Chapter 13

Another exceptional musical memory: evidence from a savant of how atonal music is processed in cognition

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Abstract

This chapter builds on the empirical work reported by Sloboda, Hermelin, and O'Connor in 1985, in which a musical savant ('NP') attempted to learn a tonal piece by Grieg and a whole-tone composition by Bartôk. NP's error rate was 8% in the former and 63% in the latter, suggesting his ability to reproduce music (at least in the short term) was confined to tonal music and was structurally based. In the current study, a second savant ('DP'), publicly renowned for his capacity for reproducing many thousands of pieces from memory, attempted to learn an atonal piece by Schoenberg and a specially composed tonal 'equivalent', which as far as possible matched the original in terms of global structure, number of notes, frequency of occurrence of melodic intervals, density, and rhythmic complexity. The results showed that DP too, despite having absolute pitch and the ability to disaggregate simultaneous clusters of four pitches with 100% accuracy, found the atonal music more difficult to memorize than the tonal. Indeed, he imposed conventional structures on the Schoenberg piece, altering pitches so they fitted within a quasi-tonal framework. The implications for DP's creativity are discussed, and the potential contribution of the findings to the ongoing debate on the place of 'compositional' and 'listening' grammars in the musical experience.

I first met John Sloboda in 1988 at a conference in Reading organized by the then Society for Research in Psychology of Music and Music Education (now known rather more succinctly as SEMPRE[1]). I was presenting a paper concerning the music education of blind children, including those with intellectual impairments, an enterprise in which I was joined by my pupil, Derek Paravicini, a prodigious musical savant. Today, Derek's exceptional pianistic talents in the context of his severe learning difficulties are internationally recognized, but at the time he was just 9 years old and attended a special school in London where I was the music teacher (see Ockelford, 2007a).

One of the most important frames of reference for my presentation was John's seminal paper, 'An exceptional musical memory', written with Beate Hermelin and Neil O'Connor, which had recently appeared in *Music Perception* (Sloboda, Hermelin, & O'Connor, 1985). This gave an account of research in which a musical savant ('NP') attempted to learn a 'tonal' piece by Grieg (the *Melodie*, from his collection of *Lyric Pieces*, op. 47, no. 3, for piano) and a so-called 'atonal' composition by Bartôk (the *Whole-Tone Scale* from *Mikrokosmos*, Book 5). Overall, NP's error rate was 8% in the former and 63% in the latter, which was taken to suggest that his ability to reproduce music (at least in the short term) was confined to 'tonal' pieces and was therefore 'structurally based' (1985, p. 166).

Replications of the experiment with other savants subsequently produced rather different results, however. For example, Leon Miller's study of Eddie, a young, visually impaired, learning disabled pianist, revealed an accuracy in reproduction over five trials of 72% for the Grieg and 37% for the Bartôk.[2] Miller observes that, for Eddie, 'the whole-tone piece clearly was a novel and interesting challenge. At the first trial he began experimenting with the pattern of intervals it contained. In later sessions with his teacher the complete piece was taught to him and it became part of his active repertoire' (1989, pp. 145–6). Miller concluded that 'the present results suggest savant skill or interest is by no means restricted to the traditional diatonic scale' (1989, pp. 145–6).

The difference in the fidelity with which the two pieces were reproduced was even less marked in the case of a high functioning autistic savant ('TR'), who was studied by Robyn Young and Ted Nettelbeck. TR is said to have replicated the Grieg almost perfectly, with the preservation of melody and harmony, although on occasion melodic embellishments were omitted and different inversions of chords were substituted (Young and Nettelbeck, 1995, p. 242). TR's exceptional abilities were similarly in evidence in his reproduction of the Bartôk: although, like NP and Eddie, he is reported to have found the piece more difficult than Grieg's *Melodie*, he made relatively few errors, and these were 'predominantly due to the interpolation of material consistent with the whole-tone scale' (1995, p. 242).

Theoretical assumptions

To interpret and understand these differing results we need to unpack some of the key assumptions underlying Sloboda and colleagues' original research. We begin with the belief that expertise (exemplified in this case by successful learning and recall) requires 'structural knowledge' (1985, p. 158). But what *is* musical structure, what form does 'music-structural knowledge' take, and why should it aid memory?

It has long been acknowledged in a wide range of musicological literatures—from the celebrated early twentieth-century *Harmonielehre* of Heinrich Schenker (1906) and Arnold Schoenberg (1911), for example, to the influential texts on music and meaning formulated by Leonard Meyer (1956, 1967, 1973) and the innovative, mathematically inspired thinking of David Lewin (1987)—that structure equates to *patterns* in sound, to *regularities* in the perceived sonic fabric. From a psychological standpoint, these are thought to facilitate the processing of perceptual information by enabling it to be encoded parsimoniously, thereby making fewer demands on data storage and retrieval: see, for example, Simon and Sumner (1968), Deutsch (1980), Deutsch and Feroe (1981), and Lerdahl and Jackendoff (1983, p. 52).

My own position, developed over the past two decades or so and conceptualized as 'zygonic' theory (for instance, Ockelford, 1991, 1999, 2002, 2004, 2005a, 2005b, 2006a, 2009, 2010a), is that all the diverse guises in which musical structure appears, whether melodic or harmonic, rhythmic or metric, motivic or thematic, tonal or textural, formal or processive, hierarchic or architectonic … stem from one common principle: *imitation*. This in turn implies the potential repetition (exact or approximate) of all the perceived aspects of musical sound: notes, intervals, chords, and keys; durations, inter-onset intervals, accents, and metres; and timbres, dynamics, modes of articulation, and textures. Analysis shows that, in Western classical music, at least, over 40 forms of repetition may be in operation at any one time, functioning in an integrated way, variously reinforcing or complementing one another, or even jockeying with each other for perceptual supremacy (Ockelford, 1999, pp. 704–761; 2010a, pp. 106–129).

As far as their impact on memory is concerned, I believe it is helpful to think of these manifestations of structure as being at the level of *events*, *groups*, or *frameworks* (cf. Ockelford, 2008a, pp. 99–102). In relation to Bartôk's *Whole-Tone Scale*, an example of structure pertaining to events is to be found at bar 3, where successive notes that constitute the top line are separated in terms of pitch by a common interval (the major 2nd, or 'whole-tone') and in the context of perceived time by an interonset interval of a quaver (equating to a little over a quarter of a second at the tempo marked). This arrangement can be interpreted zygonically and represented visually as shown in Figure 13.1. The three 'primary interperspective relationships' of *pitch* ('primary' since they are at the level adjacent to the perceptual surface and 'interperspective' since they exist between *per*ceived a*spects* of sound) are shown linking successive notes (D, E, F♯, and G♯). Zygonic theory hypothesises that the cognitive acknowledgement of this pitch structure occurs through the (typically non-conscious) mental formulation of 'secondary zygonic relationships', which reflect the fact that the second primary relationship is a repetition of the first, and that the third repeats the second. A corresponding series of relationships is assumed to unfold in relation to the *onsets* of the notes. Analysis suggests that recognition of this coordinated pitch-time structure offers an advantage to memory over the 'raw' data of 25%, since in each domain, four perceptual values can be encoded as a single primary relationship and two secondaries.

An example of structure relating to groups, which can be interpreted as zygonic relationships of rhythm and 'profile'[3] operating in parallel, is to be found in bars 1 and 5 of *Whole-Tone Scale* (see Figure 13.2). Here the implied advantage to memory is 50%.

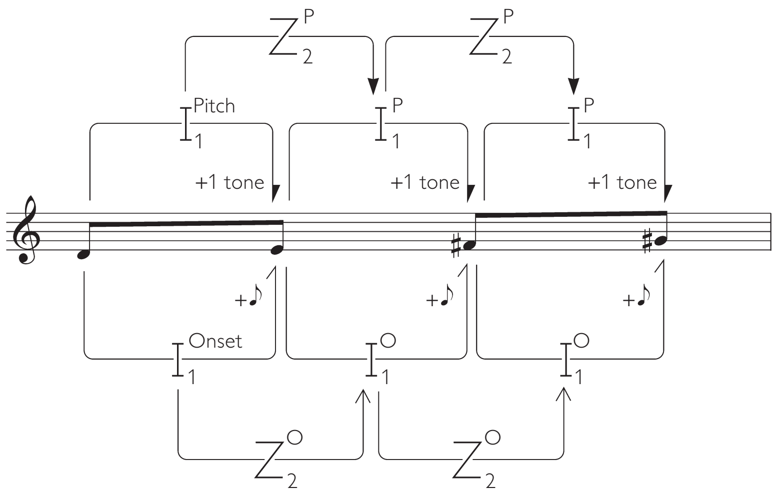


Fig. 13.1 Example of structure at the level of *events* in Bartôk's *Whole-Tone Scale*.

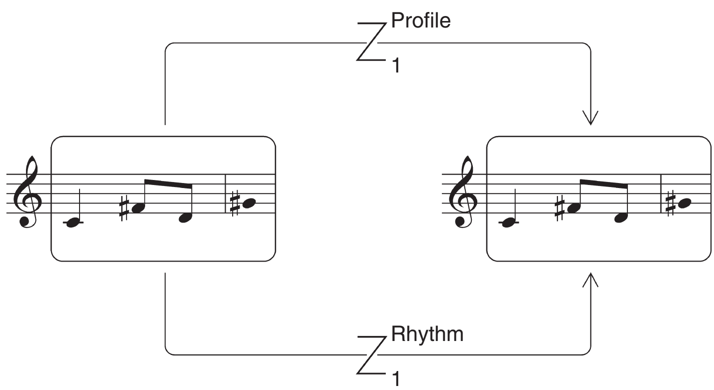


Fig. 13.2 Example of structure at the level of *groups*.

Finally, an example of structure pertaining to a framework is to be found in bars 13 and 14 of *Whole-Tone Scale*. The equidistant pentatonic substructure that is established in the opening six bars and reaffirmed in bars 7–12 appears again in bar 13, simultaneously at two new pitch levels (see Figure 13.3). Frameworks such as this enable pitches not only to be encoded as qualia in their own right and as the intervals between them, but also in a more abstract way—metaphorically, as rungs on a ladder. These may either be gauged successively in relative terms (whereby the contour in the right hand (RH) of bars 13 and 14 would be represented as +1, +1, +1, –1, –1, –1, for instance) or in relation to a perceptually predominant 'rung', which, in the passage in question, is likely to be the G♭ (as it is emphasized through being sustained), yielding the following series of values: 0, +1, +2, +3, +2, +1, 0.

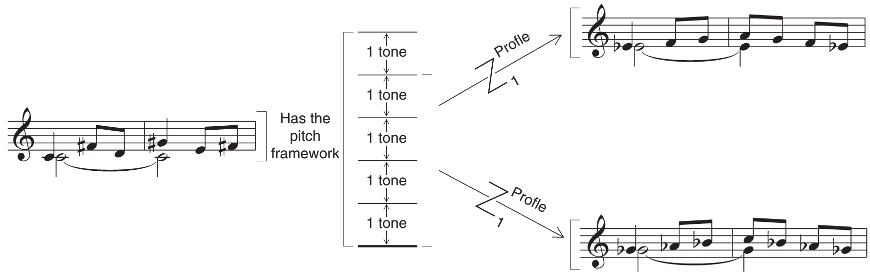


Fig. 13.3 Example of structure at the level of *frameworks*.

Although the symmetry of the whole-tone scale means that neither of these representations confers a processing advantage over those that deal more directly in the pitches and the intervals between them (see Figure 13.1), they nonetheless offer another perceptual dimension to the stimuli and offer distinct routes to codifying their underlying structure. And it seems likely that what may be termed music's 'structural multidimensionality' is an asset to the would-be memorizer: research reaching right back to Pollack and Ficks (1954) (discussed in Miller, 1956) suggests that multidimensional auditory percepts, which are richer in information than those that vary in one dimension, offer more for the mind to seize on. One can hypothesize that independent qualities pertaining to a single event mutually reinforce each other in recall and enable cross-domain assumptions to be made to fill the lacunae that may occur as traces decay.

Turning to Grieg's *Melodie*, for example, the structure underlying the three-note descent—fifth-octave F, E, D—that occurs in the RH at bar 10, can be heard at the level of events as a semi-regular descending pattern (a minor 2nd followed by a major 2nd); at the level of groups as an exact transposition of the figure comprising the melody in the second half of bar 2 (and a tonal reproduction of the comparable motives found in bars 4 and 6); and at the level of frameworks as a repeated stepwise descent, functioning as the mediant, supertonic, and tonic scale-steps in D minor,[4] as well as fulfilling the harmonic roles of the third, ninth, and root with respect to the accompanying chord (a replication of the functions and roles found in the second half of bar 2). Zygonically, these parallel structures may be represented as shown in Figure 13.4. As we shall see, evidence of just which structures are cognitively acknowledged and remembered may be provided by the nature and pattern of errors made in recall: some structures may be preserved, whereas others may be transformed, disregarded, or even replaced by forms of organization that were not originally present.

Another important factor in musical memory that was implicated in the design of Sloboda and colleagues'' (1985) experiment was that current perceptual input has the capacity to reactivate similar materials that are held in a long-term store: one of their aims was to ascertain whether NP would be able to remember music utilizing *familiar* structures better than a piece that used forms of organization that were *less familiar* (1985, p. 158)—in particular the 'tonal' construction of the Grieg as opposed to the whole-tone make-up of the Bartôk (1985, p. 165). That is to say, there was an underlying assumption that NP may have the ability to abstract the pitch framework of a passage by listening to it, and that this may revive memories of other, similar

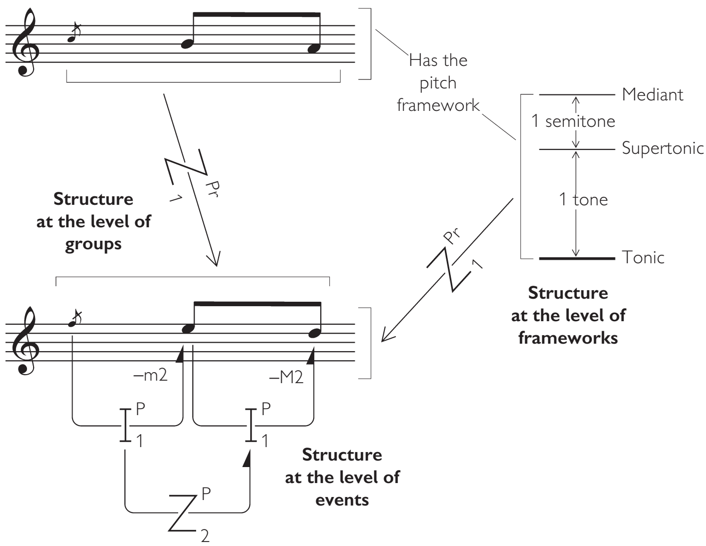


Fig. 13.4 Example of structures at the level of *events*, *groups*, and *frameworks* operating together in a fragment of Grieg's *Melodie*.

(or even identical) frameworks that had been abstracted from pieces in the past. In the case of 'tonal' frameworks, it is worth noting that these would comprise more than a neutral intervallic schema, also capturing their idiosyncratic patterns of use, yielding a context-sensitive matrix of probabilities that are realized in cognition as the distinct tendencies associated with different members of the diatonic scale (Huron, 2006). Bharucha (1987) contrasts these so-called 'schematic' memories with 'veridical' traces: long-term representations of particular groups of sounds.

Hence it is possible to model the interaction of short-term and long-term memory with the three forms of structure identified above (pertaining to events, groups, and frameworks) as shown in Figure 13.5. Note that this bears a close resemblance to the routes through which I hypothesize that expectation in music can occur (Ockelford, 2006a, p. 127).

Finally, in this introductory presentation of theories and concepts that potentially have a bearing on our understanding of musical memory, it is beneficial to consider the three forms of structure in relation to the *creation* and *cognition* of music; comparable with what Fred Lerdahl refers to as 'compositional' and 'listening' grammars (1988). It is quite possible that some of the structures employed by composers will not be recognized by listeners (Figure 13.6). Conversely, it is conceivable that listeners (attending with an music-analytical mindset) may identify structures that composers did not intentionally use. And there may be what Lerdahl (1988) refers to as 'natural' grammars at work, of which neither listeners nor composers are consciously aware. Because, as we have seen, music is structurally multidimensional, the experiences of composers and listeners that differ with respect to the forms of organization that are detected may both still be coherent (and, we may surmise, aesthetically fulfilling)—see

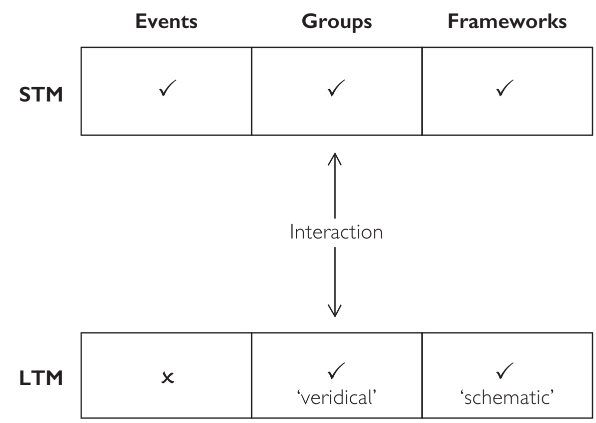


Fig. 13.5 Model of the interaction of short-term memory (STM) and long-term memory (LTM) taking into account structures at the level of *events*, *groups*, and *frameworks*.

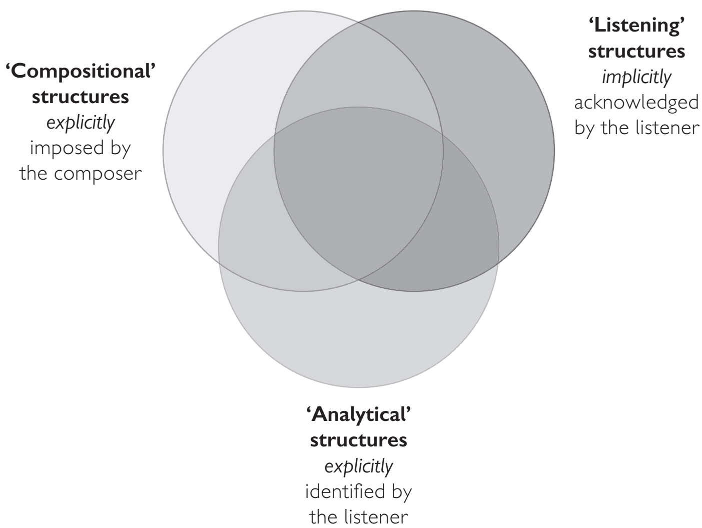


Fig. 13.6 Representation of the relationship between the cognition of 'listening', 'compositional' and 'analytical' structures.

Ockelford, 2009, p. 86–88. Occasionally, as we shall see, a compositional grammar and a listener's perception of it may conflict, and, through a failure of accommodation, may be misremembered and, consequently, produce systematic errors in recall.

To summarize, musical structure facilitates memory by enabling information to be encoded parsimoniously. It can occur at the level of events, groups, and frameworks. This may be captured in *short-term* or *long-term* memory, which interact in the dynamic process of remembering. Music is typically *structurally multidimensional*, which means that pieces can validly be heard and remembered in different ways. However, errors in recall may be an indication of a listener's constraints (or preferences) in music-structural cognition.

Revisiting the findings of Sloboda, Hermelin, and O'Connor (1985)

The theoretical assumptions made in the previous sections can be used to interrogate the results that Sloboda and colleagues obtained with NP, and to re-evaluate the conclusions they drew. First, in relation to *Whole-Tone Scale*, NP's relatively poor recall led the authors to contend that he 'needs to code material in terms of tonal structures and relations', and that his 'exceptional ability cannot at present survive outside that framework' (1985, p. 165). But is this view compatible with the hypotheses set out above? Consider NP's pattern of errors in his production of the Bartôk. It appears that his grasp of the whole-tone pitch framework on which the piece is based was not actually an issue, since he adhered to it for the great majority of the time, only occasionally straying into quasi-diatonic territory (according to Miller, who re-analysed Sloboda *et al.*, 1985 data).[5] Nor, apparently, did NP find encoding structure at the level of groups problematic, since the same melodic error was repeated 'frequently' (Sloboda *et al.*, 1985, p. 164), implying the preservation of form over content. In fact, it was at the level of events that NP evidently had difficulties: for example, 19 of the 34 mistakes that he made (56%) were due to melody notes being interchanged, with the commonest error being as shown in Figure 13.7.

What are we to make of this? Was the (oft repeated) mistake the product of more or less unpredictable 'noise' in cognition brought about by short-term memory overload, or was there perhaps something more systematic going on? Zygonic analysis of the opening of the melody of *Whole-Tone Scale* shows how deceptively complex the structure is. Despite the symmetry of the underlying intervallic framework, there is surprisingly little surface regularity in the domain of pitch as the music unfolds, with the potential presence of only two primary zygons out of a latent 21 relationships between the first seven notes (yielding a 'zygonicity' in this respect of only 0.095)[6]—see Figure 13.8. Moreover, these primary zygonic relationships of pitch function neither

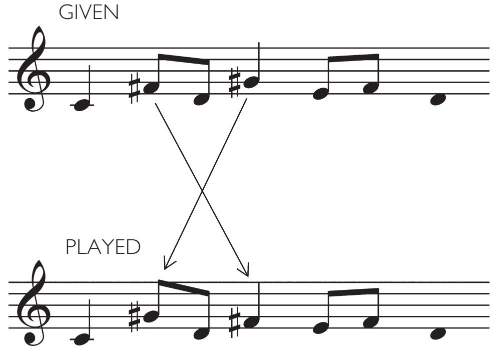


Fig. 13.7 NP's common 'interchange' error (after Sloboda *et al.*, 1985, p. 164).

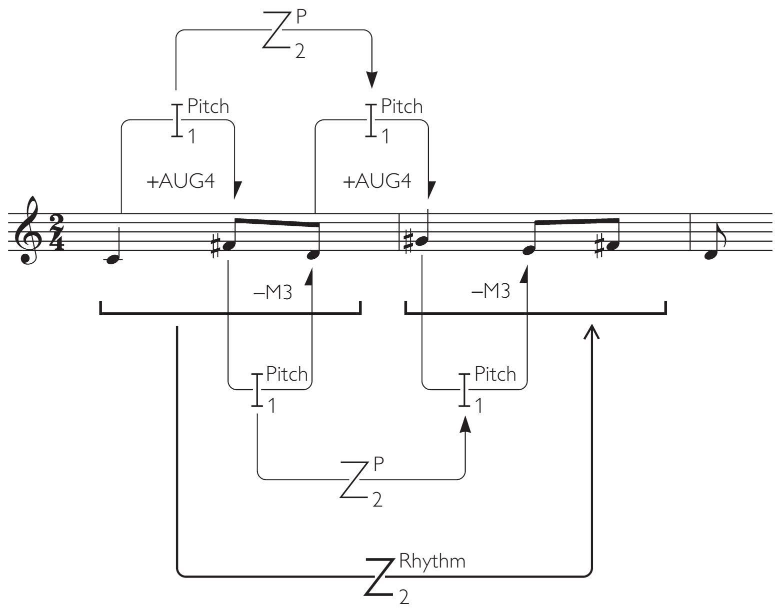


Fig. 13.8 Structures in the opening segment of *Whole-Tone Scale* in the domains of pitch and perceived time functioning out of step.

between successive nor metrically equivalent notes, reducing their likely structural impact. And while four of the six intervals between sequentially adjacent pitches can be considered to be linked through secondary zygonic relationships, again, these are not paralleled in the domain of perceived time. In fact, the initial rhythmic structure (in which the pattern of durations and interonset intervals in bar 1 is repeated in bar 2) runs *counter* to the organization of pitch. It seems probable that this asynchrony, which produces cross-domain structural conflict, may hinder processing and recall.

NP's rearrangement, incurred through the interchange of notes 2 and 4, creates a regular pitch descent and aligns it with the underlying crotchet beat, simplifying the structure in perceptual terms (see Figure 13.9). We can only speculate whether this modification was purely fortuitous or was brought about through an intuitive process of regularization (whereby qualia were transformed in cognition to form a more parsimoniously encodable pattern). The fact that NP repeated his 'error' suggests that his version was indeed more readily memorable than the original, though, as we have observed, recapitulating his mistake arguably enabled him to maintain structure at the thematic level.[7]

To reiterate, neither group- nor framework-level structures were significantly compromised in NP's recall. Hence, it appears *not* to be the case that NP needed to code music in terms of familiar 'tonal' structures. We will return to the issue of precisely what constitutes a 'tonal' structure shortly, since Sloboda *et al.*'s assertion that the Bartôk was 'atonal'—a core assumption in the design of their experiment—is problematic.

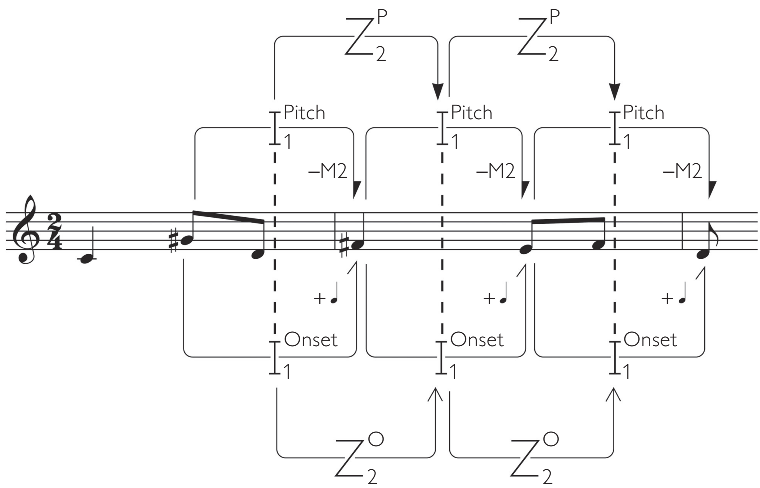


Fig. 13.9 In NP's version, structures in the domains of pitch and perceived time run in parallel.

But first, we need to answer the question of *why* NP's performance in relation to Grieg's *Melodie* (and, indeed, those of the other savants) was better than their efforts to recall Bartôk's *Whole-Tone Scale*, if comprehension of its pitch framework was not an issue.

Again, we will approach this problem by examining the structure of the *Melodie* in some detail: once more, in relation to the first seven melodic events, since these set the scene for what follows, introducing the material from which the remainder of the work grows. Here there are three potential primary zygons of pitch (see Figure 13.10) (yielding a zygonicity of 0.143), but, unlike the *Whole-Tone Scale*, their structural significance is underlined by sequential adjacency (in the case of the opening three Cs) or perceptual affinity (in the case of the two Bs, since the A interpolated between them, although consonant with the underlying harmony, has the effect of prolonging[8] the first B). With regard to melodic intervals, five can be considered to be subject to secondary zygonic influence, on each occasion between *successive* notes. Hence we may surmise that they are likely to be aurally prominent, despite the fact that only one of the secondary pitch zygons functions in parallel with comparable repetition in the domain of perceived time (in the second half of bar 2, involving the three quavers, B, A, B). Finally, it is important to note that this melodic structure, tightly integrated across the dimensions of pitch and perceived time, unfolds atop a highly repetitive harmonic background (zygonicity 0.75).

Given this level of structural coherence, which, through motivic and thematic repetition and development subsequently pervades the entire piece, it is, perhaps, little wonder that NP appeared to have few problems in reproducing Grieg's *Melodie* with a high degree of accuracy:[9] by trial 7, we are told, after about 12 minutes, and having heard no section of the piece more than four times, he 'provided an almost note-perfect performance' (Sloboda *et al.*, 1985, p. 160). Similarly, extrapolating from the data

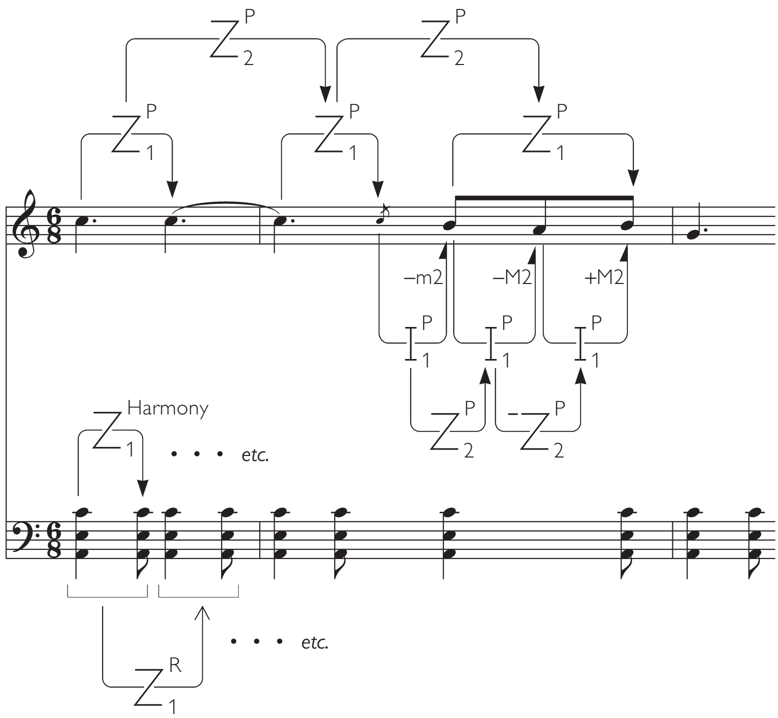


Fig. 13.10 The highly structured nature of the opening of Grieg's *Melodie*.

pertaining to Eddie's final attempts at each segment shows him achieving an accuracy (gauged through a note-matching paradigm) of 75% (Miller, 1989, p. 140). TR's recall was apparently even better.

> [He] was able to play the initial 7 bars of the Grieg after one hearing with only one incorrect note. This error (substituting a D for a B in bar 6) was, however, harmonically consistent. Three embellishments in bars 2, 4, and 6 were also omitted. He heard these seven bars 10 times in total because they were repeated in bars 41–48 and, with the exception of one missed embellishment in the fourth reproduction of the second bar, his performance was perfect. In addition, rhythm was preserved and the melody was correctly reproduced throughout the performance, except that on one occasion he played different inversions of the written chord (i.e. he retained harmonic identity but not a literal rendition). (Young and Nettelbeck, 1995, p. 242.)

This detailed account of TR's very few errors enables us to infer that, in addition to encoding structure at the level of events, he was also parsing the music as groups (suggested by the consistent omission of embellishments in his first attempt at the opening 8 bars, since these all fulfil an equivalent function in transformations of a two-bar phrase) and framework*s* (shown by his initial displacement of a note in the left hand (LH) of bar 6 by another that conformed to the harmony, and elsewhere by the use of different inversions of chords). Similarly, NP's errors were said to be 'overwhelmingly structure preserving' (Sloboda *et al.*, 1985, p. 165).

To conclude this review, we return to the notion of 'atonality', since although it is central to the design of the empirical work under investigation, there are apparent contradictions in what is reported. For example, Sloboda *et al.*, while designating the Bartôk as 'atonal', assert that NP's interchange error (see Figure 13.9) shows that he 'coded these notes [the $F^{\sharp}$ and the $G^{\sharp}$] not with respect to their immediate neighbors but with respect to the initial C' (1985, p. 164). Yet hearing pitches in relation to a reference point in this way is a core characteristic of 'tonality', which, as we have observed, entails members of a pitch framework being assigned different functions that derive from a listener's (typically non-conscious) perception of idiosyncratic patterns of usage. In his *Whole-Tone Scale*, in which such assignation is potentially difficult because each step of the underlying framework is equal in size, Bartôk starts by unambiguously 'tonicizing'[10] key notes in each phrase by sustaining them against the melody, whereby they act as perceptual 'anchors', from which the pentatonic runs do not stray. Moreover, these same anchor notes are initially used to begin and end melodies, reinforcing their prominence, and imbuing them with potentially cadential authority—the power at the end of phrases to make listeners sense closure, a key feature of pitches that act as tonics. It is important to acknowledge too that Bartôk, despite some of his music subsequently being analysed in atonal terms, was opposed to the use of 'atonality', and regarded all his music as having a tonal foundation (Bartôk, 1928/1976, p. 338). It is possible that the practice of thinking about his music in this way arose because of some theorists' *unfamiliarity* with the folk sources of many of Bartôk's mature compositions, coupled with their failure to acknowledge that pitch frameworks from outside the 'mainstream' major/minor Western tradition could function tonally too.

To summarize, the *Whole-Tone Scale* is not atonal. Admittedly, it uses a pitch framework that is encountered less frequently in the West than the major and minor diatonic scale systems, and it is based on equally spaced intervals, but Bartôk counters both of these potential obstacles to hearing the music tonally by tonicizing notes as the piece unfolds. It is worth reiterating that none of the three savants had problems in recalling this aspect of structure. Therefore, the premise that NP performed relatively poorly because the music was 'atonal' must be discounted. That does beg two questions, however:

- How would a savant perform if he or she did *not* pick up on the tonal pitch framework of a piece—if this feature of compositional grammar were not recognised?
- How would a savant perform in seeking to recall a piece that did *not* use a tonal pitch framework?

The theoretical thinking set out above suggests two possible outcomes:

- The lack of a tonal framework (or the failure to recognize one) will have a negative impact on memory since an important source of information about musical events—their perceived functionality in relation to one another—will be missing, making the perceptual input more impoverished and less easy to encode parsimoniously. This is likely to lead to short-term memory overload, with asystematic patterns of error at the level of events and groups.

- A tonal framework (or frameworks) will be *imposed*, more or less consistently, in order to 'make sense' of the music: that is, new material will be modified to facilitate assimilation. This is likely to be shown by the omission of values, or by their 'migration' at the level of events to conform to familiar structures, and through these errors being made consistently, at the level of groups.

Experiment 1

This set out to address the first question: namely, how would a savant perform if he or she did *not* pick up on the tonal pitch framework of a piece?

Subject

Derek Paravicini[11] agreed to participate in the research. For a number of reasons, Derek made a particularly suitable subject. He has an acute sense of absolute pitch (AP), which enables him to reproduce on the keyboard not only individual notes, but clusters of four pitches with 100% accuracy[12] (Ockelford, 2008a, pp. 218–225; Pring, 2008). Derek is a fluent pianist, so in music of moderate difficulty, considerations of technique do not typically corrupt or constrain his efforts to reproduce what he hears. 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. Before the current research project, he had been exposed to little twentieth-century music that moves beyond these conventions, though, and he was not known to have attempted to play atonal music. Finally, Derek had taken part in memory trials before (see, for example, the reports in Ockelford, 2007b, 2008a; Ockelford & Pring, 2005), and was familiar with the 'listen and play' protocol. Here, he had shown himself to be patient, reliable, and motivated in research situations, applying himself diligently to the task in hand, and appearing to give of his best, even when tasks were repeated several times. However, then as now, Derek has a very low level of metacognitive ability, even in relation to music: for such an advanced performer, it is extraordinary how little his efforts appear to be informed by explicit knowledge. While this lack of conscious understanding can be regarded as an advantage in tasks intended to be undertaken intuitively (since they will not be contaminated by conceptual bias or volitional strategies), it means that virtually the *only* data that are available exist in the form of music, and that the primary form of analysis must be musicological. The extent to which information such as this can validly be used to infer features of music cognition is an important epistemological issue that is taken up elsewhere (Ockelford, 2008b) and below.

Material

Bartôk's *Whole Tone Scale* was used as the source of material for this experiment since (1) it was highly unlikely that Derek would have encountered it through incidental exposure (and had he been familiar with the piece, this would quickly have become apparent), (2) it enabled comparisons with the studies by Sloboda *et al.*, Miller, and Young and Nettelbeck mentioned above, and (3) it was well-suited to test the first research question (which asked what would happen if the subject did *not* pick up on the tonal pitch framework of a piece). The reason for this is set out below.

Whole-Tone Scale was modified somewhat to bring it structurally into line at the level of groups with the pieces used in Experiment 2, so that comparisons could be made in relation to Derek's recall of each. This yielded five segments, disposed as follows. The opening 'A_1' (a shortened version of the original) was followed by the LH of bars 13–16 (B_1), after which came the RH of the same passage ('B_2'), then both these lines together, moving in parallel minor thirds ('B_3'). Finally, there followed a variant of the opening (also in thirds) derived from bars 10–12. This yielded the stimulus material showed in Figure 13.11.

The revised design of the middle segments (B_1, B_2, and B_3) was also intended to test Derek's strategies for dealing with unfamiliar pitch frameworks, for while B_1 and B_2 use pentatonic whole-tone scale systems in a readily identifiable way, the effect of their combination in B_3 is by no means perceptually straightforward. The frameworks are three semitones apart, giving the segment a 'sweet and sour' character: while the consonant sound of whole tones pervades the texture and there are no direct discords (i.e. dissonant pairs of notes that are struck at the same time), there are a number of

Fig. 13.11 The materials used in Experiment 1, adapted from Bartôk's *Whole-Tone Scale*.

implied semitonal clashes (for example, between G and G♭, and A and A♭). The simplest way of 'making sense' of this passage structurally as it unfolds is to allow the two melodic lines (and the frameworks that underpin them) to continue to exist as discrete entities in one's mind, as they did in B_1 and B_2. This appears to be what TR did: he is reported to have recognized the whole-tone scale system that lies at the heart of the Bartôk as a *con*ceptual entity (Young & Nettelbeck, 1995, p. 243), which, the authors hypothesize, helped him keep both parts in simultaneous passages intact even though their underlying pitch frameworks were at an interval of transposition (three semitones) that made them mutually incompatible (1995, p. 242).[13] However, there is something intoxicating about their combined effect, and informal discussion with a range of listeners suggests that the ear can easily be drawn into hearing the two parallel strands as one sonority, with a complex and unconventional pitch framework comprising (in ascending order) a tone, five semitones, and a further tone. As far as Derek was concerned, there seemed to be a strong possibility that this 'vertically integrated' style of listening would be the one that he would adopt, particularly given his tendency to hear contrapuntal music (made up of separate 'horizontal' strands) largely homophonically (as a series of harmonies)—shown through his previous reproductions of Bach fugues, for example, which preserve chordal sequences though not necessarily individual lines.

So, according to the two outcomes predicted above, since segment B_3 comprises 13 events (which previous observation had suggested would be beyond the span of Derek's short-term memory), and has semitonal conflicts to one adopting a homophonic listening style (which may interfere with efforts to code events at the primary zygonic level), it was likely that he would *either* make asystematic errors *or* impose a background structure to bring the material within a familiar diatonic framework. In the second of these scenarios, the most likely contender would seem to be E♭ minor, given the tonicizing effect of the sustained E♭ at the bottom the texture, the sustained G♭ above it, and the conformance of six of the eight pitches in the segment (75%) to this key (E♭, F, G♭, A♭, and B♭ and C). E♭ major would appear to be a second option, also bearing 75% conformance (E♭, F, G, A♭, and B♭ and C) and with possibility of the G♭ and A♭ treated as chromatic auxiliaries (or errors)—see Figure 13.12.

Procedure

The task of attempting to memorize the revised Bartôk was 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). 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.

The session was organized as shown in Table 13.1.

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.

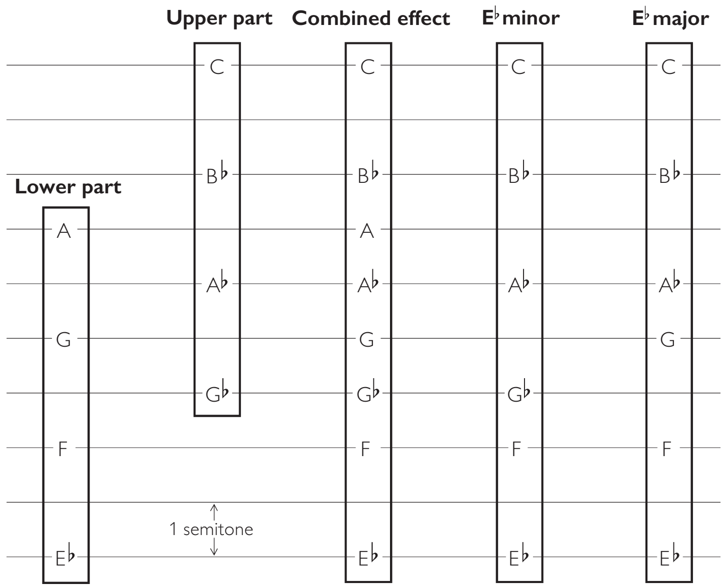


Fig. 13.12 Different whole-tone scales operating in parallel approximate to fragments of major and minor scales.

Table 13.1 Experiment 1: session organization

Listen to the whole 'piece' through	(2×)
Listen to first segment and then play	(4×)
Listen to second segment and then play	(4×)
Listen to third segment and then play	(4×)
Listen to fourth segment and then play	(4×)
Listen to fifth segment and then play	(4×)
Listen to whole 'piece' and then play	(2×)

The chunks were designed to be of such length and complexity as to lie just beyond Derek's observed short-term memory capacity (see above), 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 'piece' 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 the *Chromatic Blues*—see Ockelford, 2007b, 2008a, pp. 225–244; Ockelford & Pring, 2005) 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.

Results

The results are transcribed in Figure 13.13.

Analysis and discussion

The extent to which Derek's efforts at recall were derived from the original material and the influence of his errors on subsequent trials are charted quantitatively below (see the analysis pertaining to Experiment 2). However, the key findings in relation to

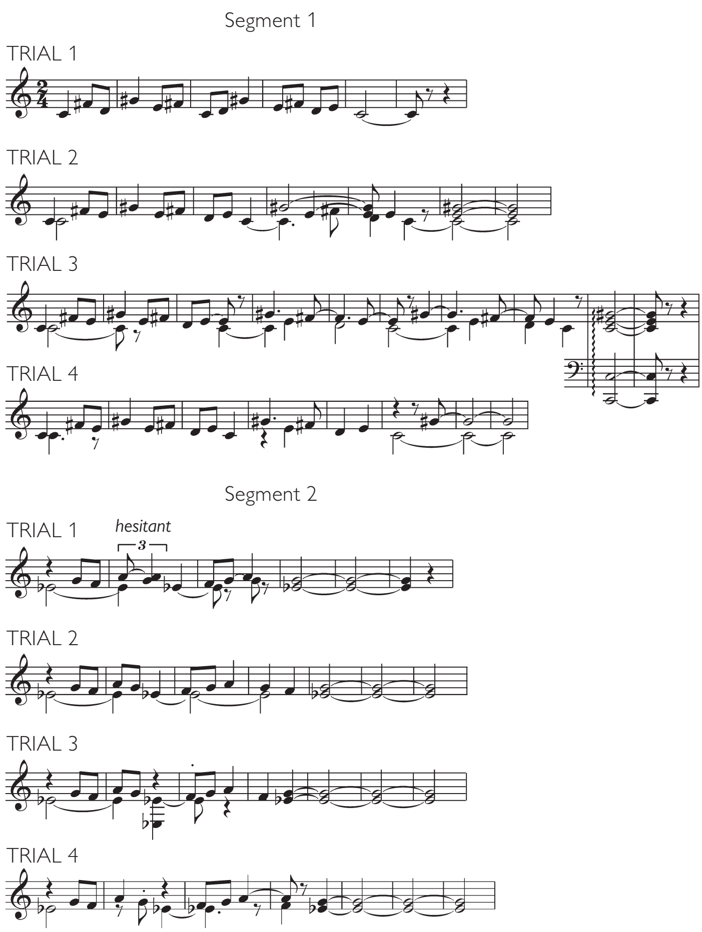


Fig. 13.13 Transcription of Derek's responses to the *Whole-Tone Scale* materials.

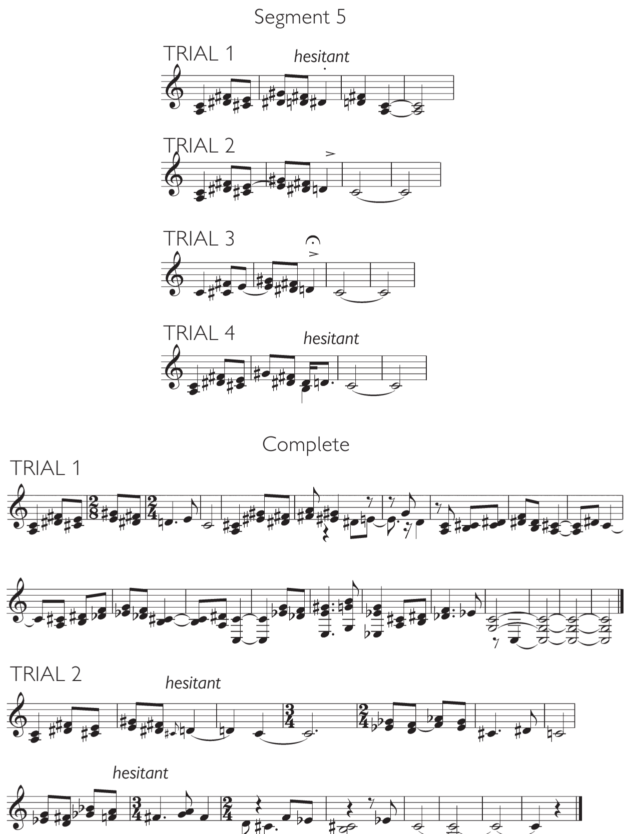


Fig. 13.13 Cont'd

the current question of the consequences of Derek recognizing, or failing to recognize, the tonal pitch framework of a piece are as follows:

- Without exception, Derek's recall of segments 1–3 conformed to the whole-tone pentatonic scale utilized in each (although pitch structure at the level of events had an average error rate of 30%). Moreover, the sense of a tonic was consistently maintained, with responses invariably beginning and ending on the same note, in the manner of the original segments. Indeed, on two occasions these tonics were doubled at the lower octave, perceptually reinforcing their anchoring effect. Clearly, then, in these excerpts, Derek had no problem in encoding structure at the level of frameworks, despite surface detail being misremembered.[14]
- In the fourth segment, however, which, as we have seen, is founded on two different whole-tone scale systems functioning simultaneously (implying a form of bitonality), Derek's responses were materially different. On only one occasion, in the lower melodic strand of Trial 2, did he adhere to the original pitch framework of a line (and even here, the top part was changed). In every other case, events

Fig. 13.13 Cont'd

were selectively modified, in accordance with Prediction 2, to conform to the scale systems of either $E^\flat$ major or $E^\flat$ minor, as Derek struggled to reconcile the novel material that he was hearing with pitch frameworks whose principles of operation were familiar to him and that he found comprehensible. His indecision becomes audible—discomforting, even—in Trial 3, as he vacillates between the major and minor modes, with no convincing resolution. Subsequent comments (unusual for him—see note 19) indicated that he was aware that what he had produced had significant errors, but (unlike TR) he lacked the conceptual understanding that would have enabled him to divide the perceptual surface into two transpositionally equivalent halves, so facilitating the cognition of the underlying pitch structure. In the absence of such a strategy, the capacity of his short-term memory was evidently exceeded, and his efforts at recall represent the uncomfortable compromise that he had to make between the forces of assimilation and accommodation.

- Segment 5 also adopts a bitonal approach, but here, because each line uses five successive pitches from the whole-tone scale (rather than the four found in the previous segment), reconciliation with the conventional major and minor modes is more problematic, and Derek did not attempt it. Rather, he regularized structure at the level of events by recalling the whole-tone quaver pairs from Trials 2, 3, and 4 of Segment 1 and allowing the pentatonic scale in the top part to predominate, which was reproduced with an average 29% errors, and only once straying from the given pitch framework (see the hesitation in Trial 4). The lower part was remembered far less consistently, though, with an average error rate of 62%, and frequent departures from the original pentatonic scale system. Furthermore, there was an average 40% difference in the domain of pitch between the lower part of each of Derek's reproductions of Segment 5. This outcome accords with Prediction 1, which hypothesized that, where pitch frameworks failed to be recognized, a likely consequence would be the overload of short-term memory, with asystematic patterns of error at the level of events and groups.

In summary, then, these findings indicate that when a compositional grammar is employed that Derek cannot detect, he either imposes a familiar framework upon the material, employing systematic migration at the level of events, or struggles to manage the perceptual load, resulting in erratic errors at all structural levels. What happens to such data in longer-term recall was one of the issues explored in Experiment 2.

Experiment 2

This set out to address the second research question: namely, how would a savant perform in seeking to recall a piece that did *not* use a tonal pitch framework?

Subject

Derek Paravicini again agreed to participate.

Material

A musically self-contained section of an authentic piece of 'atonal' music was selected—the opening 11 bars of Schoenberg's *Klavierstück*, op. 11, no. 1 (see Figure 13.14)—which were deemed to be of sufficient length and complexity to demonstrate the principles involved and yet be of a level of difficulty that would not impair Derek's capacity to play back immediately what he had heard (so that issues of performability would not interfere with the results). The Yale music theorist Allen Forte once described op. 11, no. 1 as 'Schoenberg's first atonal masterpiece'[15] and dubbed it the *Magical Kaleidoscope* on account of what he believed to be its cellular (rather than tonal) pitch structure (1981).[16] This was the title given to the piece (which necessarily had to be distinct and memorable) in working with Derek. As well as having no sense of being rooted in a particular key, a consistent sense of metre is elusive in op. 11, no. 1 too (the written time signature of 3/4 notwithstanding): informal evidence suggests that listeners attending without the benefit of a score find it difficult to identify a regular hierarchy of pulses. This can be attributed in part to the frequent absence of material on the first

Fig. 13.14 Opening of Schoenberg's *Klavierstück*, op. 11, no. 1, known as the *Magical Kaleidoscope*.

beat of the bar (four out of the 11 downbeats are silent) and partly to the way in which similar sonorities shift subtly in relation to the beat in bars 4–8. Hence the ear is left 'floating' in the domains of pitch *and* perceived time, and one has the feeling that Schoenberg was seeking to free himself from traditional constraints in *both* dimensions (cf. Rochberg, 2004, p. 95). In relation to the current empirical work, the ametrical nature of op. 11 meant that there was a possibility that the predictions made in relation to Derek's recall of pitch may apply in the domain of perceived time too, and, although this issue is not central to the research questions addressed here, the nature of Derek's *rhythmic* errors are of interest, and also will be reported, with the hope of stimulating future lines of enquiry.

A further, tonal and unambiguously metrical, passage was required for the purposes of comparison. However, given the possible confusion of results pertaining to a subject's recollection of the pitch and metrical frameworks of a piece with other aspects of its structure operating at the level of events and groups (as observed in NP's recall of Bartôk's *Whole-Tone Scale*), it was necessary to create stimulus material that differed structurally from op. 11, no. 1 only with respect to offering a sense of tonality and a clear impression of metre. 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 music 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, distinct from the *Magical Kaleidoscope* (*MK*); the name chosen was *Kooky Minuet* (*KM*)—see Figure 13.15.[17]

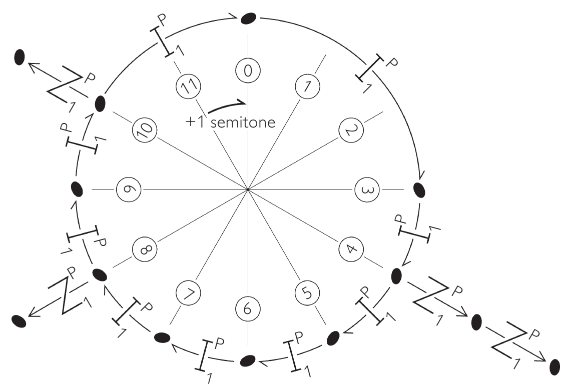
Comparative analyses of the *MK* and *KM* show just how similar they are in many structural dimensions, despite the considerable perceptual difference engendered by the presence of consistent tonal relationships in *KM*. At the level of groups, for example, both pieces are couched in the same variety of ternary form with 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 *KM*.

Fig. 13.15 Specially composed tonal equivalent of Schoenberg's op. 11, no.1, known as the *Kooky Minuet*.

At the level of events, the moment-to-moment structure of *KM* necessarily differed somewhat from that of *MK*, since it is the nature of transitions between successive pitches, the disposition of simultaneities and, more broadly, the context-sensitive frequencies of occurrence of relative values, upon which a sense of tonality is founded. However, given the aim of trying to ensure that both passages would be equally memorable at the level of events, 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. This is achieved as shown by the data presented in Figure 13.16.

Even in terms of the more exacting mode of comparison that assesses the distribution of melodic intervals between *successive* notes, the similarity between *KM* and *MK*

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. 13.16 Comparisons of the relative pitch-class sets used in *MK* and *KM*, segment by segment.

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. 13.16 Cont'd

is still high, at 78%,[18] with the majority of intervals being four semitones or smaller: over 90% in each case. Moreover, the *range* of both pieces is identical—two octaves and five semitones—and sets of the pitch-classes (pcs) are virtually identical (*KM* uses all 12 pcs, whereas *MK* omits E$^\flat$; see 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 (unsurprisingly, 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 in Figure 13.17.

In the domain of perceived time, there are important similarities too—as well as some key differences. The distributions of relative durations used are 72% similar (Figure 13.18). More significant, perhaps, in perceptual terms, are the distributions of interonset intervals (expressed as ratios) between successive notes, which have a similarity of 78%. Observe also that the average *density* of each stimulus (in terms of the number of simultaneous notes per event) is very similar.

However, a crucial aspect of rhythm is the 'relative metrical location' ('RML') of events (that is, their position in relation to the prevailing metre; see Ockelford, 2006a, p. 133), and here, there are notable differences between *MK* and *KM*. For example, only 64% of the first beat 'slots' in *MK* are filled with the onsets of notes, as opposed to 100% in *KM*, and the RMLs of the first notes of the 'B' segments in *MK* are different in each case, whereas in *KM* they are the same (see comments above). Hence there is a far stronger sense of metre functioning in *KM* than *MK*. (See Figure 13.19.)

In summary, then, the substantive difference between the passages is that the structure pertaining to the pitch and perceived temporal framework*s* that are used engender in one case (*KM*) a clear sense of tonality and a strong impression of metre, and in the other (*MK*) do not. That is, in *KM*, it was hypothesized that Derek would be able to gauge events *functionally* in relation to others, whereas in *MK*, he would not. It was anticipated that this would lead him either to experience overload in short-term memory, resulting in frequent and asystematic errors, or to *impose* frameworks on what he heard, leading to systematic inaccuracies in recall.

		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%

$$\text{Similarity (\%) } MK \text{ and } KM \text{ (melodic intervals)} = 100 - \Sigma \left(\frac{\Sigma \left| x_i - \left(\frac{\Sigma x_i}{x} \right) \right|}{x} \right) \%$$

= **78%**

Similarity (%) *MK* and *KM* (harmonic intervals)

= **56%**

Fig. 13.17 Comparisons of the melodic and harmonic intervals used in *MK* and *KM*.

Interonset interval distribution matrices

Magical Kaleidoscope

	♪	♩	♩.	𝅗𝅥	♩‿♩.
♪	14	2	2	0	0
♩	0	2	4	2	0
♩.	2	1	2	0	0
𝅗𝅥	0	2	0	0	0
♩‿♩.	0	0	0	0	0

Kooky Minuet

	♪	♩	♩.	𝅗𝅥	♩‿♩.
♪	16	3	1	3	0
♩	4	7	2	4	0
♩.	2	1	0	0	0
𝅗𝅥	0	3	1	0	0
♩‿♩.	0	0	0	0	0

Interonset ratio distributions

	Interval (ratio)	1:1	1:2	1:3	1:4	2:1	2:3	3:1	3:2	4:3
MK	Frequency	28	4	2	0	2	4	2	1	0
	Relative frequency	65%	9.5%	4.5%	0%	4.5%	9.5%	4.5%	2.5%	0%
KM	Frequency	23	7	1	3	7	2	2	1	1
	Relative frequency	49%	15%	2%	6%	15%	4.5%	4.5%	2%	2%

Similarity (%) *MK* and *KM* (intervallic ratio)

= **78%**

Simultaneous notes per event

Density	1	2	3	4	
MK	18	15	5	21	Average density = 2.51
KM	14	4	23	6	Average density = 2.49

Fig. 13.18 Comparisons of the distributions of interonset intervals in *MK* and *KM*, and of chordal densities.

	RML	0.5	1	1.5	2	2.5	3	3.5
MK	Frequency	0	7	5	11	6	11	6
	Proportion of slots filled	0%	64%	45%	100%	55%	100%	45%
KM	Frequency	0	8	3	8	5	8	5
	Proportion of slots filled	0%	100%	38%	100%	63%	100%	63%

Fig. 13.19 Comparison of the distribution of events within metrical structures in *MK* and *KM*.

Procedure

As before, the memory tasks were undertaken by Derek as part of his usual schedule of learning, performing and recording. Although the *MK* and *MK* 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 below). I had previously recorded the materials and Derek reproduced them using the same equipment as in Experiment 1. Again, Derek's efforts were 'tidied up' rhythmically so as to make sense in notational terms; where rhythmic uncertainties occurred (such as hesitations) these were marked on the score; and the transcriptions were verified by a musician with no prior knowledge of the project.

Results

The results are transcribed in Figures 13.20 and 13.21.

Analysis and discussion

In the research undertaken previously by Sloboda *et al.*, Miller, and Nettelbeck and Young, different protocols were employed for measuring the fidelity of reproduction. Here, the notion of 'derivation', central to zygonic theory, is used to underpin the analyses that follow, since it arguably offers a more valid means of gauging how the

Fig. 13.20 Transcription of Derek's responses to the *MK* materials.

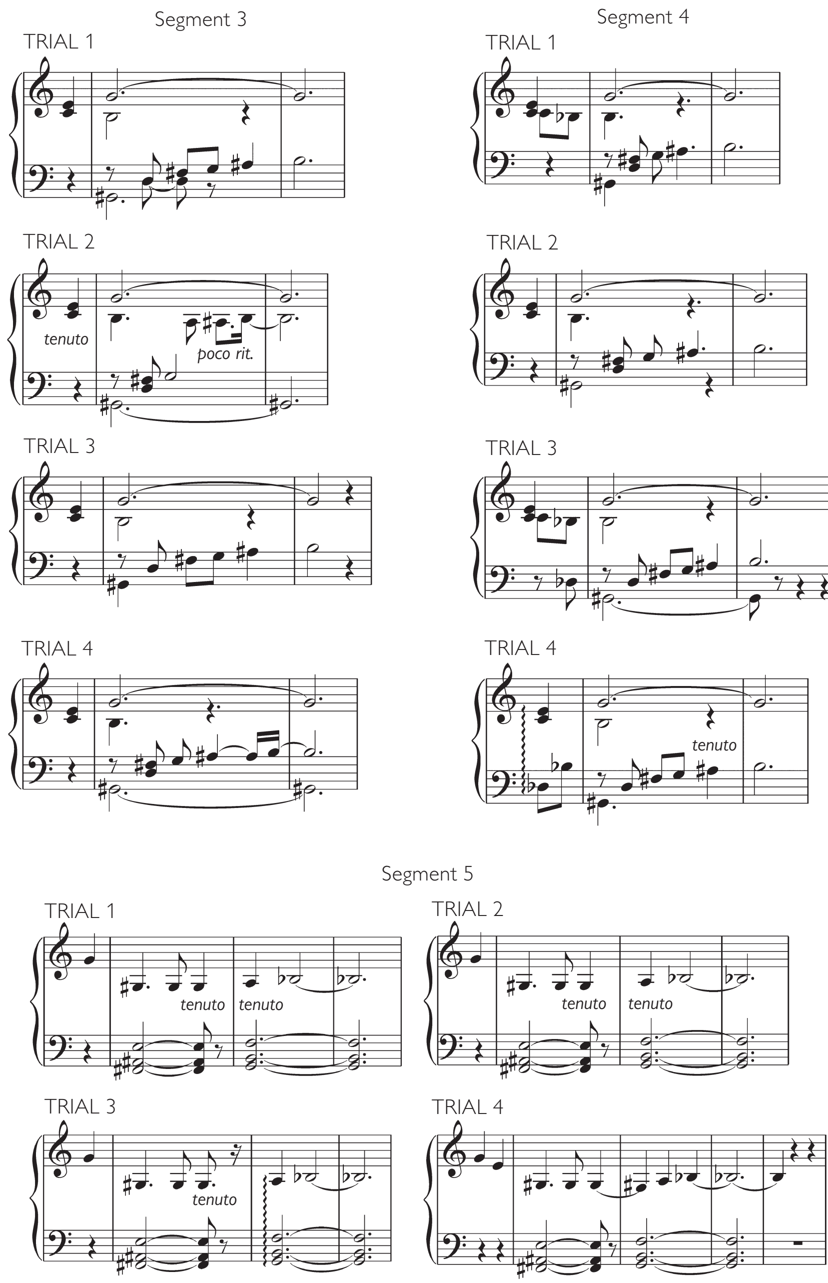


Fig. 13.20 Cont'd

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, 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, it is the question of musical *derivation* rather than *similarity* that is the appropriate proxy through which we can interrogate and seek to understand matters of recall. 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 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 set out below, which was developed to determine the zygonicity of relationships *between* groups of notes (that is, the strength with which one group of

Fig. 13.21 Transcription of Derek's responses to *KM*.

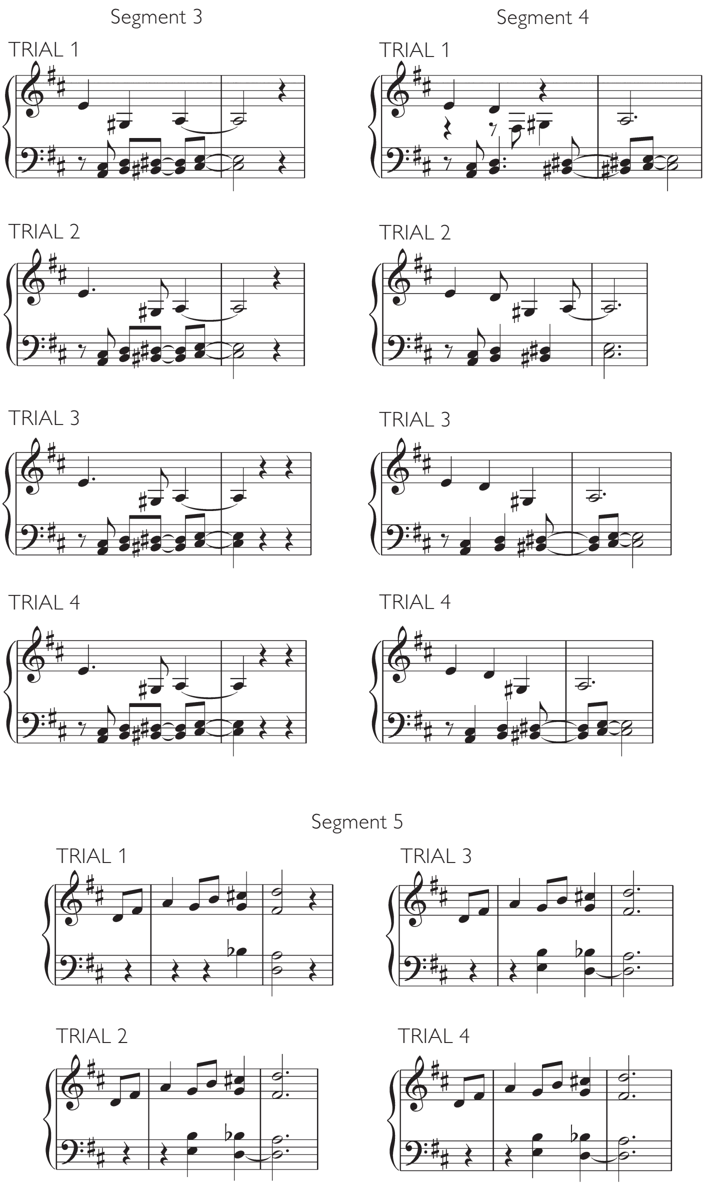


Fig. 13.21 Cont'd

notes is deemed to derive from the other), seeks to take into account both similarity *and* salience (Ockelford, 2005a, 2006a, 2007b). The result is termed the 'derivation index' (Ockelford, 2008a). The two chief conveyors of musical structure, pitch and perceived time (Boulez, 1963/1971, p. 37), are scrutinized separately. The former includes considerations of pitch, pitch-class, and melodic and harmonic intervals.

The latter has regard to interonset intervals, durations and relative metrical location. Data are 'streamed' according to their position in the texture ('top', 'middle', or 'bottom', where 'middle' may include a number of simultaneous sounds), since there is evidence that the salience of events may vary according to their relative textural location (Ockelford, 2008a, p. 224). The procedure is as given below.

Algorithm for calculating the derivation index of one group of notes from another

Zygonicity in the domain of perceived time

- Align the two series of events to ensure maximal congruence (in order of priority) of interonset interval, duration and RML.
- Events may be omitted from either series provided that sequentiality is not compromised.
- For each match count 1.
- For correct onset but incorrect duration, count 0.5.
- The raw score is the number of zygonic relationships of rhythm = #Z(R)
- Let the total number of actual and potential sequential relationships between events in the domain of perceived time = #Rel
- The strength of derivation of rhythm is ZYG(R) ('zygonicity' of rhythm), where **ZYG(R) = #Z(R)/#Rel**

Zygonicity in the domain of pitch

- Align the two series of events to ensure maximal congruence in the domain of pitch (taking into account individual notes and intervals).
- Events may be omitted from either series, provided sequentiality is not compromised.
- For each match count 1.
- For correct pitch-class but incorrect octave, count 0.5.
- Discounting exact or partial matches involving pitch-class, identify among any remaining pitch events intervallic matches 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 raw score is the number of zygonic relationships of pitch = #Z(P)
- Let the total number of actual and potential sequential relationships between events in the domain of pitch = #Rel
- The strength of derivation of pitch is ZYG(P) ('zygonicity' of pitch), where **ZYG(P) = #Z(P)/#Rel**

Global zygonicity

- Zygonicity in the domains of pitch and perceived time can be expressed as: **ZYG(P+R) = (#Z(P)+#Z(R))/(#Rel•2)**.

It could be argued that this process is more subjective (and therefore less reliable) than a protocol that entailed same/different note-for-note matching, whose results would be unequivocal. But work to date (see, for example, Ockelford, 2006b, 2007c, 2010b) suggests that the 'zygonicity' measure does appear to give intuitively more satisfying results, and although using musical *meta*cognition to interrogate music-cognitive processing is not unproblematic, it is probably less perilous than relying on an apparently more rigorous, but less ecologically sensitive, mathematical approach. Of course, there are ways of addressing the subjectivity problem, including using two raters or more, and in the current project, the scores were verified by another musician who was not otherwise involved in the research.

To give an example of the algorithm in action, see Figure 13.22, which shows Segment 1 of *KM*, and Derek's initial response to it. Taking first the top line, there are

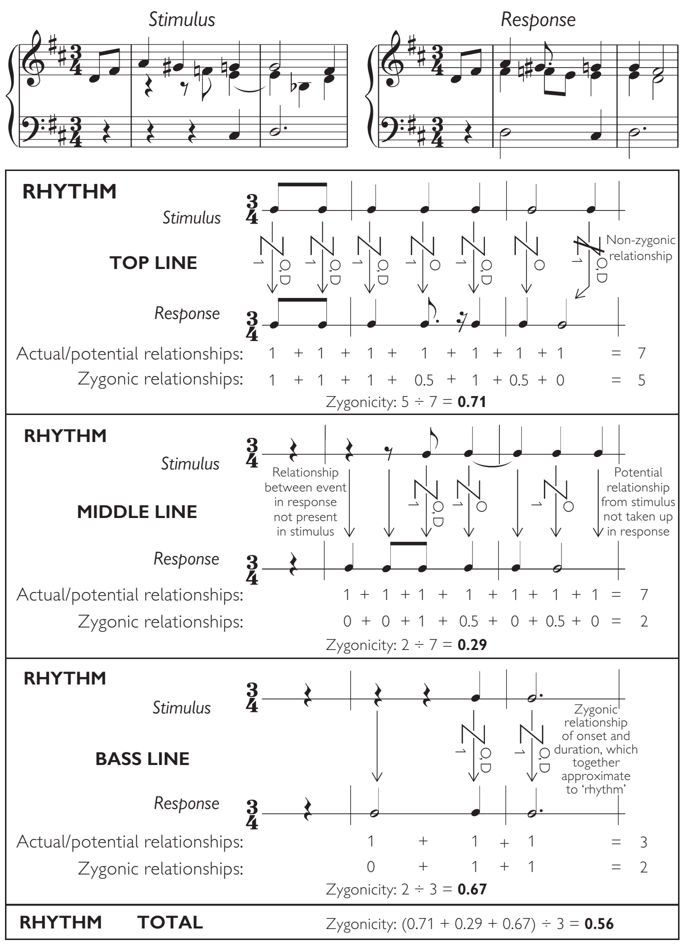
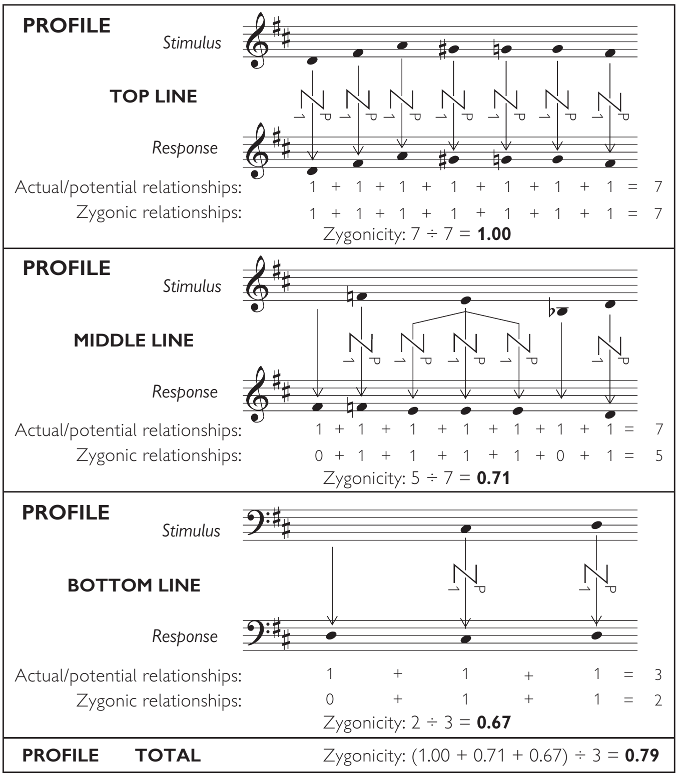


Fig. 13.22 Example of the calculation of a derivation index ('zygonicity').



TOP LINE	Zygonicity (R + P): (0.72 + 1.00) ÷ 2 = **0.86**
MIDDLE LINE	Zygonicity (R + P): (0.29 + 0.71) ÷ 2 = **0.50**
BOTTOM LINE	Zygonicity (R + P): (0.67 + 0.67) ÷ 2 = **0.67**
GLOBAL	Zygonicity (R + P): (0.56 + 0.79) ÷ 2 = **0.68**

Fig. 13.22 Cont'd

seven events in both the stimulus and the response. In the domain of pitch, Derek's recall is entirely accurate (7 ÷ 7 events correct, zygonicity = 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 ÷ 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 (zygonicity = 0.71), and 1 + 0.5 + 0.5 = 2 in the domain of perceived time (zygonicity = 0.29). In the bottom part, two of the three notes that Derek plays are correct with respect to pitch and rhythm (zygonicity = 0.67 in each case). Hence the zygonicity for pitch in the segment as a whole is (1 + 0.71 + 0.67) ÷ 3 = 0.79, and for rhythm is (0.71 + 0.29 + 0.67) ÷ 3 = 0.56. Global zygonicity = (0.79 + 0.56) ÷ 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.

Magical Kaleidoscope, Segment 1 (bars 1–3)

Derek's first attempt to recall this segment was extraordinary to witness. Here was someone who had shown that he could consistently disembed highly dissonant nine-note clusters with a striking immediacy and over 93% accuracy (Ockelford, 2008a, p. 222; Pring, 2008, pp. 219–222), 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. But he really had made a mistake, and the errors continued, with a derivation index in the domain of pitch for the segment as a whole of 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 derivation index of 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 (Ockelford & Pring, 2005), 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.[19] 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 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 now consider how this compares with Derek's recall of the opening of *KM*.

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 derivation index 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. Ockelford, 2009; Repp, 1997). Given that errors could be made at the level of events, groups or frameworks, 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 because: (a) it permitted him to remember more of the stimulus by enabling him to encode the 13 events more efficiently, or (b) it allowed him to make coherent assumptions where his short-term memory capacity was exceeded, or (c) 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 which he consistently maintains. This way of hearing the ascending run of quavers 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 derivation index 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 neighbours '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 at the level of 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 derivation index 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 RH 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 derivation indices 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 indices 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 profile) 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 LH chords forward by a crotchet—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 discernable 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$^{\sharp}$ (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 derivation index 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$^{\sharp}$ becomes a more orthodox D$^{\flat}$, and the chromatic G$^{\sharp}$ 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 (and metrical and ametrical) music. In relation to atonal or ametrical music, 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 and metrical music, in contrast, Derek's errors are purely systematic, *reinforcing* the prevailing tonality and metre 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 same types of cognitive manipulation.

Derek's ability to infer tonal and metrical '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 derivation indices pertaining to each of the pieces that Derek reproduced (Figure 13.23). Taking his recall in the domains of pitch and rhythm together, Derek's versions of the five segments of *KM* ($M = 0.70$, $SD = 0.10$) were significantly more strongly derived from the originals than were those of *MK* ($M = 0.47$, $SD = 0.11$), $t(19) = 7.39$, $p < 0.0001$. Similarly, the *Whole-Tone Scale* segments ($M = 0.62$, $SD = 0.10$) were significantly more accurately recalled than those of *MK* $t(19) = 5.37$, $p < 0.0001$. Note, however, that the difference between *Whole-Tone Scale* and *KM* was far less marked $t(19) = 2.22$, $p = 0.04$.

Separate analyses of Derek's recall of the pitch and perceived temporal components of each piece provide insights into the nature of his cognitive processing that pertains to different perceptual domains. With regard to *profile* (i.e. melodic and harmonic intervals), the average derivation indices are as follows: *Whole-Tone Scale* ($M = 0.64$, $SD = 0.13$), *MK* ($M = 0.61$, $SD = 0.17$), and *KM* ($M = 0.83$, $SD = 0.10$). The difference between *Whole-Tone Scale* and *MK* is not significant, whereas the differences between *MK* and *KM*, $t(19) = 6.51$, $p < 0.0001$ and *Whole-Tone Scale* and *KM*, $t(19) = 8.80$, $p < 0.0001$, are—the implication being that, whether a tonal pitch framework is not recognized (as in the 'bitonal' sections of *Whole-Tone Scale*) or non-existent (as in *MK*),

Derivation indices for Derek's recall of *Whole-Tone Scale*,
trial by trial and segment by segment

		Segment 1			*Segment 2*			*Segment 3*			*Segment 4*			*Segment 5*		
		Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global
Trial 1	Top	0.71	0.64	0.68	0.45	0.73	0.59	0.50	0.75	0.63	0.75	0.63	0.69	0.79	0.71	0.75
	Middle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bottom	–	–	–	–	–	–	–	–	–	0.69	0.63	0.66	0.69	0.38	0.53
	Total	**0.71**	**0.64**	**0.68**	**0.45**	**0.73**	**0.59**	**0.50**	**0.75**	**0.63**	**0.72**	**0.63**	**0.67**	**0.73**	**0.53**	**0.63**
Trial 2	Top	0.53	0.59	0.56	0.46	0.69	0.58	0.46	0.83	0.65	0.86	0.71	0.79	0.92	0.67	0.79
	Middle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bottom	–	–	–	–	–	–	–	–	–	1.00	0.83	0.92	0.86	0.57	0.71
	Total	**0.53**	**0.59**	**0.56**	**0.46**	**0.69**	**0.58**	**0.46**	**0.83**	**0.65**	**0.92**	**0.77**	**0.85**	**0.88**	**0.62**	**0.75**
Trial 3	Top	0.35	0.42	0.38	0.42	0.69	0.56	0.58	0.83	0.71	0.65	0.60	0.63	0.93	0.71	0.82
	Middle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bottom	–	–	–	–	–	–	–	–	–	0.67	0.44	0.56	0.92	0.17	0.54
	Total	**0.35**	**0.42**	**0.56**	**0.42**	**0.69**	**0.56**	**0.58**	**0.83**	**0.71**	**0.66**	**0.53**	**0.59**	**0.92**	**0.46**	**0.69**
Trial 4	Top	0.53	0.50	0.52	0.38	0.83	0.60	0.50	0.83	0.67	0.79	0.86	0.82	0.75	0.75	0.75
	Middle	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bottom	–	–	–	–	–	–	–	–	–	0.93	0.57	0.75	0.70	0.40	0.55
	Total	**0.53**	**0.50**	**0.52**	**0.38**	**0.83**	**0.60**	**0.50**	**0.83**	**0.67**	**0.86**	**0.71**	**0.79**	**0.73**	**0.62**	**0.67**

Means across all segments and trials	Melody	0.56	0.67	0.62
	Inner	–	–	–
	Bass	0.79	0.50	0.65
	Total	**0.61**	**0.66**	**0.64**

(a)

Fig. 13.23 Derivation indices for Derek's recall of (a) *Whole-Tone Scale*, (b) *MK*, and (c) *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*		
		Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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		Rhythm	Profile	Global
	Melody	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**

(b)

Fig. 13.23 Cont'd

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*		
		Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	Global	Rhythm	Profile	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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
	Middle	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
	Bottom	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	Melody	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**

(c)

Fig. 13.23 Cont'd

the effect on Derek's accuracy of recall is much the same in that, as we have seen, he will either make asystematic errors or impose a structure where none exists, or both.

The position with regard to rhythm is quite different, with the following average derivation indices pertaining to each series of 20 trials: *Whole-Tone Scale* (M = 0.61, SD = 0.18), *MK* (M = 0.34, SD = 0.09) and *KM* (M = 0.60, SD = 0.16). The differences between *Whole-Tone Scale* and *MK*, $t(19) = 5.27$, $p < 0.0001$, and *MK* and *KM*, $t(19) = 6.90$, $p < 0.0001$, are both highly significant, while, in contrast, the average derivation indices of *Whole-Tone Scale* and *KM* are virtually identical. The implication here is that Derek was able to recognize and utilize the regularity of the metrical frameworks expressed by *Whole-Tone Scale* and *KM* to facilitate recall, but where he failed to recognise the presence of a consistent metre (in *MK*), the result was a litany of asystematic and structure-seeking errors, significantly greater in number even than those pertaining to pitch in the same piece $t(19) = 8.34$, $p < 0.0001$. This suggests that, in Derek's case at least, perceived ametricality may be even more cognitively challenging than atonality.

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 Figures 13.24 and 13.25.

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 to Segment 5, repeated. As a result, the level of derivation from *MK* as a whole is almost immeasurably low—estimated at 0.08 (with the derivation index of rhythm being 0.05 and profile, 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 the 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 derivation index of 0.17 (with rhythm, 0.11 and profile, 0.23). It appears that the effect of atonality and, to an even greater extent, perceived ametricality, over time appears to have 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 derivation index of 0.44 at the first attempt (0.39 for rhythm and 0.49 for profile) and 0.42 at the second (0.36 for rhythm and 0.48 for profile). As these figures suggest, Derek's responses shared many similarities, with a derivation index of the second from the first of 0.88 (0.84 for rhythm and 0.92 for profile). 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

Fig. 13.24 Derek's recall of *MK*, complete.

Fig. 13.25 Derek's recall of *KM*, complete.

considered as a valid rendition of each, then the global derivation indices 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,[20] 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—one week and one 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 recognise them) may have on memory, Derek agreed to take part in two further tests, respectively a week and a 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.[21] The results after one week are shown in Figure 13.26.

Derek's version of *MK* after the seven-day break is startling. There is very little of the original material left (with an estimated global derivation index 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 7th' 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 extemporisation, two prominent atonal harmonies remain from Schoenberg's *MK*: the chord of $B^{\flat}$ 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 $B^{\flat}$. Derek resolves both these atonal aggregations, enabling them to function as chromatic harmonies: the A in the $B^{\flat}$ minor chord moves down to a G, and forms part of an $E^{\flat 7}$ harmony in second inversion (see bar 5 of Derek's rendition), and the $B^{\flat}$ in the G^7 chord moves up to is neighbouring $B^{\natural}$ to form a 'dominant 7th' chord (upon which Derek's version concludes). The derivation of this version from his previous attempt (index 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 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* one 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 derivation index, matching segment for segment yields a figure of 0.69 (rhythm 0.56 and profile 0.83). The strength of derivation from his previous attempt is 0.82 (rhythm 0.73 and profile 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 utilisation, greatly facilitate the operation of Derek's long-term musical memory.

Fig. 13.26 Derek's recall of *MK* and *KM* after one week.

Finally, Derek was asked, one year later, to play whatever he could remember of the two pieces. The results are shown in Figure 13.27. 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 (derivation index estimated at 0.08).

Fig. 13.27 Derek's recall of *MK* and *KM* after one year.

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 re-create 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 strength of derivation index 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.

Conclusion

In summary, it was found that the memory performance of one savant (Derek Paravicini) was adversely affected when either he did not *recognize* the tonal pitch framework of a piece, or where one *did not exist*: the effect was the same in either case, and resulted in two types of error: 'asystematic', in which mistakes at all structural levels were unpredictable and were not repeated; and 'systematic', in which material was assimilated into familiar patterns of organization through the modification or omission of values, constituting changes which were likely to re-occur. That is to say, the empirical work reported here supports the earlier anecdotal observation that, if the *probabilistic* way in which pitch frameworks are used to create a sense of 'tonality' is destroyed, then Derek's ability to process musical content and structure at the level of events 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 short- and long-term memory.

Of course, while these findings have intrinsic value—not least to those supporting 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 'typical' listeners process atonal or ametrical pieces (or those using unfamiliar frameworks, or familiar frameworks in novel ways)? 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, 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 & Tsimpli, 1995). Indeed, in their 1985 article, Sloboda *et al.* claim that NP'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 (p. 166). That is to say, their findings both *contextualize* the specific in the general, but also use the specific to *inform our understanding* of the general. A second source of evidence for the validity of generalising from Derek's data lies in the fact that other musicians frequently learn and practise 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 recognise pitches and disaggregate chords) in that his musical understanding is implicit rather than explicit, perceptual rather than conceptual, intuitive rather than intellectual. 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.

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 traditional diatonic and metrical frameworks 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 (or music whose tonality is difficult to perceive) 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 Bartôk (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.' In terms of present nomenclature, this equates to structure at the level of events and groups. That is to say, if structure at the level of frameworks is absent or unperceived, then other forms of organization will be required to make the music generally comprehensible, memorable and, ultimately, enjoyable.

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Notes

[1] The Society for Education, Music and Psychology REsearch.

[2] Using a note-matching procedure to gauge accuracy, which differed somewhat from Sloboda and colleagues' error-counting protocol.

[3] A series of melodic or harmonic intervals—the equivalent of rhythm in the domain of pitch; see Ockelford, 2006a, p. 99.

[4] Potentially conferring a processing advantage over encoding as successive intervals, since, in the Western diatonic system, successive steps in pitch frameworks may be separated by *different* intervals.

[5] Similar results were obtained for Eddie, the young savant with whom Miller worked. In TR's case, Young and Nettelbeck report that there was no 'deviation into the diatonic system', implying that he was 'clearly aware of how the whole tone scale operates' (1995, p. 242).

[6] 'Zygonicity' is a measure of the 'orderliness' of a passage or feature thereof, whereby the number of *zygonic* relationships between events is expressed as a proportion of the total number of *potential* relationships, where the maximum is 1 and the minimum is 0. For further information see Ockelford (2005a, pp. 73–4).

[7] There is also evidence from memory studies with Derek Paravicini (for example, Ockelford & Pring, 2005, p. 906), that *production* of material has a significant interference effect, even when the original is repeated between attempts. Zygonic analysis shows that the most powerful influence on Derek was not rehearing the original, but his latest or even penultimate performance of it—even though these occurred *before* rehearing the original stimulus.

[8] A Schenkerian concept, whereby a note or notes, or harmony or harmonies, is deemed to have the effect of extending another in time. For recent work that demonstrates the perceptual reality of prolongation near the musical surface, see Martinez (2007).

[9] Note that the central chromatic passages would present no particular difficulties to people (such as NP) who had absolute pitch.

[10] Another concept borrowed from Heinrich Schenker (1906).

[11] With his consent, Derek is named in this research, as he is in any case a public figure and since, despite the realistic accounts of his abilities in his biography (Ockelford, 2007a) and on his website, misinformation about him continues to be circulated—his supposed powers of 'instant and perfect recall' for example—whereas the way his memory works is much more subtle (through no less remarkable) than that. It is hoped that research such as that reported here will gradually inform popular perceptions of Derek's musical capabilities.

[12] Even 10-note chords are reproduced with over 90% accuracy (Ockelford, 2008a).

[13] It seems that NP was not able to adopt this strategy, and he evidently found the passage bewildering, since he played nothing at all after hearing it for the first time. The second time, extrapolation from Miller's re-analysis of Sloboda *et al.*'s data using the note-for-note matching paradigm (mentioned above), suggests an accuracy of 58% (that is, a little over half the notes were right). Eddie (using the same protocol) apparently only managed 45%. In neither case is it clear what the precise nature of the errors was.

[14] Derek's recall of Segment 1 evolved over Trials 1 and 2, such that pairs of quavers a tone (one scale-step) apart came to dominate. Rather as NP's efforts had done previously (though he used a subtly different mechanism—see Figure 13.9), this imbued the surface of the music with greater moment-to-moment regularity, leading to a simplification of structure at the level of events, and so making it easier to remember (evidence for which is shown by Derek's responses being more similar to each other than to the original): an intuitive strategy,

perhaps, when short-term memory was overloaded, to enable him to preserve deeper structures. In Segments 2 and 3, Derek continued to rely almost exclusively on pairs of quavers (or longer durations whose onsets were a quaver apart) delineating whole tones, suggesting systematic interference between segments.

[15] 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) (1949/1975, p. 86). 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.'

[16] Forte has specialized in studying the music of the so-called 'Second Viennese School', embracing works by Schoenberg, Berg, and Webern, whose use of pitch frameworks consciously moved away from the patterns of idiosyncratic usage that created the effect of 'tonality'—a radical approach which was eventually codified in Schoenberg's 'serial' procedures. Here, notionally, at least, each pitch has equal structural weight. Forte's approach to explaining the structure of atonal music is termed 'set-theoretical analysis', which holds that one group or 'set' of pitches can be regarded as *equivalent* to another, irrespective of transposition or inversion, the octave in which values are realized, whether or not they are repeated, and, additionally (quite unlike serialism), the order in which they occur (Forte, 1973). The result is that musical textures are parsed as a series of contiguous or overlapping pitch-cells, which may be regarded as more or less closely related through mathematically calculated indices of similarity (see, for example, Isaacson, 1990; Ockelford, 2005a, pp. 67–119). The lack of any evidence that such pitch sets and the relationships between them played any part in the process of composition of Op. 11, No. 1 and pieces like it, or are part of the 'typical' listening experience of this and similar works, and are therefore of any significance beyond a small community of expert music analysts, has been a matter of some contention (see, for instance, Mailman, 2007—although the possibility of acknowledging that 'analytical' grammars may work alongside those identified by Lerdahl as pertaining to composition and listening (see above) does seem to offer one way out of the epistemological impasse (Ockelford, 2009). In this regard, it is interesting to note that Derek's efforts at reproducing Op. 11, No.1 bore no relationship to the structure or content of the pitch-sets identified by Forte in his analysis, nor, indeed, to the author's supposedly more 'perceptible' account (see Ockelford, 2005a, p. 110). The extent to which Derek's reproductions (1) can be taken to illustrate his cognitive representation of atonal music and, more controversially, (2) can be considered to be broadly representative of how 'typical' (i.e. 'intuitive') listeners reconstruct such music in memory is considered in later sections of this chapter.

[17] The reverse approach to that adopted by Lalitte, Bigand, Kantor-Martynuska, & Delbé (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, it seems that structure at the level of events and groups was not controlled with the same rigour as in the current work.

[18] Using the following similarity measure (Ockelford, 2005a, p. 41):

$$\text{Simolarity of two setsof values (\%)} = 100 - \Sigma\left(\frac{\Sigma\left|X_i - \left(\frac{\Sigma X_i}{X}\right)\right|}{X}\right)\%$$

[19] 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 about NP, who showed signs of distress at being asked to reproduce the Bartôk.

[20] The two quavers 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.

[21] 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.

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