistically significant: $U(26) = 38$, $P = 0.017$. That is to say, the data presented here suggest that Sergeant's listeners as a whole tended to *suppress* anti-tonal pitches in their probe-tone results by around 3%, and *elevate* tonal pitches by around 5%. In other words, they tended to listen to at least five of the 12-tone series *tonally*. Of course, it could fairly be argued that the sample of rows is too small and the analytical assumptions too great for this to be anything other than an indicative result, which future, more substantial, research in this area may support or confute. Nonetheless, the principles underlying the analysis appear to be theoretically coherent and are capable of consistent application, yielding data that make intuitive musical sense. Hence the approach adopted, while novel and even speculative in nature, seems to merit further investigation.

Table 9.8 Quantitative evaluation of potential tonal and anti-tonal listening: (a) Segements 1 and 3; (b) Segments 6, 7, and 8

Chords of resolution (in B minor/major)

SEGMENT 1			V		i	
			Ratio R–P:R+P		Ratio R–P:R+P	
Pitch-class	Response	Predicted	Anti-tonal	Tonal	Anti-tonal	Tonal
	3.86	3.74		+0.016		+0.016
	3.57	4.01	-0.058			-0.058
	3.36	4.11		-0.010	-0.010	
	4.93	3.46		+0.175	+0.175	
	3.07	4.00	-0.132		-0.132	
	2.86	2.34	+0.100			+0.100
		Means	**-0.090**	**+0.091**	**-0.057**	**-0.058**

Chords of resolution (in A minor/major)

SEGMENT 3			I		i		IV		iv	
			Ratio R–P:R+P		Ratio R–P:R+P		Ratio R–P:R+P		Ratio R–P:R+P	
P-c	R	P	A	T	A	T	A	T	A	T
	4.06	3.75	+0.040		+0.040		+0.040		+0.040	
	3.91	4.25	-0.042		-0.042			-0.042	-0.042	
	4.01	4.42	-0.049		-0.049		-0.049		-0.049	
	3.33	3.50	-0.025		-0.025		-0.025		-0.025	
	3.83	3.00		+0.122		+0.122		+0.122		+0.122
	3.28	3.50		-0.032		-0.032	-0.032		-0.032	
		Means	**-0.076**	**+0.090**	**-0.076**	**+0.090**	**-0.066**	**+0.080**	**-0.108**	**+0.122**

Table 9.8 (continued) Quantitative evaluation of potential tonal and anti-tonal listening: (a) Segements 1 and 3; (b) Segments 6, 7, and 8

Chords of resolution (in B♭ major)

SEGMENT 6			IV		V	
			Ratio R–P:R+P		Ratio R–P:R+P	
P-c	R	P	A	T	A	T
	4.00	3.97	+0.004		+0.004	
	3.92	3.50	+0.057			+0.057
	3.83	3.79	+0.005			+0.005
	4.83	3.87		+0.110	+0.110	
	3.08	3.95	-0.124		-0.124	
	3.58	3.15		+0.064	+0.064	
	Means		**-0.058**	**+0.174**	**+0.054**	**+0.062**

Chords of resolution (in G minor/major)

SEGMENT 7			V		iv	
			Ratio R–P:R+P		Ratio R–P:R+P	
P-c	R	P	A	T		
	4.00	3.19	+0.113		+0.113	
	2.92	3.58	-0.102		-0.102	
	3.75	3.37	+0.053		+0.053	
	3.67	3.63		+0.005	+0.005	
	2.83	3.33	-0.081		-0.081	
	3.50	3.58	-0.011			-0.011
	Means		**-0.028**	**+0.005**	**+0.012**	**-0.011**

Chords of resolution (in C minor/major)

SEGMENT 8			I		i		IV		iv	
			Ratio R–P:R+P		Ratio R–P:R+P		Ratio R–P:R+P		Ratio R–P:R+P	
P-c	R	P	A	T						
	3.75	3.50	+0.034		+0.034		+0.034		+0.034	
	4.08	3.04		+0.146	+0.146		+0.146		+0.146	
	3.83	3.99	-0.020		-0.020		-0.020		-0.020	
	4.17	3.89		+0.035		+0.035		+0.035		+0.035
	3.17	3.82	-0.093		-0.093			-0.093	-0.093	
	2.92	3.68		-0.115		-0.115	-0.115		-0.115	
	Means		**-0.079**	**+0.066**	**+0.067**	**-0.080**	**+0.045**	**-0.058**	**-0.048**	**+0.035**

Summary

The two studies undertaken by Desmond Sergeant and me reported here identify two forms of antistructure: (a) that pertaining to a lack of repetition and (b) that involving the avoidance of the relative pitch schemata characteristic of tonality. The results suggest that listeners can intuitively recognize (a) while, at least in some cases, resisting the atonal style of perception indicated by (b). This finding is subtly different from that of Krumhansl *et al.* (1987), whose subjects fell into two groups: either detecting and responding to *both* forms of antistructure or *neither*. The wide variation in the way that listeners reported hearing the potential "tonal flecks" in the segments presented to them in Study 2 indicates that, where tonal information is very limited, many "solutions" are possible.

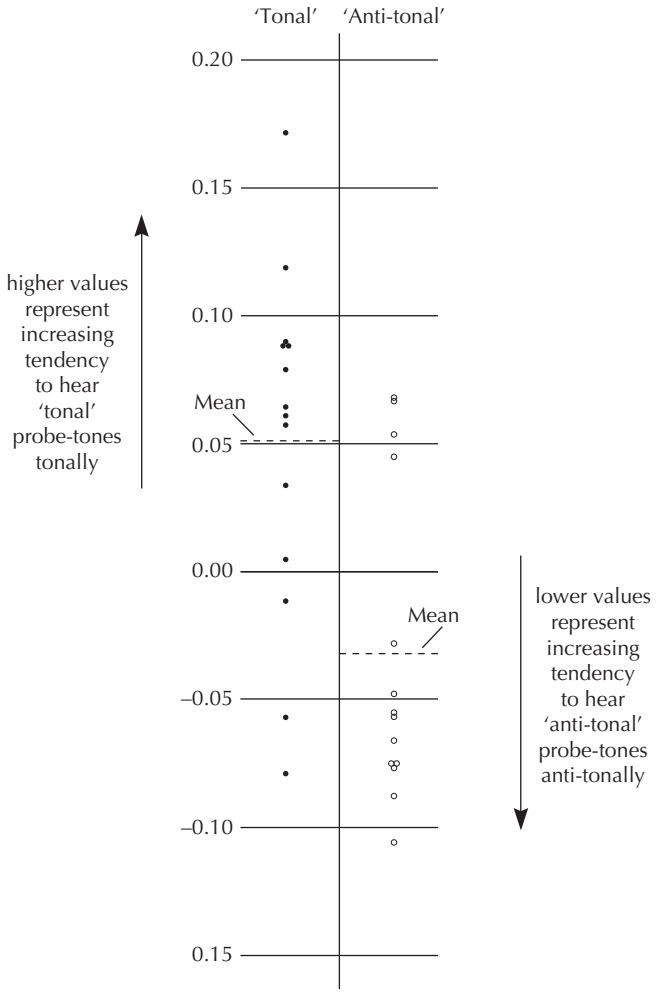


Fig. 9.25 Deviations from predicted responses to "tonal" and "anti-tonal" probe-tones.

These findings suggest that, while experienced listeners attending to serial music may indeed be able to detect certain aspects of its artificial compositional grammar (the eschewal of pitch repetition), other types of structure that were not necessarily designed by the composer (the syntax of tonality) may be imposed by listeners. Moreover, the way such listening grammars are construed, given the little structural information available, may be highly idiosyncratic. So the manner in which listeners experience serial music may vary considerably between individuals.

Conclusion

In this chapter we examined the impact on listeners of the decision made by the Second Viennese School of composers in the early 20th century to avoid using some of the principles that had more or less unthinkingly informed the creation and cognition of music up to that point. In particular we explored whether the notion of "atonality"—the conscious avoidance of the stylistically

informed probabilistic use of intervallic frameworks in the domain of pitch—has a perceptual reality for listeners, and if so what the nature of that reality is. To this end, we used zygonic theory to build models of what the cognitive consequences of atonality are likely to be on perception, memory, and recall, and tested them on a range of musicians with differing but advanced levels of skill.

The findings suggest that, even for those with the capacity to re-create or improvise new pieces fluently in the Western "musical vernacular," atonal music is difficult to grasp and remember, and that listeners are not readily able to "turn off" the tendency to listen tonally. Rather like viewers of the Rorschach blot, listeners will tend to impose familiar structures on stimuli where none is actually present. Even if it involves considerable mental contortion, listeners will irrepressibly assimilate strings of music-like sounds into predetermined schemata. Composers may believe that conceptually they have made a break with tradition, but the structure-seeking ears of their audiences may well make connections that were not intended to be heard.

However, there does seem to be a sense in which the avoidance of repetition ("antistructure") can indeed be perceived and used to fuel anticipation in the course of listening. It is contended, though, that being able to anticipate what is *not* coming next is ultimately a poor substitute for having a fair sense of what *may* follow; and that, as Bartók suggests, if composers are to write atonal music that is to be generally apprehensible, then other structures will need to be adopted that can be grasped quickly and intuitively by those without access to a score (or even explanatory notes). In short, the income of the eye should not be needed to subsidize the enforced poverty of the ear.

Part V

The future of applied musicology

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Chapter 10

Conclusion

Leafing through this book, it is a source of some satisfaction to observe the amount of music—or, at least, the visual representation of musical sounds—that pervades the text. A mischievous part of me thinks that perhaps books purporting to be about *music* education, therapy, or psychology should bear a notice on the cover indicating how much of the content has to do directly with the stuff itself, rather than words about words about sounds—rather as the packaging on sausages has to tell consumers the amount of meat they contain. Of course, just as the taste and texture demanded of such foodstuffs means that they cannot comprise meat alone, so applied musicology makes no claim to be able to stand in isolation from other forms of music-related research in the social and behavioral sciences. In epistemological terms, I like to think of applied musicology as lying midway between the intellectually robust connective tissue of the cognitive neurosciences of music on the one hand, and the rather more amorphous and idiosyncratic, highly processed products of post-modern sociological research on the other, thickly descriptive and finely textured though some of its music-related discourses may be. However, it remains my belief that the richest and most vital source of information about the musical mind is *the music that we as human beings produce*, either as individuals or, more commonly, with others. This contention notwithstanding, applied musicology will, I hope, prove to be a good neighbor to its sister disciplines, offering insight-driven data to corroborate (or contradict) the observations and intuitions of the colleagues to the intellectual left and right, and not concerned with protecting epistemological boundaries at the expense of exploring new interdisciplinary synergies.

What of the future? It is one thing to undertake research, with the time and means to reflect on practice in the hope of demonstrating the "proof of principle" of new analytical techniques; it is quite another to make these approaches accessible and practicable for teachers and therapists to use in the course of their everyday work. I hope that information technology may be of assistance here in being able to undertake some of the more mechanical aspects of applied musicological analysis (such as the identification of repetition), leaving practitioners to use the limited time and resources available to them to make the judgments that currently only human beings can make: identifying, for example, when repetition derives from *imitation*—the central tent of zygonic theory, and crucial in determining intentionality and influence in musical interactions. Indeed, significant steps in this direction have already been made with the *Sounds of Intent* website (<http://www.soundsofintent.org>), described in Chapter 5. Although the underlying music-developmental framework draws heavily on zygonic theory, the evaluations of musical engagement that teachers and therapists are asked to make are couched in everyday (musical) language, and the scheme of precise quantitative assessment that the system makes possible operates invisibly in the background. Programs such as this are surely the way forward in forging from academic disciplines such as applied musicology the tools that all educational and therapeutic practitioners can use.

I believe that another future lies in using zygonic theory in other applied musicological contexts. For example, Gloria Zapata, a doctoral student at the University of Roehampton, has already

extended the thinking presented in Chapters 3 and 4 to gauge levels of musical creativity among disadvantaged children in Colombia—one measure of success in an innovative program that uses music to promote emotional development and social cohesion among communities with hitherto restricted cultural and artistic opportunities. John Brockhouse, also associated with the Applied Music Research Centre at Roehampton, is currently using the $I = R\ (1 - P)$ principle to judge whether a profoundly autistic student he works with, using a KorgnanoPAD, is producing patterns that are driven aurally or kinesthetically.

Beyond projects such as these, there is no reason why applied musicology should be restricted to a zygonic-theoretical approach. Other systems of musical analysis could be "applied" in social and behavioral research contexts. Indeed, putting such systems to work in the fuzzy and ephemeral world of children's spontaneous music-making (for example) could provide something of a litmus test of their value beyond the rarefied world of Lydia Goehr's imaginary museum of musical works. And while I have some sympathy with the notion of music analysis serving as an "ear opener" for a musical elite, surely harnessing its sophisticated techniques to function as a "mind opener" for those working through music with, for instance, non-verbal people, is just as valuable a cause. It is hard to conceive that such interdisciplinary approaches would not be mutually enriching.

Appendix 1

ZYG Values Pertaining to Derek's Recall of *Chromatic Blues*

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
1 : 1	Melody	7	6	0.86	3.5	0.50	9.5	0.68	11	4.5	0.41	1	0.09	5.5	0.25	7	6	0.86	3.5	0.50	9.5	0.68
	Inner	13	7.5	0.58	1	0.08	8.5	0.33	22	3.5	0.16	5	0.23	8.5	0.19	14	6.5	0.46	2	0.14	8.5	0.30
	Bass	12	12	1.00	8	0.67	20	0.83	9	2	0.22	1.5	0.17	3.5	0.19	14	11	0.79	10	0.71	21	0.75
	Sum/Mean	**32**	**25.5**	**0.80**	**12.5**	**0.39**	**38**	**0.59**	**42**	**10**	**0.24**	**7.5**	**0.18**	**17.5**	**0.21**	**35**	**23.5**	**0.67**	**15.5**	**0.44**	**39**	**0.56**
2 : 2	Melody	7	0	0.00	1.5	0.21	1.5	0.11	11	3	0.27	0	0.00	3	0.14	7	0	0.00	1.5	0.21	1.5	0.11
	Inner	12	0	0.00	0	0.00	0	0.00	24	1	0.04	0	0.00	1	0.02	12	0	0.00	0	0.00	0	0.00
	Bass	18	8	0.44	3	0.17	11	0.31	15	5	0.33	0	0.00	5	0.17	15	5.5	0.37	2.5	0.17	8	0.27
	Sum/Mean	**37**	**8**	**0.22**	**4.5**	**0.12**	**12.5**	**0.17**	**50**	**9**	**0.18**	**0**	**0.00**	**9**	**0.09**	**34**	**5.5**	**0.16**	**4**	**0.12**	**9.5**	**0.14**
2 : 3	Melody	8	4.5	0.56	5.5	0.69	10	0.63	11	3	0.27	1.5	0.14	4.5	0.20	7	5	0.71	3.5	0.50	8.5	0.61
	Inner	18	0	0.00	0	0.00	0	0.00	21	1	0.05	0	0.00	1	0.02	15	2.5	0.17	0	0.00	2.5	0.08
	Bass	16	11	0.69	7	0.44	18	0.56	16	3	0.19	1.5	0.09	4.5	0.14	12	8	0.67	5	0.42	13	0.54
	Sum/Mean	**42**	**15.5**	**0.37**	**12.5**	**0.30**	**28**	**0.33**	**48**	**7**	**0.15**	**3**	**0.06**	**10**	**0.10**	**34**	**15.5**	**0.46**	**8.5**	**0.25**	**24**	**0.35**
3 : 4	Melody	7	0	0.00	3	0.43	3	0.21	13	1.5	0.12	0	0.00	1.5	0.06	7	0	0.00	3	0.43	3	0.21
	Inner	12	0	0.00	0	0.00	0	0.00	18	0	0.00	0	0.00	0	0.00	12	0	0.00	0	0.00	0	0.00
	Bass	14	9.5	0.68	9	0.64	18.5	0.66	15	3	0.20	0	0.00	3	0.10	12	6	0.50	6.5	0.54	12.5	0.52
	Sum/Mean	**33**	**9.5**	**0.29**	**12**	**0.36**	**21.5**	**0.33**	**46**	**4.5**	**0.10**	**0**	**0.00**	**4.5**	**0.05**	**31**	**6**	**0.19**	**9.5**	**0.31**	**15.5**	**0.25**
3 : 5	Melody	7	3.5	0.50	5	0.71	8.5	0.61	9	6.5	0.72	5	0.56	11.5	0.64	7	6	0.86	6	0.86	12	0.86
	Inner	12	2.5	0.21	3	0.25	5.5	0.23	18	3	0.17	6	0.33	9	0.25	12	7	0.58	5	0.42	12	0.50
	Bass	13	9	0.69	11	0.85	20	0.77	7	3	0.43	1	0.14	4	0.29	12	12	1.00	12	1.00	24	1.00
	Sum/Mean	**32**	**15**	**0.47**	**19**	**0.59**	**34**	**0.53**	**34**	**12.5**	**0.37**	**12**	**0.35**	**24.5**	**0.36**	**31**	**25**	**0.81**	**23**	**0.74**	**48**	**0.77**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
4 : 6	Melody	7	6	0.86	6	0.86	12	0.86	9	8.5	0.94	8	0.89	16.5	0.92	7	6	0.86	6	0.86	12	0.86
	Inner	14	3.5	0.25	3	0.21	6.5	0.23	19	10	0.53	10	0.53	20	0.53	13	6	0.46	4	0.31	10	0.38
	Bass	12	12	1.00	12	1.00	24	1.00	6	3	0.50	3	0.50	6	0.50	12	9.5	0.79	10	0.83	19.5	0.81
	Sum/Mean	**33**	**21.5**	**0.65**	**21**	**0.64**	**42.5**	**0.64**	**34**	**21.5**	**0.63**	**21**	**0.62**	**42.5**	**0.63**	**32**	**21.5**	**0.67**	**20**	**0.63**	**41.5**	**0.65**
4 : 7	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	8	0.89	17	0.94	7	6	0.86	6	0.86	12	0.86
	Inner	12	9.5	0.79	7	0.58	16.5	0.69	18	13	0.72	16	0.89	29	0.81	13	6.5	0.50	5	0.38	11.5	0.44
	Bass	12	10.5	0.88	10	0.83	20.5	0.85	6	5	0.83	6	1.00	11	0.92	12	12	1.00	12	1.00	24	1.00
	Sum/Mean	**31**	**26**	**0.84**	**23**	**0.74**	**49**	**0.79**	**33**	**27**	**0.82**	**30**	**0.91**	**57**	**0.86**	**32**	**24.5**	**0.77**	**23**	**0.72**	**47.5**	**0.74**
5 : 8	Melody	7	6	0.86	6	0.86	12	0.86	9	8.5	0.94	9	1.00	17.5	0.97	7	6	0.86	6	0.86	12	0.86
	Inner	14	4.5	0.32	4	0.29	8.5	0.30	18	7.5	0.42	16	0.89	23.5	0.65	13	7	0.54	4	0.31	11	0.42
	Bass	12	8	0.67	7	0.58	15	0.63	7	4	0.57	6	0.86	10	0.71	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**33**	**18.5**	**0.56**	**17**	**0.52**	**35.5**	**0.54**	**34**	**20**	**0.59**	**31**	**0.91**	**51**	**0.75**	**32**	**24.5**	**0.77**	**22**	**0.69**	**46.5**	**0.73**
5 : 9	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	12	7	0.58	6	0.50	13	0.54	19	10	0.53	16	0.84	26	0.68	13	7	0.54	4	0.31	11	0.42
	Bass	12	12	1.00	12	1.00	24	1.00	6	3.5	0.58	6	1.00	9.5	0.79	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**31**	**25**	**0.81**	**24**	**0.77**	**49**	**0.79**	**34**	**22.5**	**0.66**	**31**	**0.91**	**53.5**	**0.79**	**32**	**24.5**	**0.77**	**22**	**0.69**	**46.5**	**0.73**
6 : 10	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	15	10	0.67	8	0.53	18	0.60	18	9.5	0.53	14	0.78	23.5	0.65	12	8.5	0.71	7	0.58	15.5	0.65
	Bass	12	11.5	0.96	12	1.00	23.5	0.98	6	5	0.83	6	1.00	11	0.92	12	12	1.00	12	1.00	24	1.00
	Sum/Mean	**34**	**27.5**	**0.81**	**26**	**0.76**	**53.5**	**0.79**	**33**	**23.5**	**0.71**	**29**	**0.88**	**52.5**	**0.80**	**31**	**26.5**	**0.85**	**25**	**0.81**	**51.5**	**0.83**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
6 : 11	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	8	7	0.88	7	0.88	14	0.88
	Inner	12	11	0.92	8	0.67	19	0.79	18	9.5	0.53	14	0.78	23.5	0.65	12	9	0.75	10	0.83	19	0.79
	Bass	12	10	0.83	11	0.92	21	0.88	6	5	0.83	6	1.00	11	0.92	12	12	1.00	12	1.00	24	1.00
	Sum/Mean	**31**	**27**	**0.87**	**25**	**0.81**	**52**	**0.84**	**33**	**23.5**	**0.71**	**29**	**0.88**	**52.5**	**0.80**	**32**	**28**	**0.88**	**29**	**0.91**	**57**	**0.89**
7 : 12	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	12	9	0.75	7	0.58	16	0.67	18	9.5	0.53	14	0.78	23.5	0.65	12	9	0.75	7	0.58	16	0.67
	Bass	12	11	0.92	12	1.00	23	0.96	6	5	0.83	6	1.00	11	0.92	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**31**	**26**	**0.84**	**25**	**0.81**	**51**	**0.82**	**33**	**23.5**	**0.71**	**29**	**0.88**	**52.5**	**0.80**	**31**	**26.5**	**0.85**	**25**	**0.81**	**51.5**	**0.83**
7 : 13	Melody	7	6	0.86	6	0.86	12	0.86	11	9	0.82	11	1.00	20	0.91	7	6	0.86	6	0.86	12	0.86
	Inner	12	10	0.83	8	0.67	18	0.75	20	11	0.55	15	0.75	26	0.65	12	10	0.83	9	0.75	19	0.79
	Bass	12	11	0.92	12	1.00	23	0.96	6	4	0.67	5	0.83	9	0.75	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**31**	**27**	**0.87**	**26**	**0.84**	**53**	**0.85**	**37**	**24**	**0.65**	**31**	**0.84**	**55**	**0.74**	**31**	**27.5**	**0.89**	**27**	**0.87**	**54.5**	**0.88**
8 : 14	Melody	7	6	0.86	6	0.86	12	0.86	10	9	0.90	10	1.00	19	0.95	7	6	0.86	6	0.86	12	0.86
	Inner	13	10	0.77	8	0.62	18	0.69	18	8	0.44	14	0.78	22	0.61	13	11	0.85	9	0.69	20	0.77
	Bass	12	10	0.83	11	0.92	21	0.88	6	5	0.83	6	1.00	11	0.92	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**32**	**26**	**0.81**	**25**	**0.78**	**51**	**0.80**	**34**	**22**	**0.65**	**30**	**0.88**	**52**	**0.76**	**32**	**28**	**0.88**	**27**	**0.84**	**55**	**0.86**
8 : 15	Melody	7	7	1.00	6	0.86	13	0.93	12	9	0.75	12	1.00	21	0.88	7	6	0.86	6	0.86	12	0.86
	Inner	12	9.5	0.79	8	0.67	17.5	0.73	18	6.5	0.36	14	0.78	20.5	0.57	12	11	0.92	9	0.75	20	0.83
	Bass	12	11	0.92	12	1.00	23	0.96	7	4	0.57	7	1.00	11	0.79	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**27.5**	**0.89**	**26**	**0.84**	**53.5**	**0.86**	**37**	**19.5**	**0.53**	**33**	**0.89**	**52.5**	**0.71**	**31**	**28**	**0.90**	**27**	**0.87**	**55**	**0.89**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
9 : 16	Melody	7	7	1.00	7	1.00	14	1.00	10	9	0.90	9	0.90	18	0.90	7	6	0.86	6	0.86	12	0.86
	Inner	12	10	0.83	8	0.67	18	0.75	18	9	0.50	15	0.83	24	0.67	12	11	0.92	10	0.83	21	0.88
	Bass	12	11	0.92	12	1.00	23	0.96	6	4.5	0.75	6	1.00	10.5	0.88	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**28**	**0.90**	**27**	**0.87**	**55**	**0.89**	**34**	**22.5**	**0.66**	**30**	**0.88**	**52.5**	**0.77**	**31**	**28**	**0.90**	**28**	**0.90**	**56**	**0.90**
9 : 17	Melody	7	7	1.00	7	1.00	14	1.00	10	9	0.90	9	0.90	18	0.90	8	6	0.75	6	0.75	12	0.75
	Inner	12	9	0.75	8	0.67	17	0.71	21	11	0.52	13.5	0.64	24.5	0.58	12	11	0.92	10	0.83	21	0.88
	Bass	13	11	0.85	12	0.92	23	0.88	7	2.5	0.36	4	0.57	6.5	0.46	12	11	0.92	11	0.92	22	0.92
	Sum/Mean	**32**	**27**	**0.84**	**27**	**0.84**	**54**	**0.84**	**38**	**22.5**	**0.59**	**26.5**	**0.70**	**49**	**0.64**	**32**	**28**	**0.88**	**27**	**0.84**	**55**	**0.86**
10 : 18	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	12	10	0.83	8	0.67	18	0.75	18	9.5	0.53	14	0.78	23.5	0.65	12	10	0.83	9	0.75	19	0.79
	Bass	12	11	0.92	12	1.00	23	0.96	6	4	0.67	5	0.83	9	0.75	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**27**	**0.87**	**26**	**0.84**	**53**	**0.85**	**33**	**22.5**	**0.68**	**28**	**0.85**	**50.5**	**0.77**	**31**	**27**	**0.87**	**27**	**0.87**	**54**	**0.87**
11 : 19	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	8	0.89	17	0.94	7	6	0.86	6	0.86	12	0.86
	Inner	12	10	0.83	10	0.83	20	0.83	19	13	0.68	15	0.79	28	0.74	12	9.5	0.79	9	0.75	18.5	0.77
	Bass	12	11	0.92	12	1.00	23	0.96	6	5	0.83	5	0.83	10	0.83	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**27**	**0.87**	**28**	**0.90**	**55**	**0.89**	**34**	**27**	**0.79**	**28**	**0.82**	**55**	**0.81**	**31**	**26.5**	**0.85**	**27**	**0.87**	**53.5**	**0.86**
11 : 20	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	8	0.89	17	0.94	7	6	0.86	6	0.86	12	0.86
	Inner	12	11	0.92	11	0.92	22	0.92	19	13	0.68	15	0.79	28	0.74	12	10.5	0.88	11	0.92	21.5	0.90
	Bass	12	11	0.92	12	1.00	23	0.96	6	5	0.83	5	0.83	10	0.83	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**28**	**0.90**	**29**	**0.94**	**57**	**0.92**	**34**	**27**	**0.79**	**28**	**0.82**	**55**	**0.81**	**31**	**27.5**	**0.89**	**29**	**0.94**	**56.5**	**0.91**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
12 : 21	Melody	7	6	0.86	6	0.86	12	0.86	9	8.5	0.94	8	0.89	16.5	0.92	8	5.5	0.69	6	0.75	11.5	0.72
	Inner	12	10	0.83	10	0.83	20	0.83	18	12.5	0.69	14	0.78	26.5	0.74	12	9.5	0.79	10	0.83	19.5	0.81
	Bass	12	11.5	0.96	12	1.00	23.5	0.92	6	5	0.83	5	0.83	10	0.83	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**27.5**	**0.89**	**28**	**0.90**	**55.5**	**0.90**	**33**	**26**	**0.79**	**27**	**0.82**	**63**	**0.80**	**32**	**26**	**0.81**	**28**	**0.88**	**54**	**0.84**
12 : 22	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	8	0.89	17	0.94	7	6	0.86	6	0.86	12	0.86
	Inner	12	10	0.83	10	0.83	20	0.83	18	15	0.83	14	0.78	29	0.81	12	9.5	0.79	10	0.83	19.5	0.81
	Bass	12	11.5	0.96	12	1.00	23.5	0.92	6	3	1.00	5	0.83	11	0.92	12	12	1.00	12	1.00	27	1.00
	Sum/Mean	**31**	**27.5**	**0.89**	**28**	**0.90**	**55.5**	**0.90**	**33**	**30**	**0.91**	**27**	**0.82**	**57**	**0.86**	**31**	**27.5**	**0.89**	**28**	**0.90**	**55.5**	**0.90**
13 : 23	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	8	0.89	17	0.94	7	6	0.86	6	0.86	12	0.86
	Inner	12	10.5	0.88	11	0.92	21.5	0.90	19	12.5	0.66	13	0.68	25.5	0.67	13	10.5	0.81	12	0.92	22.5	0.87
	Bass	12	11	0.92	12	1.00	23	0.96	6	4.5	0.75	4	0.67	8.5	0.71	12	11	0.92	12	1.00	23	0.96
	Sum/Mean	**31**	**27.5**	**0.89**	**29**	**0.94**	**56.5**	**0.91**	**34**	**26**	**0.76**	**25**	**0.74**	**51**	**0.75**	**32**	**27.5**	**0.86**	**30**	**0.94**	**57.5**	**0.90**
13 : 24	Melody	7	6	0.86	6	0.86	12	0.86	7	6	0.86	6	0.86	12	0.86	7	6	0.86	6	0.86	12	0.86
	Inner	12	10.5	0.88	11	0.92	21.5	0.90	19	13	0.68	19	1.00	32	0.84	12	11	0.92	11	0.92	22	0.92
	Bass	12	11.5	0.96	12	1.00	23.5	0.98	6	4.5	0.75	3	0.50	7.5	0.63	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**19**	**16.5**	**0.87**	**17**	**0.89**	**33.5**	**0.88**	**26**	**19**	**0.73**	**25**	**0.96**	**44**	**0.85**	**19**	**17**	**0.89**	**17**	**0.89**	**34**	**0.89**
14 : 25	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	12	9	0.75	9	0.75	18	0.75	19	14	0.74	17	0.89	31	0.82	13	11	0.85	10.5	0.81	21.5	0.83
	Bass	12	11	0.92	12	1.00	23	0.96	8	5	0.63	6	0.75	11	0.69	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**31**	**26**	**0.84**	**27**	**0.87**	**53**	**0.85**	**36**	**28**	**0.78**	**32**	**0.89**	**60**	**0.83**	**32**	**28.5**	**0.89**	**28.5**	**0.89**	**57**	**0.89**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
14 : 26	Melody	7	6	0.86	6	0.86	12	0.86	9	9	1.00	9	1.00	18	1.00	7	6	0.86	6	0.86	12	0.86
	Inner	12	10.5	0.88	11	0.92	21.5	0.90	23	19	0.83	17	0.74	36	0.78	12	10.5	0.88	11	0.92	21.5	0.90
	Bass	12	11.5	0.96	12	1.00	23.5	0.98	6	4	0.67	4	0.67	8	0.67	12	11.5	0.96	12	1.00	23.5	0.98
	Sum/Mean	**31**	**28**	**0.90**	**29**	**0.94**	**57**	**0.92**	**38**	**32**	**0.84**	**30**	**0.79**	**62**	**0.82**	**31**	**28**	**0.90**	**29**	**0.94**	**57**	**0.92**
Sums/ Means	Melody	183	143	0.78	147	0.80	290	0.79	250	203	0.81	193	0.77	395.5	0.79	185	144	0.78	145	0.78	288	0.78
	Inner	327	205	0.63	178	0.54	383	0.58	498	244.5	0.49	321	0.64	565	0.57	324	215	0.66	189	0.58	403.5	0.62
	Bass	326	280	0.86	281	0.86	561	0.86	193	109.5	0.57	113	0.59	222.5	0.58	317	280	0.88	285	0.90	564.5	0.89
	Sum/Mean	**836**	**627**	**0.75**	**606**	**0.72**	**1233**	**0.74**	**941**	**557**	**0.59**	**626**	**0.67**	**1183**	**0.63**	**826**	**638**	**0.77**	**618**	**0.75**	**1256**	**0.76**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
1 : 1	Melody	11	4	0.36	1	0.09	5	0.23	17	8	0.47	4	0.24	12	0.35	53	28.5	0.54	13	0.25	41.5	0.39
	Inner	20	5.5	0.28	0.5	0.03	6	0.15	25	0	0.00	2	0.08	2	0.04	94	23	0.24	10.5	0.11	33.5	0.18
	Bass	10	2.5	0.25	0	0.00	2.5	0.13	7	1	0.14	1	0.14	2	0.14	52	28.5	0.55	20.5	0.39	49	0.47
	Sum/Mean	**41**	**12**	**0.29**	**1.5**	**0.04**	**13.5**	**0.16**	**49**	**9**	**0.18**	**7**	**0.14**	**16**	**0.16**	**199**	**80**	**0.40**	**44**	**0.22**	**124**	**0.31**
2 : 2	Melody	15	4.5	0.30	0	0.00	4.5	0.15	18	13	0.72	17.5	0.97	30.5	0.85	58	20.5	0.35	20.5	0.35	41	0.35
	Inner	22	3	0.14	0	0.00	3	0.07	15	0	0.00	0	0.00	0	0.00	85	4	0.05	0	0.00	4	0.02
	Bass	14	4	0.29	0	0.00	4	0.14	7	1	0.14	0.5	0.07	1.5	0.11	69	23.5	0.34	6	0.09	29.5	0.21
	Sum/Mean	**51**	**11.5**	**0.23**	**0**	**0.00**	**11.5**	**0.11**	**40**	**14**	**0.35**	**18**	**0.45**	**32**	**0.40**	**212**	**48**	**0.23**	**26.5**	**0.13**	**74.5**	**0.18**
2 : 3	Melody	9	1	0.11	0	0.00	1	0.06	16	3.5	0.22	0.5	0.03	4	0.13	51	17	0.33	11	0.22	28	0.27
	Inner	20	1	0.05	1	0.05	2	0.05	13	0.5	0.04	0.5	0.04	1	0.04	87	5	0.06	1.5	0.02	6.5	0.04
	Bass	13	1.5	0.12	0	0.00	1.5	0.06	7	1	0.14	0.5	0.07	1.5	0.11	64	24.5	0.38	14	0.22	38.5	0.30
	Sum/Mean	**42**	**3.5**	**0.08**	**1**	**0.02**	**4.5**	**0.05**	**36**	**5**	**0.14**	**1.5**	**0.04**	**6.5**	**0.09**	**202**	**46.5**	**0.23**	**26.5**	**0.13**	**73**	**0.18**
3 : 4	Melody	10	1.5	0.15	1	0.10	2.5	0.13	16	13	0.81	7	0.44	20	0.63	53	16	0.30	14	0.26	30	0.28
	Inner	19	2.5	0.13	1.5	0.08	4	0.11	14	0	0.00	0	0.00	0	0.00	75	2.5	0.03	1.5	0.02	4	0.03
	Bass	8	1.5	0.19	0	0.00	1.5	0.09	7	1	0.14	0.5	0.07	1.5	0.11	56	21	0.38	16	0.29	37	0.33
	Sum/Mean	**37**	**5.5**	**0.15**	**2.5**	**0.07**	**8**	**0.11**	**37**	**14**	**0.38**	**7.5**	**0.20**	**21.5**	**0.29**	**184**	**39.5**	**0.21**	**31.5**	**0.17**	**71**	**0.19**
3 : 5	Melody	15	6.5	0.43	3	0.20	9.5	0.32	16	12	0.75	7.5	0.47	19.5	0.61	54	34.5	0.64	26.5	0.49	61	0.56
	Inner	20	3.5	0.18	4.5	0.23	8	0.20	17	0	0.00	0	0.00	0	0.00	79	16	0.20	18.5	0.23	34.5	0.22
	Bass	6	2	0.33	0	0.00	2	0.17	7	1	0.14	0.5	0.07	1.5	0.11	45	27	0.60	24.5	0.54	51.5	0.57
	Sum/Mean	**41**	**12**	**0.29**	**7.5**	**0.18**	**19.5**	**0.24**	**40**	**13**	**0.33**	**8**	**0.20**	**21**	**0.26**	**178**	**77.5**	**0.44**	**69.5**	**0.39**	**147**	**0.41**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
4 : 6	Melody	11	8.5	0.77	6	0.55	14.5	0.66	16	12	0.75	7.5	0.47	19.5	0.61	50	41	0.82	33.5	0.67	74.5	0.75
	Inner	21	2	0.10	5	0.24	7	0.17	15	0	0.00	0	0.00	0	0.00	82	21.5	0.26	22	0.27	43.5	0.27
	Bass	6	2	0.33	2	0.33	4	0.33	7	1	0.14	0.5	0.07	1.5	0.11	43	27.5	0.64	27.5	0.64	55	0.64
	Sum/Mean	**38**	**12.5**	**0.33**	**13**	**0.34**	**25.5**	**0.34**	**38**	**13**	**0.34**	**8**	**0.21**	**21**	**0.28**	**175**	**90**	**0.51**	**83**	**0.47**	**173**	**0.49**
4 : 7	Melody	10	9	0.90	8	0.80	17	0.85	16	14.5	0.91	7.5	0.47	22	0.69	49	44.5	0.91	35.5	0.72	80	0.82
	Inner	18	9.5	0.53	14	0.78	23.5	0.65	16	4.5	0.28	4	0.25	8.5	0.27	77	43	0.56	46	0.60	89	0.58
	Bass	6	3.5	0.58	4	0.67	7.5	0.63	7	1.5	0.21	0.5	0.07	2	0.14	43	32.5	0.76	32.5	0.76	65	0.76
	Sum/Mean	**34**	**22**	**0.65**	**26**	**0.76**	**48**	**0.71**	**39**	**20.5**	**0.53**	**12**	**0.31**	**32.5**	**0.42**	**169**	**120**	**0.71**	**114**	**0.67**	**234**	**0.69**
5 : 8	Melody	9	8.5	0.94	8	0.89	16.5	0.92	16	15	0.94	9	0.56	24	0.75	48	44	0.92	38	0.79	82	0.85
	Inner	18	8	0.44	13	0.72	21	0.58	16	4	0.25	6.5	0.41	10.5	0.33	79	31	0.39	43.5	0.55	74.5	0.47
	Bass	6	3.5	0.58	4	0.67	7.5	0.63	6	1.5	0.25	2	0.33	3.5	0.29	43	28.5	0.66	31	0.72	59.5	0.69
	Sum/Mean	**33**	**20**	**0.61**	**25**	**0.76**	**45**	**0.68**	**38**	**20.5**	**0.54**	**17.5**	**0.46**	**38**	**0.50**	**170**	**103.5**	**0.61**	**112.5**	**0.66**	**216**	**0.64**
5 : 9	Melody	9	9	1.00	8	0.89	17	0.94	16	15	0.94	8.5	0.53	23.5	0.73	48	45	0.94	37.5	0.78	82.5	0.86
	Inner	18	6	0.33	12	0.67	18	0.50	16	4.5	0.28	6.5	0.41	11	0.34	78	34.5	0.44	44.5	0.57	79	0.51
	Bass	6	3.5	0.58	5	0.83	8.5	0.71	6	2.5	0.42	2.5	0.42	5	0.42	42	33	0.79	37.5	0.89	70.5	0.84
	Sum/Mean	**33**	**18.5**	**0.56**	**25**	**0.76**	**43.5**	**0.66**	**38**	**22**	**0.58**	**17.5**	**0.46**	**39.5**	**0.52**	**168**	**112.5**	**0.67**	**119.5**	**0.71**	**232**	**0.69**
6 : 10	Melody	9	9	1.00	9	1.00	18	1.00	16	15	0.94	8.5	0.53	23.5	0.73	48	45	0.94	38.5	0.80	83.5	0.87
	Inner	18	11	0.61	13.5	0.75	24.5	0.68	16	4.5	0.28	6	0.38	10.5	0.33	79	43.5	0.55	48.5	0.61	92	0.58
	Bass	6	5	0.83	6	1.00	11	0.92	7	2.5	0.36	2.5	0.36	5	0.36	43	36	0.84	38.5	0.90	74.5	0.87
	Sum/Mean	**33**	**25**	**0.76**	**28.5**	**0.86**	**53.5**	**0.81**	**39**	**22**	**0.56**	**17**	**0.44**	**39**	**0.50**	**170**	**124.5**	**0.73**	**125.5**	**0.74**	**250**	**0.74**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
6 : 11	Melody	9	8.5	0.94	9	1.00	17.5	0.97	16	14.5	0.91	10	0.63	24.5	0.77	49	45	0.92	41	0.84	86	0.88
	Inner	19	9.5	0.50	14	0.74	23.5	0.62	16	4	0.25	6.5	0.41	10.5	0.33	77	43	0.56	52.5	0.68	95.5	0.62
	Bass	6	5	0.83	6	1.00	11	0.92	6	2.5	0.42	2.5	0.42	5	0.42	42	34.5	0.82	37.5	0.89	72	0.86
	Sum/Mean	**34**	**23**	**0.68**	**29**	**0.85**	**52**	**0.76**	**38**	**21**	**0.55**	**19**	**0.50**	**40**	**0.53**	**168**	**122.5**	**0.73**	**131**	**0.78**	**253.5**	**0.75**
7 : 12	Melody	9	9	1.00	9	1.00	18	1.00	17	14.5	0.85	8.5	0.50	23	0.68	49	44.5	0.91	38.5	0.79	83	0.85
	Inner	19	11	0.58	14	0.74	25	0.66	17	4.5	0.26	6	0.35	10.5	0.31	78	43	0.55	48	0.62	91	0.58
	Bass	6	4	0.67	5	0.83	9	0.75	6	2.5	0.42	2.5	0.42	5	0.42	42	34	0.81	37.5	0.89	71.5	0.85
	Sum/Mean	**34**	**24**	**0.71**	**28**	**0.82**	**52**	**0.76**	**40**	**21.5**	**0.54**	**17**	**0.43**	**38.5**	**0.48**	**169**	**121.5**	**0.72**	**124**	**0.73**	**245.5**	**0.73**
7 : 13	Melody	9	9	1.00	9	1.00	18	1.00	17	15.5	0.91	7	0.41	22.5	0.66	51	45.5	0.89	39	0.76	84.5	0.83
	Inner	19	11	0.58	14	0.74	25	0.66	15	5.5	0.37	6.5	0.43	12	0.40	78	47.5	0.61	52.5	0.67	100	0.64
	Bass	6	4	0.67	5	0.83	9	0.75	6	2.5	0.42	3	0.50	5.5	0.46	42	33	0.79	37	0.88	70	0.83
	Sum/Mean	**34**	**24**	**0.71**	**28**	**0.82**	**52**	**0.76**	**38**	**23.5**	**0.62**	**16.5**	**0.43**	**40**	**0.53**	**171**	**126**	**0.74**	**128.5**	**0.75**	**254.5**	**0.74**
8 : 14	Melody	9	9	1.00	9	1.00	18	1.00	16	13.5	0.84	6	0.38	19.5	0.61	49	43.5	0.89	37	0.76	80.5	0.82
	Inner	19	8.5	0.45	16	0.84	24.5	0.64	15	6.5	0.43	6.5	0.43	13	0.43	78	44	0.56	53.5	0.69	97.5	
	Bass	7	5.5	0.79	7	1.00	12.5	0.89	6	3	0.50	3	0.50	6	0.50	43	34.5	0.80	39	0.91	73.5	0.85
	Sum/Mean	**35**	**23**	**0.66**	**32**	**0.91**	**55**	**0.79**	**37**	**23**	**0.62**	**15.5**	**0.42**	**38.5**	**0.52**	**170**	**122**	**0.72**	**129.5**	**0.76**	**251.5**	**0.74**
8 : 15	Melody	9	9	1.00	9	1.00	18	1.00	18	15.5	0.86	9	0.50	24.5	0.68	53	46.5	0.88	42	0.79	88.5	0.83
	Inner	19	8.5	0.45	16	0.84	24.5	0.64	14	4.5	0.32	6	0.43	10.5	0.38	75	40	0.53	53	0.71	93	0.62
	Bass	7	4.5	0.64	5	0.71	9.5	0.68	7	2.5	0.36	3	0.43	5.5	0.39	45	33	0.73	39	0.87	72	0.80
	Sum/Mean	**35**	**22**	**0.63**	**30**	**0.86**	**52**	**0.74**	**39**	**22.5**	**0.58**	**18**	**0.46**	**40.5**	**0.52**	**173**	**119.5**	**0.69**	**134**	**0.77**	**253.5**	**0.73**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
9 : 16	Melody	9	9	1.00	9	1.00	18	1.00	19	15	0.79	11	0.58	26	0.68	52	46	0.88	42	0.81	88	0.85
	Inner	19	8	0.42	17	0.89	25	0.66	13	4	0.31	6	0.46	10	0.38	74	42	0.57	56	0.76	98	0.66
	Bass	6	4.5	0.75	6	1.00	10.5	0.88	6	2.5	0.42	2.5	0.42	5	0.42	42	33.5	0.80	38.5	0.92	72	0.86
	Sum/Mean	**34**	**21.5**	**0.63**	**32**	**0.94**	**53.5**	**0.79**	**38**	**21.5**	**0.57**	**19.5**	**0.51**	**41**	**0.54**	**168**	**121.5**	**0.72**	**136.5**	**0.81**	**258**	**0.77**
9 : 17	Melody	9	9	1.00	9	1.00	18	1.00	19	15	0.79	9	0.47	24	0.63	53	46	0.87	40	0.75	86	0.81
	Inner	19	9.5	0.50	14	0.74	23.5	0.62	14	4	0.29	6	0.43	10	0.36	78	44.5	0.57	51.5	0.66	96	0.62
	Bass	7	4	0.57	5	0.71	9	0.64	6	2.5	0.42	2.5	0.42	5	0.42	45	31	0.69	34.5	0.77	65.5	0.73
	Sum/Mean	**35**	**22.5**	**0.64**	**28**	**0.80**	**50.5**	**0.72**	**39**	**21.5**	**0.55**	**17.5**	**0.45**	**39**	**0.50**	**176**	**121.5**	**0.69**	**126**	**0.72**	**247.5**	**0.70**
10 : 18	Melody	9	9	1.00	9	1.00	18	1.00	18	15.5	0.86	8	0.44	23.5	0.65	50	45.5	0.91	38	0.76	83.5	0.84
	Inner	19	11	0.58	16	0.84	27	0.71	13	5.5	0.42	5	0.38	10.5	0.40	74	46	0.62	52	0.70	98	0.66
	Bass	6	5	0.83	6	1.00	11	0.92	7	2.5	0.36	2.5	0.36	5	0.63	43	33.5	0.78	37.5	0.87	71	0.83
	Sum/Mean	**34**	**25**	**0.74**	**31**	**0.91**	**56**	**0.82**	**38**	**23.5**	**0.62**	**15.5**	**0.41**	**39**	**0.51**	**167**	**125**	**0.75**	**127.5**	**0.76**	**252.5**	**0.76**
11 : 19	Melody	9	9	1.00	8	0.89	17	0.94	16	15	0.94	13	0.81	28	0.88	48	45	0.94	41	0.85	86	0.90
	Inner	18	11	0.61	13	0.72	24	0.67	9	6	0.67	5.5	0.61	11.5	0.64	70	49.5	0.71	52.5	0.75	102	0.73
	Bass	6	4	0.67	4	0.67	8	0.67	3	2.5	0.83	2.5	0.83	5	0.83	39	33.5	0.86	35.5	0.91	69	0.88
	Sum/Mean	**33**	**24**	**0.73**	**25**	**0.76**	**49**	**0.74**	**28**	**23.5**	**0.84**	**21**	**0.75**	**44.5**	**0.79**	**157**	**128**	**0.82**	**129**	**0.82**	**257**	**0.82**
11 : 20	Melody	9	9	1.00	8	0.89	17	0.94	16	15	0.94	13.5	0.84	28.5	0.89	48	45	0.94	41.5	0.86	86.5	0.90
	Inner	18	14	0.78	16	0.89	30	0.83	9	6	0.67	5.5	0.61	11.5	0.64	70	54.5	0.78	58.5	0.84	113	0.81
	Bass	6	4	0.67	4	0.67	8	0.67	3	2.5	0.83	2.5	0.83	5	0.83	39	33.5	0.86	35.5	0.91	69	0.88
	Sum/Mean	**33**	**27**	**0.82**	**28**	**0.85**	**55**	**0.83**	**28**	**23.5**	**0.84**	**21.5**	**0.77**	**45**	**0.80**	**157**	**133**	**0.85**	**135.5**	**0.86**	**268.5**	**0.86**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
12 : 21	Melody	9	9	1.00	8	0.89	17	0.94	18	15	0.83	13	0.72	28	0.78	51	44	0.86	41	0.80	85	0.83
	Inner	18	12	0.67	14	0.78	26	0.72	9	4.5	0.50	5.5	0.61	10	0.56	69	48.5	0.70	53.5	0.78	102	0.74
	Bass	6	5	0.83	5	0.83	10	0.83	4	2.5	0.63	3	0.75	5.5	0.69	40	35	0.88	37	0.93	72	0.90
	Sum/Mean	**33**	**26**	**0.79**	**27**	**0.82**	**53**	**0.80**	**31**	**22**	**0.71**	**21.5**	**0.69**	**43.5**	**0.70**	**160**	**127.5**	**0.80**	**131.5**	**0.82**	**259**	**0.81**
12 : 22	Melody	9	9	1.00	8	0.89	17	0.94	17	15.5	0.91	13	0.76	28.5	0.84	49	45.5	0.93	41	0.84	86.5	0.88
	Inner	18	13	0.72	15	0.83	28	0.78	9	6	0.67	5.5	0.61	11.5	0.64	69	53.5	0.78	54.5	0.79	108	0.78
	Bass	6	6	1.00	5	0.83	11	0.92	3	2.5	0.83	3	1.00	5.5	0.92	39	38	0.97	37	0.95	75	0.96
	Sum/Mean	**33**	**28**	**0.85**	**28**	**0.85**	**56**	**0.85**	**29**	**24**	**0.83**	**21.5**	**0.74**	**45.5**	**0.78**	**157**	**137**	**0.87**	**132.5**	**0.84**	**269.5**	**0.86**
13 : 23	Melody	9	9	1.00	9	1.00	18	1.00	16	14.5	091	12	0.75	26.5	0.83	48	44.5	0.93	41	0.85	85.5	0.89
	Inner	18	12	0.67	17	0.94	29	0.81	9	6	0.67	4.5	0.50	10.5	0.58	71	51.5	0.73	57.5	0.81	109	0.77
	Bass	6	3	0.50	6	1.00	9	0.75	3	2.5	0.83	3	1.00	5.5	0.92	39	32	0.82	37	0.95	69	0.88
	Sum/Mean	**33**	**24**	**0.73**	**32**	**0.97**	**56**	**0.85**	**28**	**23**	**0.82**	**19.5**	**0.70**	**42.5**	**0.76**	**158**	**128**	**0.81**	**135.5**	**0.86**	**263.5**	**0.83**
13 : 24	Melody	9	9	1.00	8	0.89	17	0.94	16	15.5	0.97	13	0.81	28.5	0.89	46	42.5	0.92	39	0.85	81.5	0.89
	Inner	18	12	0.67	17	0.94	29	0.81	9	6	0.67	4.5	0.50	10.5	0.58	70	52.5	0.75	62.5	0.89	115	0.82
	Bass	6	4	0.67	6	1.00	10	0.83	3	2.5	0.83	3	1.00	5.5	0.92	39	34	0.87	36	0.92	70	0.90
	Sum/Mean	**27**	**21**	**0.78**	**25**	**0.93**	**46**	**0.85**	**25**	**21.5**	**0.86**	**17.5**	**0.70**	**39**	**0.78**	**116**	**68**	**0.82**	**101.5**	**0.88**	**196.5**	**0.85**
14 : 25	Melody	9	9	1.00	9	1.00	18	1.00	16	14.5	0.91	12	0.75	26.5	0.83	48	44.5	0.93	42	0.88	86.5	0.90
	Inner	18	14.5	0.81	16	0.89	30.5	0.85	9	6	0.67	4.5	0.50	10.5	0.58	71	54.5	0.77	57	0.80	111.5	0.79
	Bass	7	3	0.43	3	0.43	6	0.43	3	2.5	0.83	3	1.00	5.5	0.92	42	33	0.79	36	0.86	69	0.82
	Sum/Mean	**34**	**26.5**	**0.78**	**28**	**0.82**	**54.5**	**0.80**	**28**	**23**	**0.82**	**19.5**	**0.70**	**42.5**	**0.76**	**161**	**132**	**0.82**	**135**	**0.84**	**267**	**0.83**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
14 : 26	Melody	9	9	1.00	9	1.00	18	1.00	16	14.5	0.91	12.5	0.78	27	0.84	48	44.5	0.93	42.5	0.89	87	0.91
	Inner	19	14	0.74	16	0.84	30	0.79	9	6	0.67	6.5	0.72	12.5	0.69	75	60	0.80	61.5	0.82	121.5	0.81
	Bass	7	4	0.57	4	0.57	8	0.57	3	2.5	0.83	3	1.00	5.5	0.92	40	33.5	0.84	35	0.88	68.5	0.86
	Sum/Mean	**35**	**27**	**0.77**	**29**	**0.83**	**56**	**0.80**	**28**	**23**	**0.82**	**22**	**0.79**	**45**	**0.80**	**163**	**138**	**0.85**	**139**	**0.85**	**277**	**0.85**
Sums/ Means	Melody	252	205	0.81	183	0.73	388	0.77	434	360	0.83	248	0.57	607.5	0.70	1304	1054	0.81	914.5	0.70	1969	0.75
	Inner	491	232	0.41	310	0.63	542	0.55	352	103	0.29	116	0.33	219	0.31	1992	998.5	0.50	1113	0.56	2112	0.53
	Bass	182	98.5	0.54	103	0.57	202	0.55	143	54.5	0.38	55.5	0.39	110	0.38	1161	821.5	0.71	837.5	0.72	1659	0.71
	Sum/Mean	**925**	**535**	**0.58**	**596**	**0.64**	**1131**	**0.61**	**929**	**517**	**0.56**	**420**	**0.45**	**936.5**	**0.50**	**4457**	**2874**	**0.64**	**2865**	**0.64**	**5739**	**0.64**

Appendix 2

ZYG Values Pertaining to S's Recall of *Chromatic Blues*

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
1 : 1	Melody	7	6	0.86	3	0.43	9	0.64	7	3	0.43	3	0.43	6	0.43	13	2.5	0.19	0	0.00	2.5	0.10
	Inner	12	4	0.33	2	0.17	6	0.25	12	0	0.00	0	0.00	0	0.00	18	2	0.11	1	0.06	3	0.08
	Bass	14	11.5	0.82	8	0.57	19.5	0.70	12	9	0.75	8	0.67	17	0.71	12	2	0.17	2	0.17	4	0.17
	Sum/Mean	**33**	**21.5**	**0.65**	**13**	**0.39**	**34.5**	**0.52**	**31**	**12**	**0.39**	**11**	**0.35**	**23**	**0.37**	**43**	**6.5**	**0.15**	**3**	**0.07**	**9.5**	**0.11**
2 : 2	Melody	13	1	0.08	2	0.15	3	0.12	14	1	0.07	2	0.14	3	0.11	10	5	0.50	0	0.00	5	0.25
	Inner	14	0.5	0.04	2	0.14	2.5	0.09	12	0	0.00	0	0.00	0	0.00	21	2.5	0.12	0	0.00	2.5	0.06
	Bass	14	9.5	0.68	11	0.79	20.5	0.73	14	11	0.79	9	0.64	20	0.71	14	1.5	0.11	0	0.00	1.5	0.05
	Sum/Mean	**41**	**11**	**0.27**	**15**	**0.37**	**26**	**0.32**	**40**	**12**	**0.30**	**11**	**0.28**	**23**	**0.29**	**45**	**9**	**0.20**	**0**	**0.00**	**9**	**0.10**
2 : 3	Melody	9	5.5	0.61	4	0.44	9.5	0.53	7	6	0.86	4	0.57	10	0.71	10	2	0.20	1.5	0.15	3.5	0.18
	Inner	13	2.5	0.19	2	0.15	4.5	0.17	14	2.5	0.18	4	0.29	6.5	0.23	18	0	0.00	1	0.06	1	0.03
	Bass	12	12	1.00	11	0.92	23	0.96	14	12	0.86	12	0.86	24	0.86	9	1	0.11	0	0.00	1	0.06
	Sum/Mean	**34**	**20**	**0.59**	**17**	**0.50**	**37**	**0.54**	**35**	**20.5**	**0.59**	**20**	**0.57**	**40.5**	**0.58**	**37**	**3**	**0.08**	**2.5**	**0.07**	**5.5**	**0.07**
3 : 4	Melody	7	6	0.86	6	0.86	12	0.86	7	7	1.00	7	1.00	14	1.00	12	3.5	0.29	3	0.25	6.5	0.27
	Inner	12	12	0.17	1	0.08	3	0.13	12	2.5	0.21	2.5	0.21	5	0.21	18	4	0.22	0	0.00	4	0.11
	Bass	12	12	1.00	9.5	0.79	21.5	0.90	14	11.5	0.82	9	0.64	20.5	0.73	6	5.5	0.92	0	0.00	5.5	0.46
	Sum/Mean	**31**	**20**	**0.65**	**16.5**	**0.53**	**36.5**	**0.59**	**33**	**21**	**0.64**	**18.5**	**0.56**	**39.5**	**0.60**	**36**	**13**	**0.36**	**3**	**0.08**	**16**	**0.22**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
3 : 5	Melody	8	6	0.75	6	0.75	12	0.75	7	5.5	0.79	7	1.00	12.5	0.89	9	3.5	0.39	3	0.33	6.5	0.36
	Inner	13	3.5	0.27	3	0.23	6.5	0.25	14	2	0.14	2	0.14	4	0.14	18	2	0.11	1	0.06	3	0.08
	Bass	12	12	1.00	9.5	0.79	21.5	0.90	15	12	0.80	10.5	0.70	22.5	0.75	6	4	0.67	0	0.00	4	0.33
	Sum/Mean	**33**	**21.5**	**0.65**	**18.5**	**0.56**	**40**	**0.61**	**36**	**19.5**	**0.54**	**19.5**	**0.54**	**39**	**0.54**	**33**	**9.5**	**0.29**	**4**	**0.12**	**13.5**	**0.20**
4 : 6	Melody	7	7	1.00	7	1.00	14	1.00	7	7	1.00	7	1.00	14	1.00	11	7.5	0.68	4	0.36	11.5	0.52
	Inner	14	3.5	0.25	4	0.29	7.5	0.27	19	3.5	0.18	4	0.21	7.5	0.20	18	1	0.06	0	0.00	1	0.03
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	2	0.33	1	0.17	3	0.25
	Sum/Mean	**33**	**22.5**	**0.68**	**22**	**0.67**	**44.5**	**0.67**	**39**	**22.5**	**0.58**	**22**	**0.56**	**44.5**	**0.57**	**35**	**10.5**	**0.30**	**5**	**0.14**	**15.5**	**0.22**
4 : 7	Melody	7	7	1.00	7	1.00	14	1.00	7	7	1.00	6.5	0.93	13.5	0.96	10	8	0.80	6	0.60	14	0.70
	Inner	15	3	0.20	3	0.20	6	0.20	18	4	0.22	4	0.22	8	0.22	18	5	0.28	2.5	0.14	7.5	0.21
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	3	0.50	0.5	0.08	3.5	0.29
	Sum/Mean	**34**	**22**	**0.65**	**21**	**0.62**	**43**	**0.63**	**38**	**23**	**0.61**	**21.5**	**0.57**	**44.5**	**0.59**	**34**	**16**	**0.47**	**9**	**0.26**	**25**	**0.37**
5 : 8	Melody	7	6	0.86	6	0.86	12	0.86	7	7	1.00	6	0.86	13	0.93	9	8	0.89	7	0.78	15	0.83
	Inner	14	4.5	0.32	4	0.29	8.5	0.30	16	4.5	0.28	3	0.19	7.5	0.23	18	4	0.22	1.5	0.08	5.5	0.15
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	3	0.50	1.5	0.25	4.5	0.38
	Sum/Mean	**33**	**22.5**	**0.68**	**21**	**0.64**	**43.5**	**0.66**	**36**	**23.5**	**0.65**	**20**	**0.56**	**43.5**	**0.60**	**33**	**15**	**0.45**	**10**	**0.30**	**25**	**0.38**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
5 : 9	Melody	8	6	0.75	6	0.75	12	0.75	7	6	0.86	4	0.57	10	0.71	9	8	0.89	7	0.78	15	0.83
	Inner	12	4.5	0.38	4	0.33	8.5	0.35	16	3	0.19	3	0.19	6	0.19	18	7	0.39	2	0.11	9	0.25
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	7.5	0.58	19.5	0.75	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**32**	**22.5**	**0.70**	**21**	**0.66**	**43.5**	**0.68**	**36**	**21**	**0.58**	**14.5**	**0.40**	**35.5**	**0.49**	**33**	**18**	**0.55**	**12**	**0.36**	**30**	**0.45**
6 : 10	Melody	7	6	0.86	6	0.86	12	0.86	7	7	1.00	6	0.86	13	0.93	9	6	0.67	7	0.78	13	0.72
	Inner	12	5	0.42	3	0.25	8	0.33	12	4.5	0.38	4	0.33	8.5	0.35	18	6	0.33	5	0.28	11	0.31
	Bass	12	12	1.00	11	0.92	23	0.96	13	11.5	0.88	12	0.92	23.5	0.90	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**31**	**23**	**0.74**	**20**	**0.65**	**43**	**0.69**	**32**	**23**	**0.72**	**22**	**0.69**	**45**	**0.70**	**33**	**15**	**0.45**	**15**	**0.45**	**30**	**0.45**
6 : 11	Melody	7	5	0.71	5	0.71	10	0.71	7	7	1.00	7	1.00	14	1.00	10	9	0.90	7	0.70	16	0.80
	Inner	12	4	0.33	3	0.25	7	0.29	15	5	0.33	5	0.33	10	0.33	18	8	0.44	6	0.33	14	0.39
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	12	0.92	24	0.92	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**31**	**21**	**0.68**	**19**	**0.61**	**40**	**0.65**	**35**	**24**	**0.69**	**24**	**0.69**	**48**	**0.69**	**34**	**20**	**0.59**	**16**	**0.47**	**36**	**0.53**
7 : 12	Melody	8	6	0.75	5	0.63	11	0.69	7	6	0.86	6	0.86	12	0.86	9	8	0.89	7	0.78	15	0.83
	Inner	12	5	0.42	3	0.25	8	0.33	15	4	0.27	3	0.20	7	0.23	18	5	0.28	6	0.33	11	0.31
	Bass	12	12	1.00	9.5	0.79	21.5	0.90	13	12	0.92	11	0.85	23	0.88	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**32**	**23**	**0.72**	**17.5**	**0.55**	**40.5**	**0.63**	**35**	**22**	**0.63**	**20**	**0.57**	**42**	**0.60**	**33**	**16**	**0.48**	**16**	**0.48**	**32**	**0.48**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
7 : 13	Melody	8	6	0.75	6	0.75	12	0.75	7	7	1.00	7	1.00	14	1.00	9	8	0.89	7	0.78	15	0.83
	Inner	12	3.5	0.29	4	0.33	7.5	0.31	17	5	0.29	5.5	0.32	10.5	0.31	18	7.5	0.42	7	0.39	14.5	0.40
	Bass	12	12	1.00	11	0.92	23	0.96	14	12	0.86	11	0.79	23	0.82	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**32**	**21.5**	**0.67**	**21**	**0.66**	**42.5**	**0.66**	**38**	**24**	**0.63**	**23.5**	**0.62**	**47.5**	**0.63**	**33**	**18.5**	**0.56**	**17**	**0.52**	**35.5**	**0.54**
8 : 14	Melody	7	7	1.00	7	1.00	14	1.00	7	6	0.86	6	0.86	12	0.86	9	8	0.89	7	0.78	15	0.83
	Inner	12	1	0.08	1	0.08	2	0.08	13	2	0.15	1.5	0.12	3.5	0.13	18	7	0.39	5.5	0.31	12.5	0.35
	Bass	12	12	1.00	11	0.92	23	0.96	14	12	0.86	11	0.79	23	0.82	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**31**	**20**	**0.65**	**19**	**0.61**	**39**	**0.63**	**34**	**20**	**0.59**	**18.5**	**0.54**	**38.5**	**0.57**	**33**	**18**	**0.55**	**15.5**	**0.47**	**33.5**	**0.51**
8 : 15	Melody	7	6	0.86	6	0.86	12	0.86	8	7	0.88	7	0.88	14	0.88	9	8	0.89	9	1.00	17	0.94
	Inner	12	2.5	0.21	3.5	0.29	6	0.25	12	1	0.08	2	0.17	3	0.13	18	6	0.33	7	0.39	13	0.36
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**31**	**20.5**	**0.66**	**20.5**	**0.66**	**41**	**0.66**	**33**	**20**	**0.61**	**20**	**0.61**	**40**	**0.61**	**33**	**17**	**0.52**	**19**	**0.58**	**36**	**0.55**
9 : 16	Melody	7	6	0.86	6	0.86	12	0.86	7	6	0.86	6	0.86	12	0.86	9	8	0.89	7	0.78	15	0.83
	Inner	12	3.5	0.29	5.5	0.46	9	0.38	15	2.5	0.17	6	0.40	8.5	0.28	18	6.5	0.36	7	0.39	13.5	0.38
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	3	0.50	3	0.50	6	0.50
	Sum/Mean	**31**	**21.5**	**0.69**	**22.5**	**0.73**	**44**	**0.71**	**35**	**20.5**	**0.59**	**23**	**0.66**	**43.5**	**0.62**	**33**	**17.5**	**0.53**	**17**	**0.52**	**34.5**	**0.52**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
9 : 17	Melody	7	6	0.86	6	0.86	12	0.86	7	6	0.86	6	0.86	12	0.86	9	8	0.89	9	1.00	17	0.94
	Inner	12	3	0.25	5	0.42	8	0.33	12	4	0.33	4.5	0.38	8.5	0.35	18	5.5	0.31	9	0.50	14.5	0.40
	Bass	12	12	1.00	11	0.92	23	0.96	13	11	0.85	11	0.85	22	0.85	6	3	0.50	4	0.67	7	0.58
	Sum/Mean	**31**	**21**	**0.68**	**22**	**0.71**	**43**	**0.69**	**32**	**21**	**0.66**	**21.5**	**0.67**	**42.5**	**0.66**	**33**	**16.5**	**0.50**	**22**	**0.67**	**38.5**	**0.58**
10 : 18	Melody	7	6	0.86	6	0.86	12	0.86	7	7	1.00	7	1.00	14	1.00	9	8	0.89	7	0.78	15	0.83
	Inner	12	3	0.25	5.5	0.46	8.5	0.35	12	2.5	0.21	4	0.33	6.5	0.27	18	5	0.28	8	0.44	13	0.36
	Bass	12	12	1.00	11	0.92	23	0.96	12	12	1.00	11	0.92	23	0.96	6	3	0.50	4	0.67	7	0.58
	Sum/Mean	**31**	**21**	**0.68**	**22.5**	**0.79**	**43.5**	**0.70**	**31**	**21.5**	**0.69**	**22**	**0.71**	**43.5**	**0.70**	**33**	**16**	**0.48**	**19**	**0.58**	**35**	**0.53**
10 : 19	Melody	7	6	0.86	6	0.86	12	0.86	8	6	0.75	6	0.75	12	0.75	9	8	0.89	9	1.00	17	0.94
	Inner	12	3.5	0.29	4.5	0.38	8	0.33	12	2.5	0.21	4	0.33	6.5	0.27	18	5.5	0.31	8	0.44	13.5	0.38
	Bass	12	12	1.00	11	0.92	23	0.96	12	12	1.00	11	0.92	23	0.96	6	3	0.50	4	0.67	7	0.58
	Sum/Mean	**31**	**21.5**	**0.69**	**21.5**	**0.69**	**43**	**0.69**	**32**	**20.5**	**0.64**	**21**	**0.66**	**41.5**	**0.65**	**33**	**16.5**	**0.50**	**21**	**0.64**	**37.5**	**0.57**
11 : 20	Melody	7	7	1.00	7	1.00	14	1.00	7	6	0.86	1	0.14	7	0.50	9	8	0.89	5.5	0.61	13.5	0.75
	Inner	13	3	0.23	2.5	0.19	5.5	0.21	13	3	0.23	3.5	0.27	6.5	0.25	18	4.5	0.25	6	0.33	10.5	0.29
	Bass	12	12	1.00	11	0.92	23	0.96	12	12	1.00	11	0.92	23	0.96	6	3	0.50	2.5	0.42	5.5	0.46
	Sum/Mean	**32**	**22**	**0.69**	**20.5**	**0.64**	**42.5**	**0.66**	**32**	**21**	**0.66**	**15.5**	**0.48**	**36.5**	**0.57**	**33**	**15.5**	**0.47**	**14**	**0.42**	**29.5**	**0.45**

Session : Trial		Excerpt 1							Excerpt 3							Excerpt 2						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
11 : 21	Melody	7	6	0.86	6	0.86	12	0.86	7	6	0.86	5	0.71	11	0.79	9	8	0.89	5	0.56	13	0.72
	Inner	12	4	0.33	5.5	0.46	9.5	0.40	12	6.5	0.54	4.5	0.38	11	0.46	18	5.5	0.31	4.5	0.25	10	0.28
	Bass	12	12	1.00	11	0.92	23	0.96	13	12	0.92	11	0.85	23	0.88	6	3	0.50	2.5	0.42	5.5	0.46
	Sum/Mean	**31**	**22**	**0.71**	**22.5**	**0.73**	**44.5**	**0.72**	**32**	**24.5**	**0.77**	**20.5**	**0.64**	**45**	**0.70**	**33**	**16.5**	**0.50**	**12**	**0.36**	**28.5**	**0.43**
Sums/ Means	Melody	159	124	0.78	119	0.75	243	0.76	156	126.5	0.81	117	0.75	243	0.78	202	143	0.71	118	0.58	261	0.65
	Inner	264	69	0.26	71	0.27	140	0.27	293	64.5	0.22	70	0.24	134.5	0.23	381	99.5	0.26	88	0.23	187.5	0.25
	Bass	256	249	0.97	224	0.87	473	0.92	276	246	0.89	223	0.81	469	0.85	143	61	0.43	46	0.32	107	0.37
	Sum/Mean	**679**	**442**	**0.65**	**414**	**0.61**	**855**	**0.63**	**725**	**437**	**0.60**	**410**	**0.56**	**846.5**	**0.58**	**726**	**304**	**0.42**	**252**	**0.35**	**555.5**	**0.38**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
1 : 1	Melody	13	3	0.23	1	0.08	4	0.15	16	2.5	0.16	9	0.56	11.5	0.36	56	17	0.30	16	0.29	33	0.29
	Inner	24	6	0.25	1	0.04	7	0.15	8	1.5	0.19	2	0.25	3.5	0.22	74	13.5	0.18	6	0.08	19.5	0.13
	Bass	13	3.5	0.27	3	0.23	6.5	0.25	3	0.5	0.17	2	0.67	2.5	0.42	54	26.5	0.49	23	0.43	49.5	0.46
	Sum/Mean	**50**	**12.5**	**0.25**	**5**	**0.10**	**17.5**	**0.18**	**27**	**4.5**	**0.17**	**13**	**0.48**	**17.5**	**0.32**	**184**	**57**	**0.31**	**45**	**0.24**	**102**	**0.28**
2 : 2	Melody	13	2.5	0.19	3	0.23	5.5	0.21	16	7.5	0.47	3.5	0.22	11	0.34	66	17	0.26	10.5	0.16	27.5	0.21
	Inner	20	0.5	0.03	1	0.05	1.5	0.04	8	0	0.00	1	0.13	1	0.06	75	3.5	0.05	4	0.05	7.5	0.05
	Bass	17	3	0.18	0	0.00	3	0.09	3	1	0.33	1.5	0.50	2.5	0.42	62	26	0.42	21.5	0.35	47.5	0.38
	Sum/Mean	**50**	**6**	**0.12**	**4**	**0.08**	**10**	**0.10**	**27**	**8.5**	**0.31**	**6**	**0.22**	**14.5**	**0.27**	**203**	**46.5**	**0.23**	**36**	**0.18**	**82.5**	**0.20**
2 : 3	Melody	9	0	0.00	2	0.22	2	0.11	18	13	0.72	8	0.44	21	0.58	53	26.5	0.50	19.5	0.37	46	0.43
	Inner	18	0	0.00	0	0.00	0	0.00	8	3	0.38	1.5	0.19	4.5	0.28	71	8	0.11	8.5	0.12	16.5	0.12
	Bass	8	0.5	0.06	2	0.25	2.5	0.16	3	1	0.33	1	0.33	2	0.33	46	26.5	0.58	26	0.57	52.5	0.57
	Sum/Mean	**35**	**0.5**	**0.01**	**4**	**0.11**	**4.5**	**0.06**	**29**	**17**	**0.59**	**10.5**	**0.36**	**27.5**	**0.47**	**170**	**61**	**0.36**	**54**	**0.32**	**115**	**0.34**
3 : 4	Melody	9	0.5	0.06	0	0.00	0.5	0.03	17	11	0.65	7	0.41	18	0.53	52	28	0.54	23	0.44	51	0.49
	Inner	18	2.5	0.14	1	0.06	3.5	0.10	8	6	0.75	3	0.38	9	0.56	68	17	0.25	7.5	0.11	24.5	0.18
	Bass	9	2.5	0.28	1	0.11	3.5	0.19	3	1	0.33	1	0.33	2	0.33	44	32.5	0.74	20.5	0.47	53	0.60
	Sum/Mean	**36**	**5.5**	**0.15**	**2**	**0.06**	**7.5**	**0.10**	**28**	**18**	**0.64**	**11**	**0.39**	**29**	**0.52**	**164**	**77.5**	**0.47**	**51**	**0.31**	**128.5**	**0.39**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
3 : 5	Melody	11	4.5	0.41	4	0.36	8.5	0.39	19	14	0.74	10	0.53	24	0.63	54	33.5	0.62	30	0.56	63.5	0.59
	Inner	18	1.5	0.08	1	0.06	2.5	0.07	8	6	0.75	3	0.38	9	0.56	71	15	0.21	10	0.14	25	0.18
	Bass	6	3	0.50	1	0.17	4	0.33	3	1	0.33	1	0.33	2	0.33	42	32	0.76	22	0.52	54	0.64
	Sum/Mean	**35**	**9**	**0.26**	**6**	**0.17**	**15**	**0.21**	**30**	**21**	**0.70**	**14**	**0.47**	**35**	**0.58**	**167**	**80.5**	**0.48**	**62**	**0.37**	**142.5**	**0.43**
4 : 6	Melody	10	4.5	0.45	3	0.30	7.5	0.38	17	13	0.76	5	0.29	18	0.53	52	39	0.75	26	0.50	65	0.63
	Inner	18	6	0.33	5	0.28	11	0.31	8	5	0.63	3	0.38	8	0.50	77	19	0.25	16	0.21	35	0.23
	Bass	6	3	0.50	2	0.33	5	0.42	3	1	0.33	1	0.33	2	0.33	40	30	0.75	26	0.65	56	0.70
	Sum/Mean	**34**	**13.5**	**0.40**	**10**	**0.29**	**23.5**	**0.35**	**28**	**19**	**0.68**	**9**	**0.32**	**28**	**0.50**	**169**	**88**	**0.52**	**68**	**0.40**	**156**	**0.46**
4 : 7	Melody	10	6.5	0.62	3	0.30	9.5	0.48	16	12.4	0.78	8	0.50	20.4	0.64	50	40.9	0.82	30.5	0.61	71.4	0.71
	Inner	18	7.5	0.42	4	0.22	11.5	0.32	8	7	0.88	3	0.38	10	0.63	77	26.5	0.34	16.5	0.21	43	0.28
	Bass	6	3	0.50	2	0.33	5	0.42	3	1	0.33	1	0.33	2	0.33	40	31	0.78	25.5	0.64	56.5	0.71
	Sum/Mean	**34**	**17**	**0.50**	**9**	**0.26**	**26**	**0.38**	**27**	**20.4**	**0.76**	**12**	**0.44**	**32.4**	**0.60**	**167**	**98.4**	**0.59**	**72.5**	**0.43**	**170.9**	**0.51**
5 : 8	Melody	10	7	0.70	5	0.50	12	0.60	16	15	0.94	11	0.69	26	0.81	49	43	0.88	35	0.71	78	0.80
	Inner	18	8.5	0.47	6	0.33	14.5	0.40	8	5	0.63	3	0.38	8	0.50	74	26.5	0.36	17.5	0.24	44	0.30
	Bass	6	3.5	0.58	3	0.50	6.5	0.54	3	1	0.33	1	0.33	2	0.33	40	31.5	0.79	27.5	0.69	59	0.74
	Sum/Mean	**34**	**19**	**0.56**	**14**	**0.41**	**33**	**0.49**	**27**	**21**	**0.78**	**15**	**0.56**	**36**	**0.67**	**163**	**101**	**0.62**	**80**	**0.49**	**181**	**0.56**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
5 : 9	Melody	10	8	0.80	5	0.50	13	0.65	16	15	0.94	9	0.56	24	0.75	50	43	0.86	31	0.62	74	0.74
	Inner	18	5.5	0.31	4	0.22	9.5	0.26	8	6	0.75	2	0.25	8	0.50	72	26	0.36	15	0.21	41	0.28
	Bass	6	3.5	0.58	2	0.33	5.5	0.46	3	1	0.33	1	0.33	2	0.33	40	31.5	0.79	24.5	0.61	56	0.70
	Sum/Mean	**34**	**17**	**0.50**	**11**	**0.32**	**28**	**0.41**	**27**	**22**	**0.81**	**12**	**0.44**	**34**	**0.63**	**162**	**100.5**	**0.62**	**70.5**	**0.44**	**171**	**0.53**
6 : 10	Melody	9	9	1.00	7	0.78	16	0.89	17	13	0.76	8	0.47	21	0.62	49	41	0.84	34	0.69	75	0.77
	Inner	18	7	0.39	7	0.39	14	0.39	8	5	0.63	2	0.25	7	0.44	68	27.5	0.40	21	0.31	48.5	0.36
	Bass	6	3	0.50	4	0.67	7	0.58	3	1	0.33	1	0.33	2	0.33	40	30.5	0.76	31	0.78	61.5	0.77
	Sum/Mean	**33**	**19**	**0.58**	**18**	**0.55**	**37**	**0.56**	**28**	**19**	**0.68**	**11**	**0.39**	**30**	**0.54**	**157**	**99**	**0.63**	**86**	**0.55**	**185**	**0.59**
6 : 11	Melody	9	7	0.78	5	0.56	12	0.67	16	13	0.81	8	0.50	21	0.66	49	41	0.84	32	0.65	73	0.74
	Inner	18	8.5	0.47	4	0.22	12.5	0.35	8	3	0.38	2	0.25	5	0.31	71	28.5	0.40	20	0.28	48.5	0.34
	Bass	6	3	0.50	2	0.33	5	0.42	3	1	0.33	1	0.33	2	0.33	40	31	0.78	29	0.73	60	0.75
	Sum/Mean	**33**	**18.5**	**0.56**	**11**	**0.33**	**29.5**	**0.45**	**27**	**17**	**0.63**	**11**	**0.41**	**28**	**0.52**	**160**	**100.5**	**0.63**	**81**	**0.51**	**181.5**	**0.57**
7 : 12	Melody	9	9	1.00	6	0.67	15	0.83	18	15	0.83	11	0.61	26	0.72	51	44	0.86	35	0.69	79	0.77
	Inner	18	5	0.28	6	0.33	11	0.31	8	6	0.75	2	0.25	8	0.50	71	25	0.35	20	0.28	45	0.32
	Bass	8	2.5	0.31	3	0.38	5.5	0.34	3	1	0.33	1	0.33	2	0.33	42	30.5	0.73	27.5	0.65	58	0.69
	Sum/Mean	**35**	**16.5**	**0.47**	**15**	**0.43**	**31.5**	**0.45**	**29**	**22**	**0.76**	**14**	**0.48**	**36**	**0.62**	**164**	**99.5**	**0.61**	**82.5**	**0.50**	**182**	**0.55**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
7 : 13	Melody	9	8.5	0.94	6	0.67	14.5	0.81	16	16	1.00	11	0.69	27	0.84	49	45.5	0.93	37	0.76	82.5	0.84
	Inner	18	5	0.28	6	0.33	11	0.31	8	6	0.75	3	0.38	9	0.56	73	27	0.37	25.5	0.35	52.5	0.36
	Bass	6	3	0.50	3	0.50	6	0.50	3	1	0.33	1	0.33	2	0.33	41	31	0.76	29	0.71	60	0.73
	Sum/Mean	**33**	**16.5**	**0.50**	**15**	**0.42**	**31.5**	**0.48**	**27**	**23**	**0.85**	**15**	**0.56**	**38**	**0.70**	**163**	**103.5**	**0.63**	**91.5**	**0.56**	**195**	**0.60**
8 : 14	Melody	9	8.5	0.94	7	0.78	15.5	0.86	16	16	1.00	13	0.81	29	0.91	48	45.5	0.95	40	0.83	85.5	0.89
	Inner	18	5	0.28	6	0.33	11	0.31	8	6	0.75	2	0.25	8	0.50	69	21	0.30	16	0.23	37	0.27
	Bass	6	3	0.50	3	0.50	6	0.50	3	1	0.33	1	0.33	2	0.33	41	31	0.76	29	0.71	60	0.73
	Sum/Mean	**33**	**16.5**	**0.50**	**16**	**0.48**	**32.5**	**0.49**	**27**	**23**	**0.85**	**16**	**0.59**	**39**	**0.72**	**158**	**97.5**	**0.62**	**85**	**0.54**	**182.5**	**0.58**
8 : 15	Melody	9	7	0.78	6	0.67	13	0.72	16	15	0.94	11	0.69	26	0.81	49	43	0.88	39	0.80	82	0.84
	Inner	18	5	0.28	7	0.39	12	0.33	8	6	0.75	2	0.25	8	0.50	68	20.5	0.30	21.5	0.32	42	0.31
	Bass	6	3	0.50	4	0.67	7	0.58	3	3	1.00	2	0.67	5	0.83	40	33	0.83	31	0.78	64	0.80
	Sum/Mean	**33**	**15**	**0.45**	**17**	**0.52**	**32**	**0.48**	**27**	**24**	**0.89**	**15**	**0.56**	**39**	**0.72**	**157**	**96.5**	**0.61**	**91.5**	**0.58**	**188**	**0.60**
9 : 16	Melody	9	8.5	0.94	8	0.89	16.5	0.92	16	16	1.00	11	0.69	27	0.84	48	44.5	0.93	38	0.79	82.5	0.86
	Inner	18	16	0.33	8	0.44	14	0.39	8	6	0.75	2	0.25	8	0.50	71	24.5	0.35	28.5	0.40	53	0.37
	Bass	6	3	0.50	4	0.67	7	0.58	3	2	0.67	2	0.67	4	0.67	40	32	0.80	31	0.78	63	0.79
	Sum/Mean	**33**	**17.5**	**0.53**	**20**	**0.61**	**37.5**	**0.57**	**27**	**24**	**0.89**	**15**	**0.56**	**39**	**0.72**	**159**	**101**	**0.64**	**97.5**	**0.61**	**198.5**	**0.62**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
9 : 17	Melody	9	8.5	0.94	9	1.00	17.5	0.97	16	16	1.00	11	0.69	27	0.84	48	44.5	0.93	41	0.85	85.5	0.89
	Inner	18	5	0.28	8	0.44	13	0.36	8	6	0.75	2	0.25	8	0.50	68	23.5	0.35	28.5	0.42	52	0.38
	Bass	6	3	0.50	4	0.67	7	0.58	3	2	0.67	2	0.67	4	0.67	40	31	0.78	32	0.80	63	0.79
	Sum/Mean	**33**	**16.5**	**0.50**	**21**	**0.64**	**37.5**	**0.57**	**27**	**24**	**0.89**	**15**	**0.56**	**39**	**0.72**	**156**	**99**	**0.63**	**101.5**	**0.65**	**200.5**	**0.64**
10 : 18	Melody	9	9	1.00	7	0.78	16	0.89	16	16	1.00	11	0.69	27	0.84	48	46	0.96	38	0.79	84	0.88
	Inner	18	4	0.22	6	0.33	10	0.28	8	6	0.75	2	0.25	8	0.50	68	20.5	0.30	25.5	0.38	46	0.34
	Bass	6	2.5	0.42	3	0.50	5.5	0.46	3	2	0.67	2	0.67	4	0.67	39	31.5	0.81	31	0.79	62.5	0.80
	Sum/Mean	**33**	**15.5**	**0.47**	**16**	**0.48**	**31.5**	**0.48**	**27**	**24**	**0.89**	**15**	**0.56**	**39**	**0.72**	**155**	**98**	**0.63**	**94.5**	**0.61**	**192.5**	**0.62**
10 : 19	Melody	9	9	1.00	8	0.89	17	0.94	16	16	1.00	14	0.88	30	0.94	49	45	0.92	43	0.88	88	0.90
	Inner	18	5.5	0.31	8	0.44	13.5	0.38	8	4	0.50	2	0.25	6	0.38	68	21	0.31	26.5	0.39	47.5	0.35
	Bass	6	3	0.50	4	0.67	7	0.58	3	3	1.00	1.5	0.50	4.5	0.75	39	33	0.85	31.5	0.81	64.5	0.83
	Sum/Mean	**33**	**17.5**	**0.53**	**20**	**0.61**	**37.5**	**0.57**	**27**	**23**	**0.85**	**17.5**	**0.65**	**40.5**	**0.75**	**156**	**99**	**0.63**	**101**	**0.65**	**200**	**0.64**
11 : 20	Melody	9	8.5	0.94	6	0.67	14.5	0.81	16	14	0.88	12	0.75	26	0.81	48	43.5	0.91	31.5	0.66	75	0.78
	Inner	18	4.5	0.25	6	0.33	10.5	0.29	8	6	0.75	2.5	0.31	8.5	0.53	70	21	0.30	20.5	0.29	41.5	0.30
	Bass	6	3	0.50	3	0.50	6	0.50	3	1	0.33	1	0.33	2	0.33	39	31	0.79	28.5	0.73	59.5	0.76
	Sum/Mean	**33**	**16**	**0.48**	**15**	**0.45**	**31**	**0.47**	**27**	**21**	**0.78**	**15.5**	**0.57**	**36.5**	**0.68**	**157**	**95.5**	**0.61**	**80.5**	**0.51**	**176**	**0.56**

Session : Trial		Excerpt 4							Excerpt 5							Sums/Means						
		#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG	#Rel	#Z(R)	ZYG(R)	#Z(P)	ZYG(P)	#Z	ZYG
11 : 21	Melody	9	8.5	0.94	7	0.78	15.5	0.86	16	15	0.94	12	0.75	27	0.84	48	43.5	0.91	35	0.73	78.5	0.82
	Inner	18	5	0.28	8	0.44	13	0.36	8	6	0.75	2	0.25	8	0.50	68	27	0.40	24.5	0.36	51.5	0.38
	Bass	6	3	0.50	4	0.67	7	0.58	3	1	0.33	1	0.33	2	0.33	40	31	0.78	29.5	0.74	60.5	0.76
	Sum/Mean	**33**	**16.5**	**0.50**	**19**	**0.58**	**35.5**	**0.54**	**27**	**22**	**0.81**	**15**	**0.53**	**37**	**0.69**	**156**	**101.5**	**0.65**	**89**	**0.57**	**190.5**	**0.61**
Sums/ Means	Melody	203	138	0.68	108	0.53	246	0.60	346	284	0.82	204	0.59	487.9	0.71	1066	814.9	0.76	665	0.62	1480	0.69
	Inner	386	104	0.27	103	0.27	207	0.27	168	106	0.63	47	0.28	152.5	0.45	1492	442	0.30	379	0.25	821	0.28
	Bass	151	60.5	0.40	57	0.38	118	0.39	63	27.5	0.44	27	0.43	54.5	0.43	889	644	0.72	576.5	0.65	1221	0.69
	Sum/Mean	**740**	**302**	**0.41**	**268**	**0.36**	**570**	**0.38**	**577**	**417**	**0.72**	**278**	**0.48**	**694.9**	**0.60**	**3447**	**1901**	**0.55**	**1620.5**	**0.47**	**3521**	**0.51**

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