On similarity, derivation and the cognition of musical structure

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ABSTRACT Following a review of the model of similarity perception, cue abstraction and categorization, developed and empirically tested by Deliège and others over the last decade or so, it is proposed that the notion of perceived *derivation* may be a key additional element in the cognition of musical structure. Evidence is sought in the re-analysis of recent empirical work and through the identification of structures that appear to challenge the sufficiency of Deliège's model. The issue is contextualized through a discussion of the concepts of similarity, sameness and salience, utilizing contemporary thinking in cognitive psychology, philosophy and music theory – strands of thought which are drawn together through Ockelford's 'zygonic' theory of music-structural understanding. This leads to the formulation of a new, composite account of how musical structure is processed, in which similarity, salience, derivation, categorization and schematization are shown to function in an integrated way.

KEYWORDS: *categorization, grouping, perceived derivation, relationship, repetition, salience, sameness, zygonic*

1. Introduction

This article builds on the work of Irène Deliège and her followers undertaken since the late 1980s in relation to similarity perception in music, focussing particularly upon the model of cue abstraction and categorization which has framed their research and which, it is asserted, captures some of the key cognitive processes in our understanding of musical structure as it unfolds over time (Deliège, 2001a). The current article, which is theoretical in nature, interrogates this thesis and related empirical data from a psychomusicological perspective (which in methodological terms seeks to fuse the findings and concepts of cognitive psychology with the intuitions that properly underpin music theory and analysis), indicates how it may be possible to refine and extend Deliège's model, and outlines the potential implications of these proposals for future music-psychological research in this area. The result is hopefully a 'thoughtful confrontation' between empirical and theoretical approaches to understanding music – to paraphrase Gjerdingen (1999: 166) – which seeks to foster progress in both.

The article is in eight sections. Following this introduction, which rehearses the epistemological status of the article and its structure, Section 2 sets out the key elements of Deliège's model as most recently defined and exemplified – in particular drawing on the special issue of *Music Perception* (18(3), Deliège 2001)[1] entitled 'Similarity Perception ↔ Categorization ↔ Cue Abstraction' and edited by Deliège herself. Section 3 asks whether the model as it stands is *sufficient* or *necessary* to explain the processing of musical structure, with reference both to the empirical work set out in the volume of *Music Perception* cited and music-analytical examples. This approach brings to light a number of issues, which, to be addressed adequately, require a broader epistemological and conceptual base. This is provided in Section 4, which analyses similarity, sameness and salience through drawing on recent and contemporary thinking in a number of related fields, including artificial intelligence, cognitive psychology, philosophy and music theory. In Sections 5 and 6 these ideas are drawn together within the framework offered by the author's 'zygonic' theory of music-structural understanding (for example, Ockelford, 1999, 2002, 2004). Central to the theory is the notion of 'perceived derivation', and it is proposed that this be incorporated into Deliège's model, supplementing the established principles of similarity perception, cue abstraction, category construction and schematization, and thereby extending its explanatory power to a wider range of structural narratives in sound (Section 7). The newly extended model enables the questions and anomalies identified in Section 3 to be re-analysed and suggests ways in which they may be resolved, subject to the findings of future empirical work. In conclusion, Section 8 offers a summary of the arguments that have been advanced.

2. The similarity perception/categorization/cue abstraction model

The model of similarity perception, cue abstraction and categorization developed by Deliège in the late 1980s has become increasingly prominent in the cognitive psychology of music in recent years. It is based on the ideas of similarity and difference (summarized, for example, in Deliège and Mélen, 1997). The model invokes and extends the principles of gestalt perception (see, for instance, Deutsch, 1999a), through which musical information is typically chunked into motives, phrases, sections and so on. Deliège observes that, whatever the grouping principle involved, a common feature 'is to be found invariably in the perception of a difference between the confronting regions' (1987: 326), 'as opposed to a similarity between the elements within the groups' (2001a: 235). In each musical segment, attention is focused on salient features through the process of cue abstraction (see, for example, Deliège, 1996). Cues fulfil a number of functions, serving as parsimonious cognitive representations of segments, thereby facilitating their recognition, storage and comparison. Cues act in concert with the principles of similarity and difference to underpin the process of musical categorization which, Deliège claims, is always operational during attentive listening, irrespective of style or structure (2001a: 239). In the context of a piece as a whole, categorization enables cues to act as milestones – progressively marking out musical time – forming a mental line in a 'symbolic "musical space" in which the fundamental articulations of the mental schema of the work are drawn' (p. 238). The notion of a cue abstraction mechanism further suggests that musical categories are organized around prototypical structures (or imprints) derived from the traces left by the repetition of cues formulated during the hearing of a piece (cf. Rosch, 1978; Koniari et al., 2001: 299).

3. Issues

Research into segmentation processes using Deliège's model has been undertaken on music in a range of styles, including pieces by Mozart, Wagner, Debussy, Milhaud, Maderna, Webern, Berio, Boulez and Stockhausen (Deliège, 2001a: 239). The results lead Deliège to conclude that categorization is a universal feature of attentive listening although, as she avers (pp. 240, 241), it would be dangerous to believe that the 'model could be complete and that it could reproduce in all respects the phenomenal reality for which it aims to account.' That is to say, in Deliège's view, the model captures mental operations that are necessary in the cognition of musical structure, though it may not be sufficient to describe all the processes that are involved. It is not possible to explore these assertions fully using empirical data alone, since experiments devised on the basis of Deliège's hypothesis (or which are of direct relevance to it, such as Pollard-Gott's work on the emergence of thematic concepts, 1983) are still relatively scarce. However, given that the current article is theoretical in nature, it is reasonable to supplement such empirical findings as exist with intuitively derived evidence of the type that characteristically informs music analysis (see Cross, 1998). Moreover, the thinking that arises from this interdisciplinary approach will in subsequent sections indicate ways in which Deliège's model may be extended, and so suggest future empirical work – which may ultimately verify or fail to support the proposals outlined here – in the manner described by Cross (p. 4).

To test the sufficiency and necessity of the similarity perception/categorization/cue abstraction model, four examples are cited, which highlight respectively: the nature and structural function of relationships between segments in *different* categories; the capacity of a single categorical scheme (for instance, $A_1 \ldots A_2$) to produce quite different structural results;

the problem of modelling iterative change through a categorical approach; and forms of categorization identified in some empirical work which appear to be counterintuitive in music-analytical terms.

THE STRUCTURAL SIGNIFICANCE OF RELATIONSHIPS BETWEEN SEGMENTS IN DIFFERENT CATEGORIES

By definition, the process of categorization is at once inclusive and exclusive. As Rosch (1978: 28ff) puts it: 'To categorize a stimulus means to consider it, for purposes of that categorization, not only equivalent to other stimuli in the same category but also different from stimuli not in that category.' However, in the context of listening to music, we need to clarify how this principle works alongside the fundamental need for coherence. Because listeners expect pieces to make sense – to unfold coherently and cohesively over time (cf. Russo and Cuddy, 1996) – it follows that successive events must offer plausible continuations of the material recently and currently being heard, including those items which are sufficiently contrasting to be heard as exemplifying different categories (see Section 6 below; also Ockelford, 2004). Consider, for example, Schubert's Ländler for piano, D145, No. 10, used by Koniari et al. (2001) to investigate the categorization and schematization of music by children. The authors' own 'morphological' reading of the piece shows it to be wholly constructed from only two distinct motives (see Figure 1).

This analysis both underpins and is supported by the study's empirical findings, which, with a correct classification rate of 83 percent, provide very strong evidence of the ability of children (aged 10 and 11) to categorize segments in short, simple compositions such as the Ländler. However, other data from the same paper make it clear that this capacity alone is not sufficient to enable subjects to recreate the 'mental line' of the piece, since only around 8 percent of subjects were able to reconstitute the Ländler from a randomized series of its eight two-bar building-blocks. Arguably this is because the category to which a chunk is assigned is only one relational feature that is of structural significance (cf. Deliège et al., 1997), and it appears that the other forms of relationship between segments (that do not pertain to categorization) may have been degraded or eliminated in the process of extracting and isolating the chunks concerned.

THE STRUCTURAL SIGNIFICANCE OF THE NATURE OF RELATIONSHIPS BETWEEN SEGMENTS IN THE SAME CATEGORY

A related issue derives from the possibility of variation within categories (Rosch, 1978: 35ff). Consider, for instance, the first movement of Beethoven's Symphony No. 5, Op. 67. The opening four-note gesture, clearly defined and delimited from other material, dramatically sets the scene (cf. Zbikowski, 2002: 34). In terms of Deliège's model, it is not clear (and future empirical work would be required to determine) whether the salient features of this

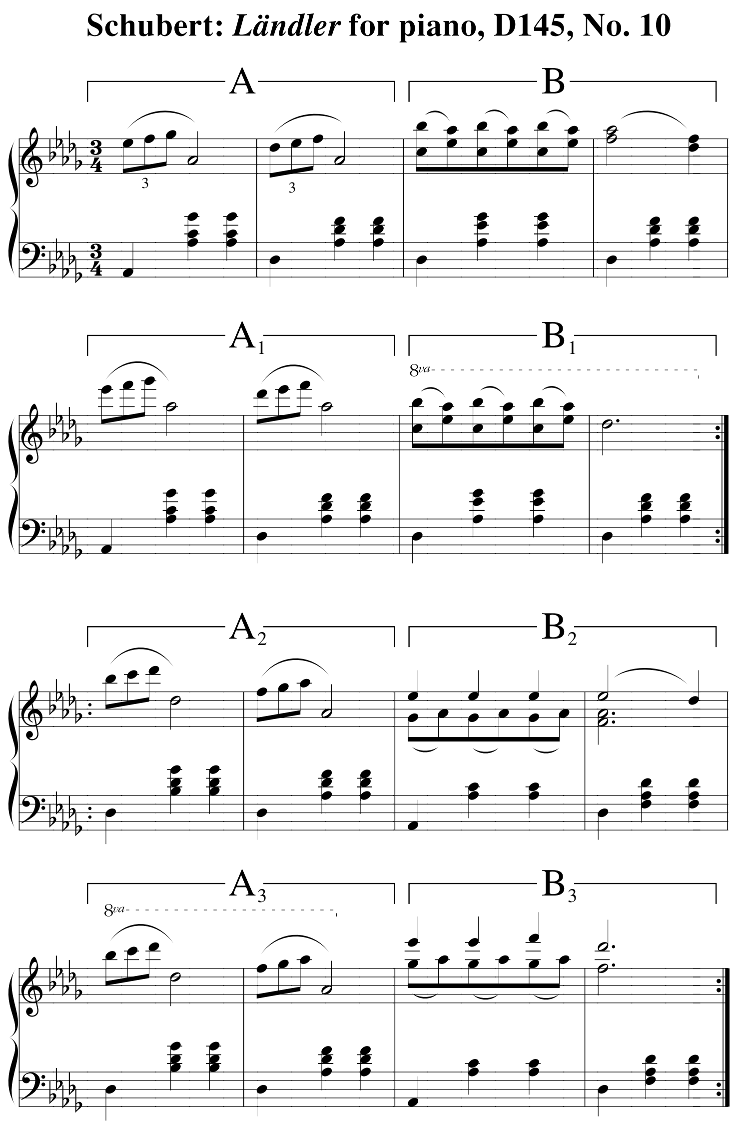

FIGURE 1 *Morphological analysis of Schubert, D145, No. 10 (after Koniari et al., 2001), showing its construction from just two distinct motives.*

motive are encoded immediately after they have been heard as a potential 'imprint'; presumably this would be affected by the listener's degree of familiarity with the work. Irrespective of the way in which the material is represented in cognition, however, we can surmise that, at the very least, key features of pitch and rhythm must be stored in short-term memory, since the tonal transposition that follows is readily recognizable as a variant of the

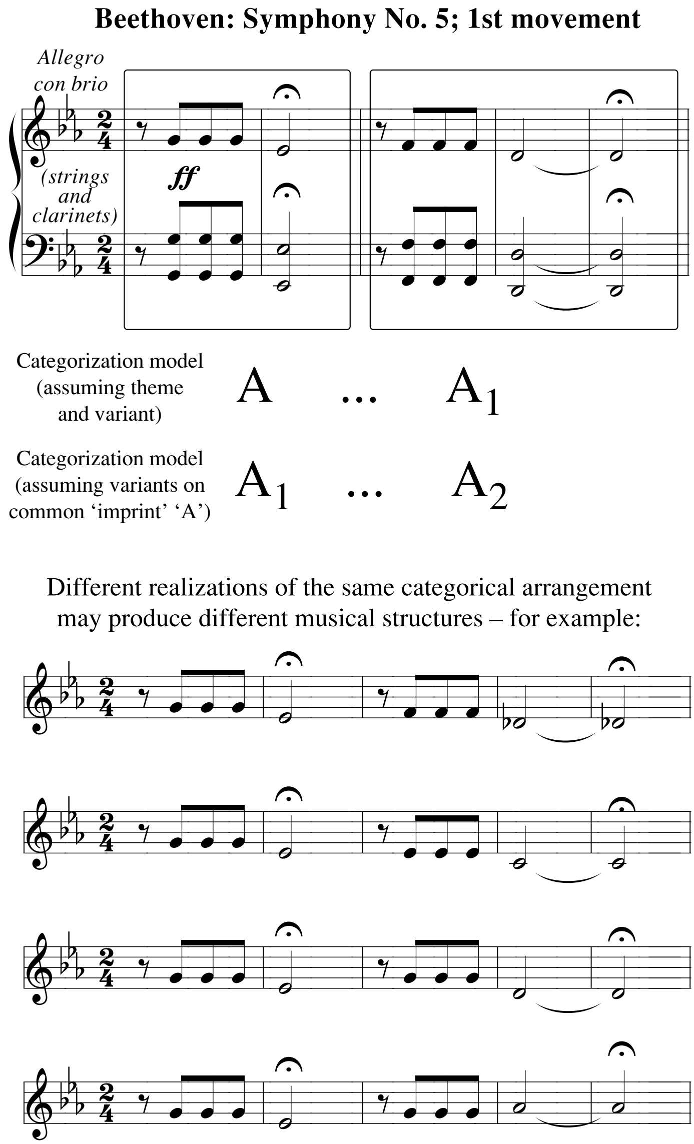

FIGURE 2 *Successive appearances of motives in the same category can have a range of structural consequences.*

opening segment. At this point, then, there are two possible formulations of Deliège's 'mental line' in symbolic musical space: either A . . . A_1 (if the second motive is regarded as a direct variant of the first), or A_1. . . A_2 (if both motives are heard as distinct reifications of the same imprint 'A').

Does either model provide an adequate metaphor, though, for the way in which the opening five bars are modelled cognitively? If all the mind were doing was to register the fact that successive motives were representatives of the same category, then presumably it would be aspects of similarity alone that would be deemed to have structural significance. Accordingly, appositions such as those shown in the lower half of Figure 2 would be regarded as different formulations of the same essential structure. Self-evidently, this is not the case, however, for it is not only recognizing sameness and similarity between the motives that is important, but gauging the differences between them too. That is, other relationships beyond those involved in the establishment of categories are (a music-analytical approach suggests) structurally relevant. Hence we may hypothesize that a more complete structural model of the opening of Op. 67 would acknowledge not only the reiteration of a motivic category, but would also include the degree of transposition (down one scale degree) and change in implied harmony (I . . . vii/V^7)[2] between Gestalts. The importance of these transitions in sub-domains of pitch becomes clear in the passage that follows, when the harmonies previously implied become realized (extended in duration), and the descending 2nd is inverted and used as the basis of a rising sequence (which ultimately is a significant factor in ensuring continuity between the imperfect cadence and pause in bars 20 and 21, and the modified reprise of the opening gesture) – see Figure 26 later. This feature of musical organization, whereby non-categorical aspects of structure evolve through change, appears to be difficult to capture in a purely categorical model. It is as though the nature of Deliège's 'mental-line' on which cues are marked out is at least as important as the motivic milestones themselves.

THE PROBLEM OF CAPTURING ITERATIVE CHANGE IN A CATEGORICAL MODEL

The challenge to the sufficiency of a model of music-structural cognition which is based on the categorization of segments becomes acute when faced with a form of development favoured by Beethoven in the first movement of the 5th Symphony, whereby chains of motives manifest progressive change, through what Meyer refers to as 'processive conformant relationships' (1973: 48–9), which may entail the successive modification, addition or removal of features (see Section 6 below; cf. Schoenberg, 1967: 10), see Figure 3. This technique enables composers to effect the substantial transformation of material through a series of small steps. Hence while successive links in the chain of development could – we may surmise – be heard as model and variant (and therefore assigned to the same category), when the first link is compared to the last, it may be evident that the categorical bounds have been exceeded and a metamorphosis has taken place. That is, while attending only to a motive and its immediate neighbours may indicate a mental-line such as the following: A_1 . . . A_2 . . . A_3 . . . A_4 . . . A_5 . . . A_6, extending the horizon of one's aural attention may reveal that, since A_1 and A_6 are contrasting, they could not reasonably be considered to be members of the same category.

A striking example of this process in the first movement of Op. 67 occurs in the development section, at bar 210. Over the previous 15 bars 'elements of the motive have been progressively deleted . . . until at this point one event stands for the original motive' (Lerdahl and Jackendoff, 1983: 43). Although this event, a chord of b♭ minor in first inversion, and the chords that follow, are heard as having been logically derived from the motive through a series of incremental changes, and while each chord may indeed substitute in some sense for a fuller version of the opening gesture, it is difficult to hear chord and motive as members of a common abstract category (or 'imprint'). In Deliège's terms, what is the cue abstracted from the original motive that pertains to the chord? Analysis suggests that the only contender is the duration of the fourth note of the opening – a minim with a pause – but this is at least twice as long in performance as the length of the chord. Moreover, Beethoven exploits the contrasting nature of original motive and the single chords that derive from it to give a jolting sense of (varied) reprise when the former suddenly reappears in bar 228.

Beethoven: Symphony No. 5; 1st movement

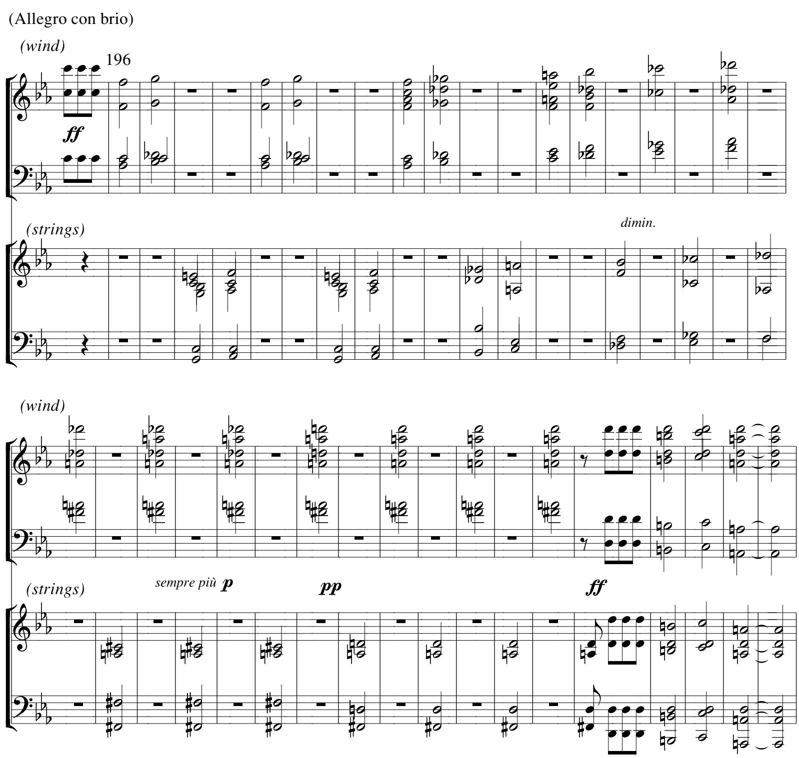

FIGURE 3 *Progressive motivic change poses a challenge to Deliège's categorical model of music perception.*

THE PROBLEM OF SIMILARITY JUDGEMENTS IDENTIFIED IN SOME EMPIRICAL WORK THAT APPEAR TO BE COUNTERINTUITIVE

Using Deliège's model as a basis for their investigation, Lamont and Dibben (2001) examined how listeners perceive similarity relationships in two contrasting styles of music (the first movement of Beethoven's Piano Sonata Op. 10, No. 1, and Schoenberg's Klavierstück Op. 33a). For each piece, listeners were asked to gauge the similarity of pairs of excerpts, having first heard each movement in its entirety. The results were analysed through multidimensional scaling, and a two-dimensional solution was found to be statistically optimal in both cases. In the Beethoven sonata, the principal dimension of similarity related to dynamics, articulation and texture, and the subsidiary dimension to contour and tessitura. In Schoenberg's piano piece, analysis showed that the primary dimension related to tempo and dynamics, and the secondary dimension to texture.

Yet these findings are sharply at odds with the intuitions of music theorists and analysts, who also seek to explain musical coherence through relationships of similarity (Deliège, 2001a: 239). According to Bent and Drabkin, for instance, the central activity of analysis is comparison of unit with unit, through which structural elements and their functions are determined. 'The central analytical act is thus the test for identity. And out of this arises the measurement of amount of difference, or degree of similarity' (1987: 5). However, music theory and analysis typically focus on structures in the domains of pitch and rhythm – see, for example, Tovey's (1931) account of Beethoven's Op. 10, No. 1, and Perle's (1981) exploration of Schoenberg's Op. 33a – since it is these dimensions that have traditionally shouldered the burden of the compositional dialectic (Boulez, 1971[1963]: 37), whereas dynamics, timbre, texture etc. have been treated as subordinate features (cf. Erickson, 1975: 12; Bregman, 1990: 456). Lamont and Dibben seek to reconcile this apparent contradiction by asserting that the lack of evidence they find to support similarity judgements based on thematic and motivic similarity is probably due to the short-term nature of the study, and that 'in time, or with explicit instruction, listeners may come to recognize and use these kinds of relationships to guide their similarity judgements' (2001: 264). Certainly, this hypothesis accords with the findings of Pollard-Gott (1983), who, in a study of Liszt's b minor piano sonata, discovered that the relationships perceived among passages corresponded with higher order thematic structure only after repeated exposure to the music (gained either during the course of the experiment or through previous experience), while the perception of other more general features, defined by extremes such as 'high' and 'low', 'loud' and 'soft', and 'simple' and 'complex', remained largely unchanged from the first hearing.

I would contend, however, that there are dangers of misconstruing the significance of these data as far as the cognition of musical structure is concerned. Consider again the first movement of Beethoven's Sonata Op. 10, No. 1. Even to listeners with no musical training (who are nonetheless broadly familiar with the western classical style) the first movement 'makes sense' at some level on a first hearing. Evidently, intuitive mental processing occurs which means that the sonata is heard as more than a meaningless jumble of sounds; quite unwittingly patterns are discerned that make the stream of auditory input recognizably 'music', with a perceived orderliness and inner logic to which the mind instinctively attunes itself. However, if one were to randomize the pitch and rhythmic content of the movement (while leaving the dynamics, articulation, texture, contour and tessitura intact) would it still make sense as music? Specifically, would not the similarity that Lamont's and Dibben's subjects observed between excerpts – originally chosen, after all, on the basis of their thematic design – be significantly affected by its absence? This is a question for future empirical work to resolve.

In the meantime, it seems reasonable to hypothesize that the orderly disposition of pitch and rhythm, which offers listeners a framework for constructing a coherent cognitive musical experience, may in part relate to categorization at the motivic or thematic level, but it need not. This implies, given the evidence of Pollard-Gott's study in particular, that it is the aspects of structure pertaining to pitch and perceived time that do not pertain to categorization that are important at first, and that the process of categorization relating to these dimensions only becomes more significant with increasing familiarity – at least in pieces utilizing intricate developmental techniques (with rather more straightforward material this may not be the case; see Dowling et al., 2001). And it may be that when listeners are presented with excerpts taken out of their original context within a piece, being denied access to the networks of local relationships in the domains of pitch and perceived time that would normally supply the necessary structural cohesion, they make judgements of a categorical nature by referring to the rather more immediate auditory features of the music (texture, dynamics etc.) – thereby inadvertently construing the 'carrier' (to borrow Ericksson's term; 1975) as the 'message'.

This is a complex argument which will be explored in some detail in the course of this article. First, we interrogate the notion that lies at the heart of Deliège's model and which is central to the issues that have been raised in relation to it – similarity – and with this, two related concepts: sameness and salience.

4. Similarity, sameness and salience

All models of music perception need to take account of the fact that pieces unfold over time (cf. West et al., 1987: 13; Deliège, 2001a: 237). One way of formulating structural descriptions that acknowledge the temporal nature of music is to 'quantise the time dimension and represent relevant facets of musical experience in each time slice' (West et al., 1987: 14). The authors suggest that the notion of 'frames', a representational system introduced into the sphere of artificial intelligence in the 1970s by Marvin Minsky, be adapted to this end (cf. Deliège, 2001b: 374). West et al. (1987) define a frame in the context of listening to music as comprising a number of percepts (likened to 'slots'), each having some 'value' (the content of its slot). This is comparable to Hampton's prototype concept, which is 'constituted by a set of attributes with associated values (where a particular attribute-value pair corresponds to a property)' (1993: 73). Frames enable 'pitch values, timbral qualities, loudness and spatial location' to be captured at the most detailed level, 'as well as higher order pitch and rhythmic structures with their associated features such as depth of texture, tonality, idiom, tempo etc.' (West et al., 1987). To avoid the loss of information that can occur in quantization, frames may be of the duration necessary to register a particular feature of musical experience. Here, however, for theoretical simplicity, we will work on the assumption that frames correspond to what are typically music's smallest units: notes.[3]

To the extent that frames and their constituent attribute-values do indeed model aspects of music perception, the nature of 'typical' musical experiences, in which listeners do not reflect consciously upon their apprehension of the auditory stimuli concerned, means that they will tend to pass by as a series of qualitative sensations. These have a complex relationship with the physical inputs to which they directly or indirectly relate. In the temporal dimension, for example (following the model of Husserl (essay written between 1905 and 1910), 1964[1928]; summarized in Miller, 1984: 120ff; and revisited in Lewin, 1986: 329ff), frames may exist in response to contemporaneous musical experience ('primal impressions'), be projected from memory into present consciousness ('retentions'), or function as expectations of the future, again existing in the conscious present ('protentions'). Whatever their provenance, it is not so much individual frames that make music what it is, but the way in which they are mutually related (cf. Krumhansl, 1990: 3). Potentially, each frame may be compared with any other through a number of parallel relationships – subconscious mental constructs linking equivalent attribute-values. In terms of the theoretical model developed by Ockelford (1991, 1993, 1999, 2002, 2004), in which attributes are termed 'perspects' ('perceived aspects'), their modes of existence 'perspective values', and the cognitive links between them 'interperspective relationships' (each bearing an 'interperspective value'), the supposed cognitive connection between two frames may be represented as shown in Figure 4 (see also Figure 7 later).

These relationships, directly linking percepts, are said to be at the 'primary' level (indicated by the subscript '1'). The model suggests that relationships between these – 'secondary' relationships – often figure in music perception too (see Figure 5).[4]

Perspects and the values which pertain to them are very diverse (see

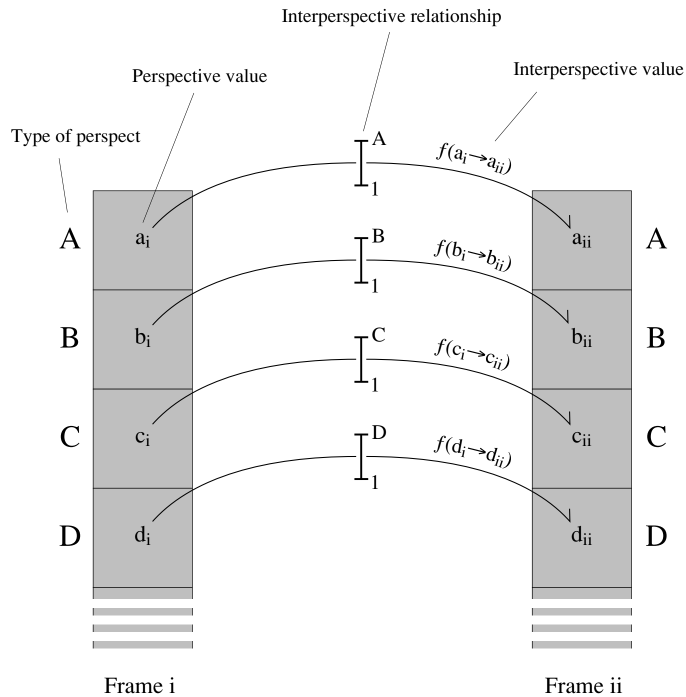

FIGURE 4 *Frames, perspects, interperspective relationships and values.*

Figure 7). Some, such as pitch, potentially exist along a number of continua, including pitch-class, height and tonal function (Deutsch, 1999b), each yielding interperspective values of difference to the ear that is suitably attuned. Others, such as duration, incur relationships that may be heard and understood as differences or ratios by listeners adopting a consciously conceptual mode of listening (forms of comparison that are implicit in standard

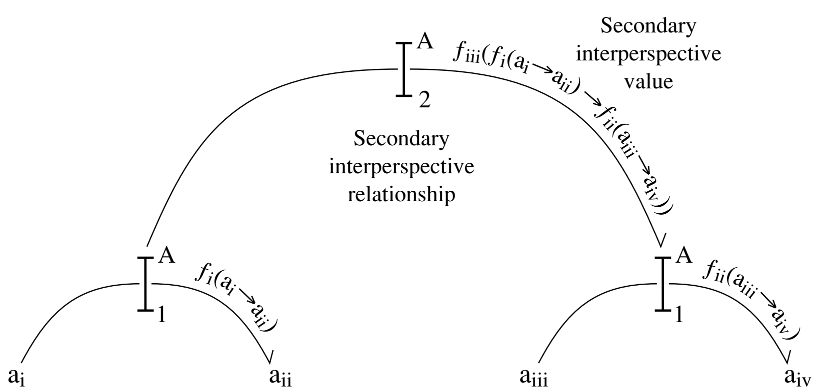

FIGURE 5 *Abstract representation of secondary interperspective relationship.*

western notation). Other perspects yet, such as timbre, bear values that are irreducible to solitary coefficients (cf. Risset and Wessel, 1999), whose inter-perspective relationships are therefore typically complex too (though see Slawson, 1985). Given this diversity, it is perhaps inevitable that while, in relation to a given sound, perspective values are bound together in a common phenomenological experience, all have come to serve distinct musical–structural functions.

While the overall similarity of two frames equates to the combined effect of the interperspective values that exist between them, the issue is by no means straightforward, for just as the perception of values depends on how they stand in relation to others (both within a single perspective domain and between domains), so judgements of similarity are context-bound too. Moreover, the experiences of listeners, and the expectations they bring to bear, are crucial factors in similarity judgements (Medin et al., 1993: 257).[5] Inevitably, then, the concept of similarity has a complex relationship with that of sameness or identity. Cambouropoulos (2001: 349–50) concludes that two entities can be judged to be identical 'only when a finite number of properties that are considered salient for a given domain of discourse are demarcated. When we say that two objects are identical we mean that all the properties . . . that describe the two objects – taken from a set of predefined properties that are considered to be pertinent in a given context – have the same values.' In western classical music, salience is typically (though not exclusively) generated through distinctive patterns of relative pitch and interonset intervals. So it is that two melodies can be considered the same irrespective of timbre and loudness: a melody sounds the same 'whether it is sung softly or loudly, blown on a trumpet or plucked on a guitar' (Zuckerkandl, 1973: 90).[6] Conversely, with equal certainty, 'the introductory brass fanfare from Tchaikovsky's 4th Symphony [for example] . . . would not spring to mind if the horn section were just to improvise at the appropriate dynamic level' (Ockelford, 1999: 4; see also comments in Section 3 earlier).

The concept of frames (which comprise a number of perspects) can be used to clarify the relationship between sameness and similarity. With respect to each perspective domain, sameness, similarity, difference and contrast can be considered to exist on a continuum, which, as we have seen, may be unidimensional in the case of loudness, for example, or multidimensional with perspects such as pitch (Shepard, 1982). None of these concepts is absolute: the limits of each vary according to context and listeners' expectations. Even 'sameness' covers a range of possibilities, extending from identity into differences that are readily perceptible in 'ideal' (laboratory) listening conditions, due to categorical perception (see, for example, Dowling and Harwood, 1986: 92). Moving from individual perspects to complete frames, a number of scenarios are possible. 'Complete' identity occurs when all values in two frames are perceived to be the same. This implies the perception of duality in a single entity, and is found where two independent lines played on a single instrument converge on one note (as, for example, in the last chord of Tallis's *Ordinal* played on the keyboard – see Figure 11 later).

However, perceived identity may also occur when two frames are linked through a combination of interperspective relationships (connecting values that are deemed to be the same, similar or substantially different), provided that – following Cambouropoulos's analysis – the values of those perspects reckoned to be salient are perceived to be the same. If they are not, then the frames may be heard as similar or even contrasting. Similarity between frames may result either from all the relationships between them being similar, or – extending Cambouropoulos's model – if salient perspects alone are linked through relationships of similarity (irrespective of the nature of the relationships between perspects deemed to be non-salient). If this is not the case, then the frames may be perceived as substantially different. 'Complete' dissimilarity will occur when all values differ significantly.

5. Similarity, derivation, and the cognition of structure

So much for similarity, sameness and salience – key principles underlying Deliège's model of music perception. Clarification of these concepts alone, however, does not enable us to address the issues raised in Section 3, and so a further factor is introduced here: the notion that one musical element can be reckoned in some sense to derive from another. We consider too the way in which perceived derivation relates to similarity and the cognition of structure.

The mental connections which, we have hypothesized, potentially link perspective values – the so-called 'interperspective relationships' depicted in Figures 4 and 5 – are essentially descriptive in nature. It seems that this is not true of all such relationships, however, some of which appear to fulfil an implicative function (cf. Meyer, 1989: 84ff), whereby one value or more is felt to derive from another or others. It is proposed that this sense of derivation arises from imitation: if one perspective value is thought to exist in imitation of another, then the second is perceived as being restricted or controlled by the first, and thus derived from it (Ockelford, 1993: 94ff). This proposition is summarized by Cone (1987: 237): 'y is derived from x (y ← x, or, to use the active voice, x generates y (x → y), if y resembles x and y follows x. By "resembles", I mean "sounds like" . . .'

Clearly, the notion of *imitation*[7] is closely related to that of *repetition*, whose fundamental importance in the creation and understanding of musical structure is affirmed by a wide range of music theorists and psychologists alike: see, for example, Schenker (1979[1935]: 9ff), Reti (1951), Ruwet (1987[1966]), Simon and Sumner (1968), Meyer (1973: 44), Deutsch and Feroe (1981), Forte (1973, 1985), Lerdahl and Jackendoff (1983: 52), Lewin (1987), Gjerdingen (1988), Nattiez (1990) and Morris (1995). However, as will become apparent, it is recognizing that the perceptual acknowledgement of repetition (which itself depends on the perception of similarity or sameness) is a necessary though not a sufficient condition for the apprehension of musical structure – which, as we have hypothesized, requires a sense of derivation – that represents the advance in theoretical thinking that is critical in this article.

The interperspective relationships through which perceived derivation (or generation) is presumed to be cognized are termed 'zygonic' by Ockelford (1991: 140ff).[8] It is hypothesized that, at the level of frames, zygonic relationships (or 'zygons') reasonably model a link thought to be constructed in

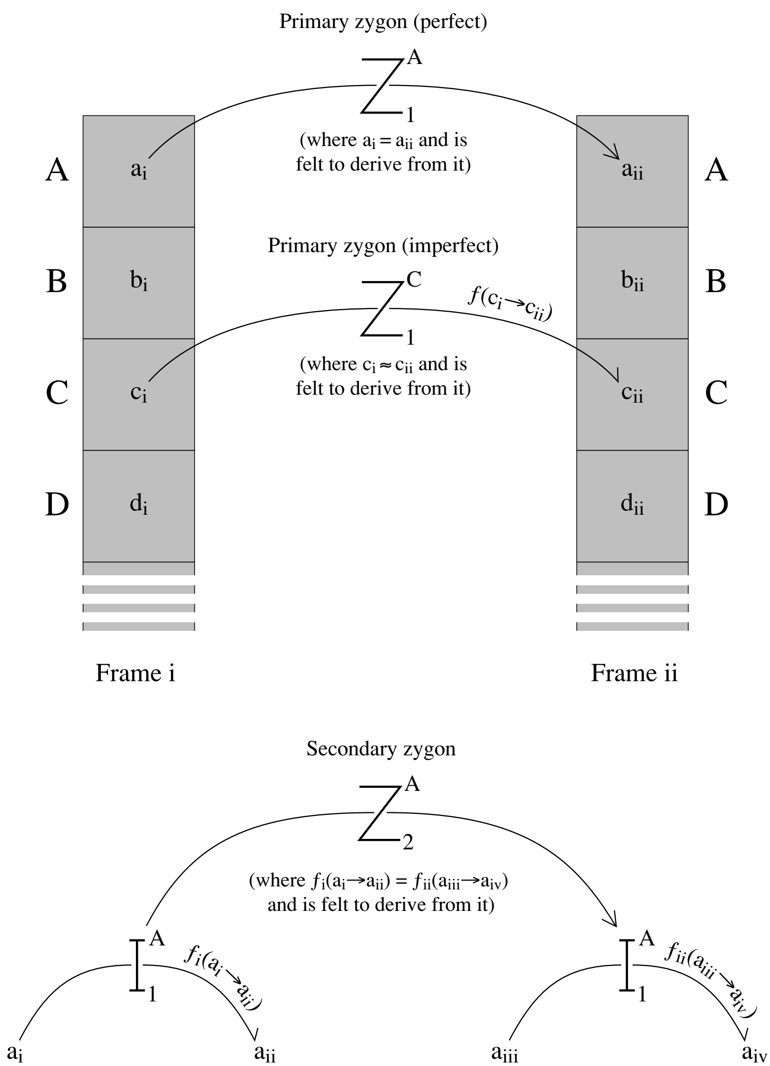

FIGURE 6 *Representation of primary and secondary zygonic relationships.*

cognition between any pairs of perspective values of the same type, where one is deemed to derive from the other. Zygons linking values that are perceived to be identical are said to be 'perfect' (and are illustrated schematically in Figure 6 using full arrowheads). However, a sense of derivation can also occur where values are merely similar, in which case the zygonic relationships concerned are termed 'imperfect' (and utilize half arrowheads) – cf. Ockelford (1999: 91). 'Secondary' interperspective relationships, through which the similarity of primaries is gauged, may also be zygonic (perfect or imperfect), where one primary interperspective value is felt to derive from another.

Zygons and other interperspective relationships are shown in action in Figure 7; their status as theoretical constructs is discussed below. The superscripts indicate each of the perspects concerned (which may be represented by initial letters – in this case 'D' for duration, 'P' for 'pitch', 'O' for 'onset' and 'L' for 'loudness'). A primary zygonic relationship of duration is shown connecting the dotted crotchet that opens bar 1 with that which appears at the beginning of bar 3, indicating that the latter is deemed to derive from the former. In the domain of pitch, two primary relationships are illustrated, one presenting the interval of a descending major 3rd, and the other a minor 3rd. Since the second of these values is felt to derive approximately from the first, an imperfect secondary zygon is considered to function between them. Here, the filled arrowheads are indicative of 'constants' – each a compound relationship comprising many potential similar strands that link values extended in time (for a fuller explanation, see Ockelford, 1999). In the perceived temporal domain, there are three primary relationships of onset (reflecting differences of ♩., ♩ and ♪) and two secondaries (both of value – ♪), which are connected (to the extent that the second of these is considered to exist in imitation of the first) through a tertiary zygon. In the domain of loudness, a single primary interperspective relationship depicts the difference in perceived dynamic levels between > ***p*** and ***p***.[9]

In the interdisciplinary context of the current article, it is particularly important to be clear about the status of zygonic relationships (cf. Ockelford, 2004). They are hypothetical constructs intended to represent aspects of subconscious cognitive processing that we may suppose to be undertaken by those listening to (or imagining) music – a supposition suggested by the regularities in musical structure, which, as Bernstein postulates, offer 'a striking model of the human brain in action and as such, a model of how we think' (1976: 169). Whatever the verity of this assumption, a zygonic relationship can at best offer only a highly simplified version of certain cognitive events that we can reasonably surmise take place during participation in musical activity. However, while simplification is necessary to make headway in theoretical terms, some idea of the underlying complexity can be gleaned by appreciating that the single concept of a zygon bequeaths a vast perceptual legacy, with many possible manifestations, not only potentially linking individual pitches, timbres, dynamics, durations and interonset intervals, but

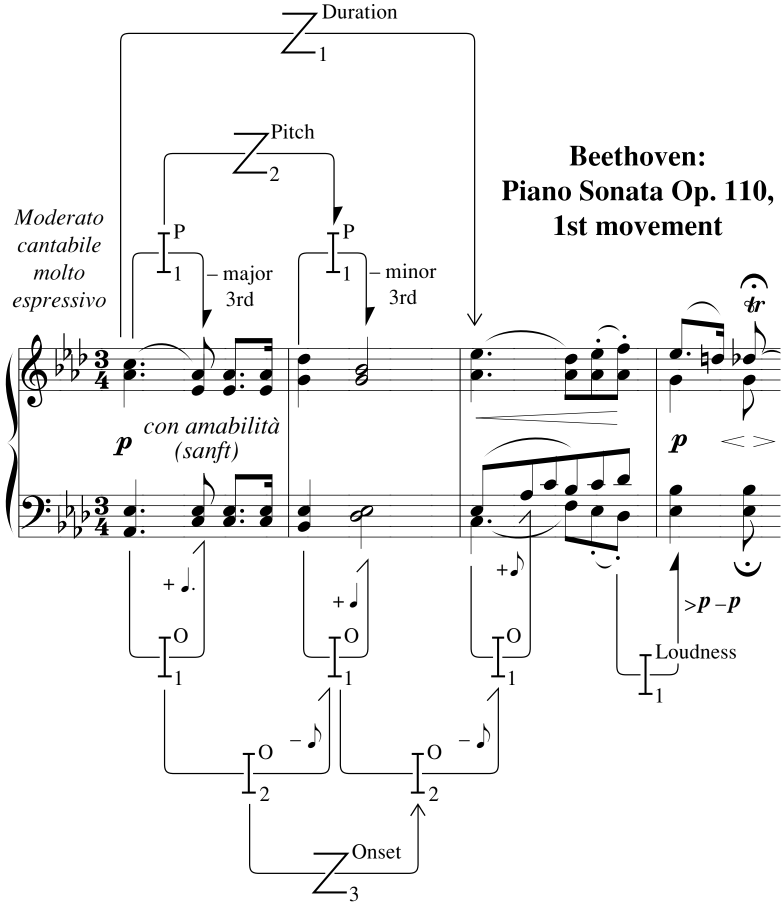

FIGURE 7 *Examples of interperspective relationships, including primary, secondary and tertiary zygons (cf. Ockelford, 2002: 196).*

also prospectively existing between tonal regions, textures, processes and forms the same; over different periods of perceived time; and within the same and between different pieces, performances and hearings. Whatever the context, zygons, it is hypothesized, may function in a number of ways: reactively, in assessing the relationship between extant values, for example, or proactively, in ideating a value as an orderly continuation from one presented. Given this variety, there is, of course, no suggestion that the one concept represents only a single aspect of cognitive processing. Hence, empirical evidence in support of the theory is likely to be drawn from a diversity of sources too. Currently, for example, one can point to experiments in auditory processing (such as the 'continuity illusion', summarized in Bregman, 1990: 344ff) and work on expectation in a musical context such as that by Cuddy and Lunney (1995), Schellenberg (1996, 1997) and Krumhansl et al. (1999) to support the presence of proactive zygonic-type processes (Ockelford, 1999: 123, 2004). Hopefully, future work may be directed specifically at the search for cognitive processing of the kind that zygonic theory, described here and elsewhere (for example, Ockelford, 2002, and in Section 7 below), suggests may exist. Pending these empirical developments, the remainder of this article continues to build on the hypothesis set out above.

The next assumption in this evolving theoretical framework is that the perceived strength of derivation of zygonic relationships is variable, and that there are two main factors which bear on this variation: the perceptual salience of the values concerned and the degree of similarity between model and derivate. These factors may interact, as the following discussion indicates.

Ockelford (2004) identifies two major issues which impinge upon salience: similarity and strength of derivation. The first is that music is replete with similarity and sameness in all domains. To understand why, consider Sloboda's observation that for the dialectics of perceived tension/resolution and motion/rest to flourish, a framework of discrete and re-identifiable locations in pitch and time is required (1985: 259). That is to say, for our cognitive processing capacities not to be overwhelmed, composers have to work within tight constraints, such that the number of different interperspective values available in each of these domains is very limited. Moreover, while the burden of the musical message is characteristically conveyed through a combination of pitch and rhythm (see comments above), 'background' restrictions of comparable rigour typically apply to other perspects too, such as timbre and loudness. Almost invariably, these fulfil a secondary role as 'carriers' of the main musical message, and in consequence tend towards relationships based on uniformity or incremental change (Boulez, 1971[1963]: 37; Erickson, 1975: 12; Bregman, 1990: 456; Ockelford, 1999: 277ff). Hence, behind the creation of every piece lie constraints which mean that many values will be similar or the same, regardless of the subsequent choices of the composer.

This ubiquity is compounded by the second issue, which is that even relatively few frames are potentially linked by vast numbers of relationships,[10] only a tiny proportion of which could feasibly be processed. Take, for example, a relatively short piece – Chopin's Prelude in b minor, Op. 28, No. 6. In one sub-domain alone (pitch-class) the 403 notes potentially bear 12,703 primary interperspective relationships between identical values. However, this is dwarfed by the number of possible secondary relationships between primary values the same, which is in excess of 500 million. While it is clear that the overwhelming majority of these could never figure in cognition, the criteria through which such potential relationships become reified are by no means straightforward, and empirical work would be required to establish the nature of the processing that actually occurs. It seems likely, however, that as well as relatively straightforward factors such as temporal proximity, the salience of events, determined not only by intrinsic perceptual characteristics (identified as 'cues' by Deliège) but also by higher order, contextually derived attributes such as structural function, will also have a bearing (cf. Dowling et al., 2001).

Against this background of fierce competition in the cognitive arena, in which – we may surmise – perceived events and sonic qualities jostle for attention as a piece of music unfolds, zygonic theory suggests that the acknowledgement of resemblance or identity has an intimate and intricate relationship with evolving attributions of structural significance. This complex matter will be approached by way of illustration – a discussion of Tallis's *Ordinal* – general principles being postulated on the basis of the four specific observations that are made. To reiterate: the purpose is to clarify how salience and similarity impact on perceived derivation.

First, conscious reflection on the listening process suggests that a strong sense of derivation links line 3 with line 1. Analysis shows that the melodies are identical and the harmonies are very similar (with some variation in the inner parts), and so it is reasonable to assume that, in terms of Deliège's model, the two segments would be processed perceptually as appearances of events in the same category (or, perhaps, different manifestations of a single 'imprint'). According to zygonic theory, the two phrases are connected through an 'invariant' (a series of parallel relationships the same), operating in the domains of pitch and perceived time, a compound connection that is both substantial with respect to the proportion of events involved (16 of the 28 chords in the piece (57%)) and unique within each verse. Inevitably, then, all feeling of imitation is channelled through this one cognitive connection. To summarize: in this case, representatives of a common category exhibit a considerable degree of similarity, and, through their unique relationship, a high level of salience; hence, it is surmised, a strong sense of derivation is engendered (see Figure 8).

Second, analytically informed listening suggests that a compound relationship of a rather different type links lines 1 and 2, characterized by the part-inversion and part-omission of material – a transformation schematized in zygonic terms in Figure 9. Here, although the connection between the two phrases again is unique (though a similar one exists between lines 3 and 4 of the *Ordinal*), and although once more a significant proportion of the total number of events is implicated (14 out of 28 events (50%)), there are substantial differences between the two segments concerned. Based on the evidence of previous empirical work, it can reasonably be hypothesized that listeners would not typically endow them with a common sense of category. To summarize: in this case, representatives of different categories display a balance of similarity and change and the relationship between them is highly salient; hence, it is surmised, a moderate sense of derivation is engendered.

Third, we reflect on the two-note figures in which pitch is repeated, that occur seven times in the course of each verse (observe that one pair crosses

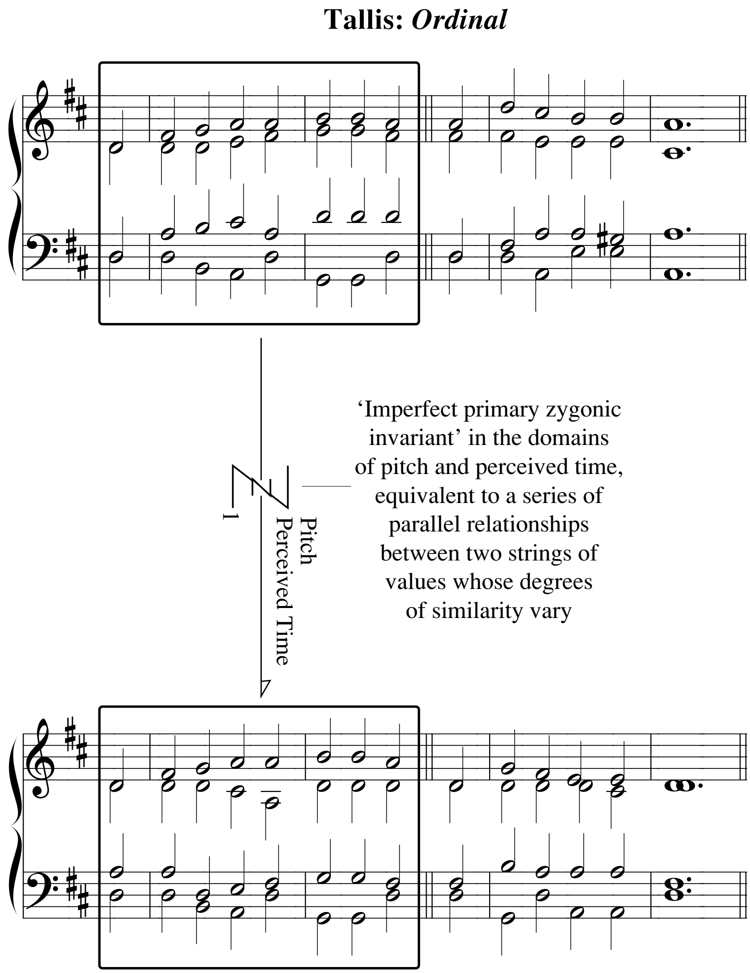

FIGURE 8 *High degrees of similarity and salience together engender a strong sense of derivation between groups.*

the phrase boundary between lines 1 and 2). In particular, we explore – in theoretical terms – the probable nature of the cognitive connection between the first two beats of the melody in bar 2 and the last two beats in the penultimate bar. Logically, a relationship of similarity (at the secondary zygonic level) exists between them, and if the two pairs were excised and compared in isolation, it may be assumed that they would be adjudged to belong to a common category on account of their high level of conformance. In the course of a normal listening experience, however, it is difficult to discern whether the relationship between them would be likely to be reified, and (if it were) how strong a sense of derivation it would bear. Extension of the zygonic analysis shown in Figure 9 would suggest an indirect link, via the penultimate and

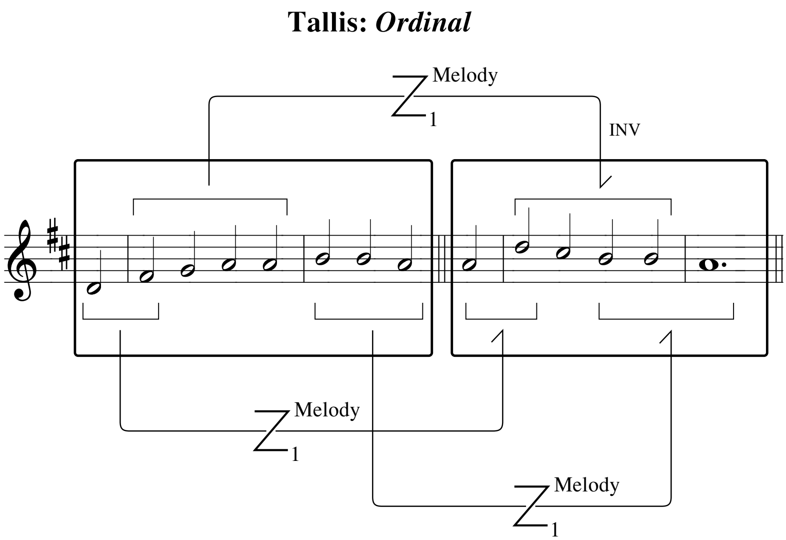

FIGURE 9 *A moderate degree of similarity and high degree of salience engender a moderate sense of derivation between groups.*

pre-penultimate notes of the second line (see Figure 10). A further possibility, utilizing Deliège's notion of 'imprint' (developed from Rosch's notion of prototype – see earlier), would be to suggest a rather different indirect connection between the two through the intermediary of an abstract categorical

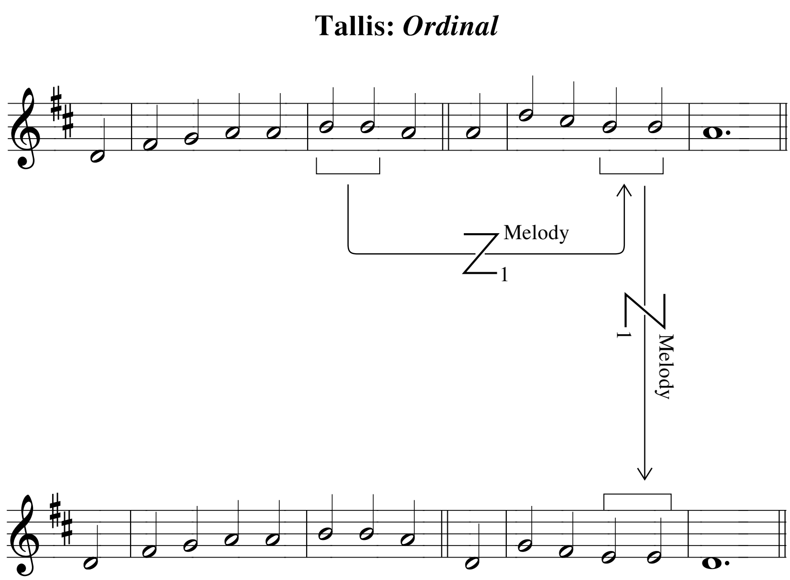

FIGURE 10 *High similarity and low salience associated with an indirect sense of derivation between events.*

representation. Clearly, empirical work would be required to ascertain which, if either, of these structural routes is likely to find a place in cognition. To summarize: we hypothesize that, in this case, high similarity but low salience means that a sense of indirect derivation is engendered, which may occur via two more salient relationships or through connections to a common prototype (or both).

Fourth, we explore indirect links further, through considering the relationships that may be ideated between the harmonies in Tallis's *Ordinal*, which without exception are versions of the major triad (see Figure 11). Take, for example, the second chord in the first complete bar (G major in first inversion), and the third chord of the fourth phrase (D major in root position). In the course of a 'typical' listening experience, what is the likely nature of the cognitive connection between them (if any)? In zygonic terms, it would seem counterintuitive to suggest that a direct relationship of derivation is operational; but equally, it would appear contrary to the natural order of things if no connection were thought to exist (implying that the similarity of the harmonies was of no musical significance). So, it seems reasonable to assume, following the line of thought adopted above, that the stylistically attuned ear will recognize (albeit subconsciously) the chords as different manifestations of essentially the same prototypical percept, which they also serve to reinforce – lending the music a fundamental consistency in the domain of harmony, against which surface variations occur. That is, we can hypothesize that an indirect zygonic relationship does function between the two chords identified – via what is variously conceptualized as a 'prototype' (Rosch), an 'imprint' (Deliège) or, since it exists beyond the confines of the piece, a 'stylistic archetype' (Cumming, 1985: 9). Cone expresses the scenario in abstract terms thus: 'x and y may both be derived from some common source (a previous w such that w → x and w → y) in which case y is not necessarily also derived from x' (1987: 240). To summarize: we hypothesize that, in this case, high similarity with low salience means that a sense of *indirect* derivation is engendered, which occurs through connections to a common prototype.

Existing in the context of 'background' connections of this type, we can surmise that the relationships linking some harmonies are sufficiently salient to permit a direct sense of derivation to exist too: between those that are temporally proximate, for example, or contribute to a parallel series of similar connections (see Figure 8).

It is reasonable to assume that indirect relationships, often functioning through prototypical categorization, constitute a major factor in listeners' successful management of the music-processing load (in the case of Tallis's *Ordinal*, for example, effectively reducing the number of potential relationships between harmonies from 378 – if each chord were cognitively connected directly to every other – to 28 – where each event is related to a prototype). Zygonic theory suggests that this is by no means the whole story, however. To take a further example, consider the relationship between the subject and

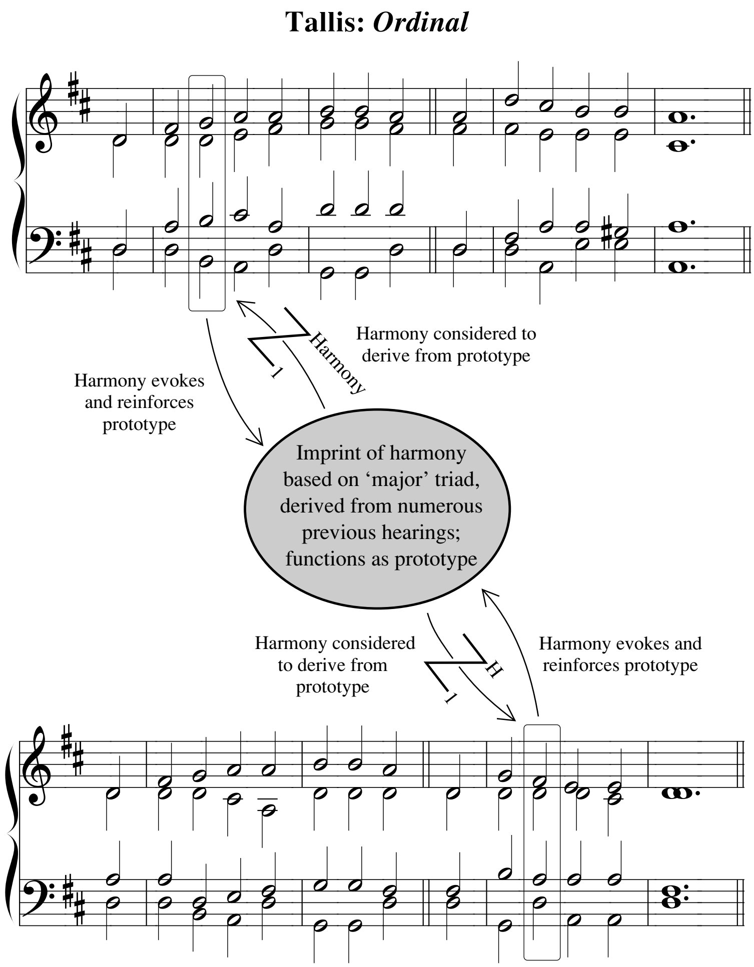

FIGURE 11 *High similarity and low salience associated with indirect derivation between events via a common prototype.*

answer of Bach's Fugue No. 22, BWV 867, from Part I of the *Well-Tempered Clavier*. To the first-time listener with limited stylistic awareness, initial analysis suggests two ways in which the latter can be heard as deriving from the former: either through retrograde repetition of pitch (class), or tonal transposition. Which is the ear more likely to light upon? Or, to state the problem in general terms: with two or more potential zygonic links between events, each or any of which may be structurally significant, how does the brain know which it will be most fruitful to attend to, which to process, which to remember and which to compare?

Ockelford (2002, 2004) proposes a number of 'preference rules' for structural interpretation which derive from the assumption that our minds instinctively adopt the principle of parsimony ('Ockham's razor') in seeking to make sense of music, such that the simplest available 'solution' is sought (cf. Fiske, 1990: x). In the context of the current discussion on categorization and salience, this chimes in well with the thinking of Rosch (1978: 28), for example, who asserts that it is 'the task of category systems . . . to provide maximum information with least cognitive effort', and with the principle identified by Sperber and Wilson (1995: 124) that processing effort 'is a negative factor: other things being equal, the greater the processing effort, the lower the relevance'. They go on to propose that a phenomenon 'is relevant to

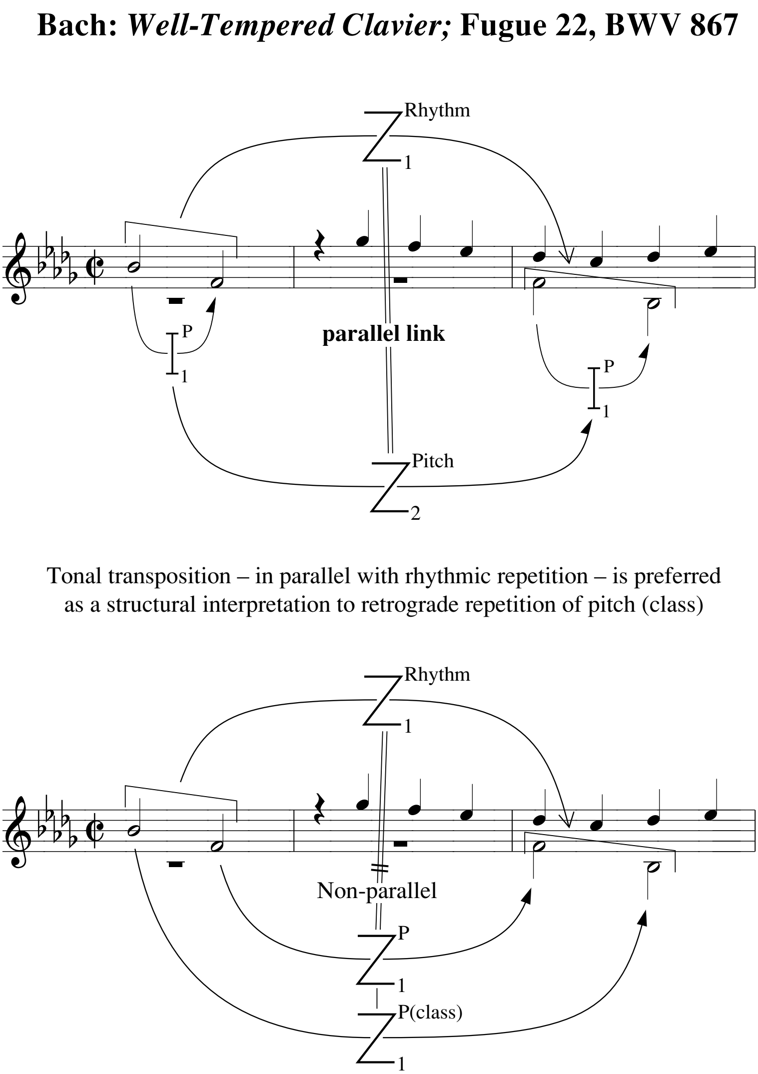

FIGURE 12 *Zygonic analysis of competing interpretations of structure.*

an individual to the extent that the contextual effects achieved when it is optimally processed are large . . . and the effort required to process it optimally is small' (p. 153).

This inherently parsimonious approach suggests that music will be modelled in cognition using the fewest possible of the simplest available mental processes. From these basic assumptions, more detailed principles can be extrapolated, which take into account the number of relationships, their nature and relative disposition. To this end, Ockelford (2002) proposes that we will tend to opt for structural interpretations whereby, other things being equal: lower levels of relationship are preferred to higher; simpler functions are preferred to more complex; perfect zygons are preferred to imperfect; a lower degree of imperfection is preferred to a higher degree; parallel processing is preferred to non-parallel, both within perspective domains and between them; and fewer relationships are preferred to more. Frequently, there will be competing preferences. Take, for example, the opening of Bach's Fugue, BWV 867, where, it is hypothesized, acknowledging the repetition of pitch-class would imply the operation of perfect primary zygons, whereas processing the passage in terms of tonal transposition would implicate imperfect secondary relationships of pitch. However, any cognitive preference for the former is likely to be overwhelmed by the parallel operation of relationships in the domain of perceived time which characterize the transposition (but not the repetition). (See Figure 12.)

The proposition that parallel processing in different perspective domains is preferred to non-parallel provides the basis for a further consideration of how groups of events and the relationships between them are perceived – and for further analysis of how Deliège's model (pertaining to the perception of groups and their categorization) relates to zygonic theory.

6. *The cognition of structure within and between groups*

Zygonic theory offers a theoretical and metatheoretical framework which can be used to explore how groups work in cognitive terms and to interrogate other models of grouping. There are two main issues: how groups are perceptually defined, and how they may be coherently related.

DEFINING GROUPS

It was noted in Section 2 that, according to Deliège, whatever the gestalt grouping principle involved (such as 'proximity', 'similarity' or 'good continuation'), it is invariably the case that a difference is perceived between the confronting regions as opposed to a similarity between the elements within groups (1987: 326, 2001a: 235). Is this explanation sufficient, however? Consider, for example, the following passsages from Stockhausen's *Kontra-Punkte* (1953; see Figure 13), which the composer describes in the foreword to the work as 'a soloistic style of playing articulated by groups'. Far from

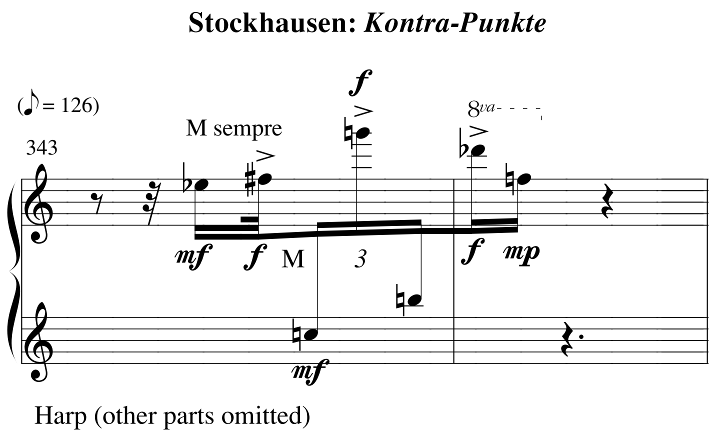

FIGURE 13 *A group formed from a succession of contrasting points of sound.*

consisting of similar elements, the group comprises a succession of distinct points of sound – with particularly marked contrasts in the domains of pitch and dynamics.

What is it, then, that makes this group a group? In general terms, Bregman (1990: 472) observes that it is the 'relative lengths of silence between moments of sound [that] will be an important determinant'. Specifically, in this case, the notes are clustered in time, with boundaries defined by rests. In terms of zygonic theory (which, to reiterate, hypothesizes that structural coherence will be reckoned to exist when one value is felt to derive from another), this suggests that the notes are bound together by a chain of imperfect primary zygonic relationships of onset, whereby the perceived temporal position of each event is felt to exist in approximate imitation of that which precedes.[11] This series of links may be conceptualized as an 'invariant system', in that successive elements are invariably connected through a similar or identical relationship. The group boundaries are marked by significantly weaker zygonic relationships which may nevertheless contribute to the formation of groups at higher hierarchical levels (cf. Bregman, who notes that 'it is the relative, not the absolute, separations that count') (see Figure 14).

It appears that grouping by onset is a prerequisite of grouping in all other domains, since unless perceived sounds are juxtaposed in time, they cannot be heard as forming part of a larger whole, no matter how similar or proximate they may be on other perspective continua. That is to say, without proximity of onset, no other form of grouping could 'get off the ground' perceptually (cf. Sloboda, 1985: 154). Given this basic requirement, there are a number of other ways in which perceived sounds can be grouped (Bregman,

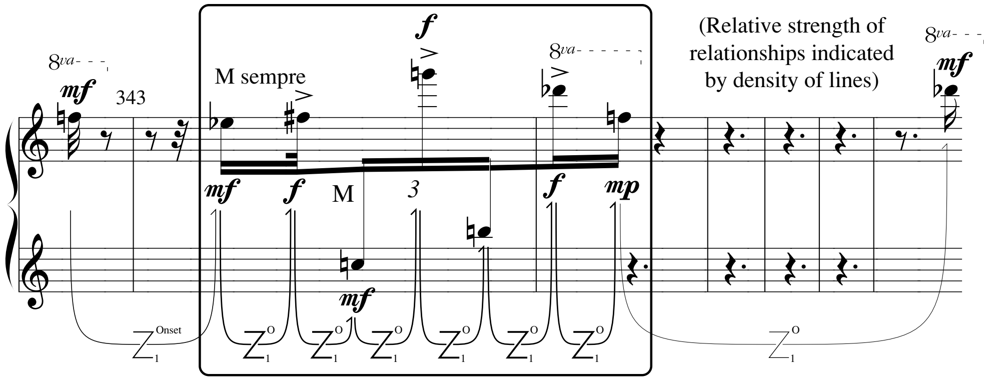

FIGURE 14 *Group determined by primary invariant zygonic system of onset.*

1990: 473). In the domain of pitch, for example, grouping may occur through proximity. The theory of perceived derivation set out in this article suggests that this will be structured in cognition through networks of potential implicative relationships, which may be conceptualized as a primary zygonic invariant system or a primary zygonic constant system (in which all elements are potentially connected in the same way). In other perspective domains, grouping may occur through the gestalt principle of similarity (Bregman, 1990: 478ff; Deutsch, 1999a: 318) – again, it is hypothesized, through relationships pertaining to primary zygonic invariant or constant systems (see Figure 15).

Grouping by good continuation is a further possibility in some domains (Deutsch, 1999a: 320), in relation to pitch, for example (in terms of zygonic theory, through secondary constant systems), or onset (through tertiary systems) (see Figure 16).

Based on a common foundation of temporal proximity, these grouping mechanisms can work in any combination, reinforcing, complementing or even competing with one another (cf. Lerdahl and Jackendoff, 1983: 36ff). Hence it is possible to model the three 'internal' gestalt grouping principles zygonically in the way illustrated by Figure 17.

This model supports and refines Deliège's proposition that gestalt perception rests on similarity between the elements within a group, since zygonic relationships – which are hypothesized to underpin grouping by proximity, similarity and good continuation – themselves depend on the sameness or similarity of values. However, the zygonic approach demonstrates specifically how a single principle produces the three different gestalt functions, variable in effect from one perspective domain to another. A fourth gestalt process that is acknowledged to play a part in music perception is that of 'common fate', which implies that a group be defined through the relationship between

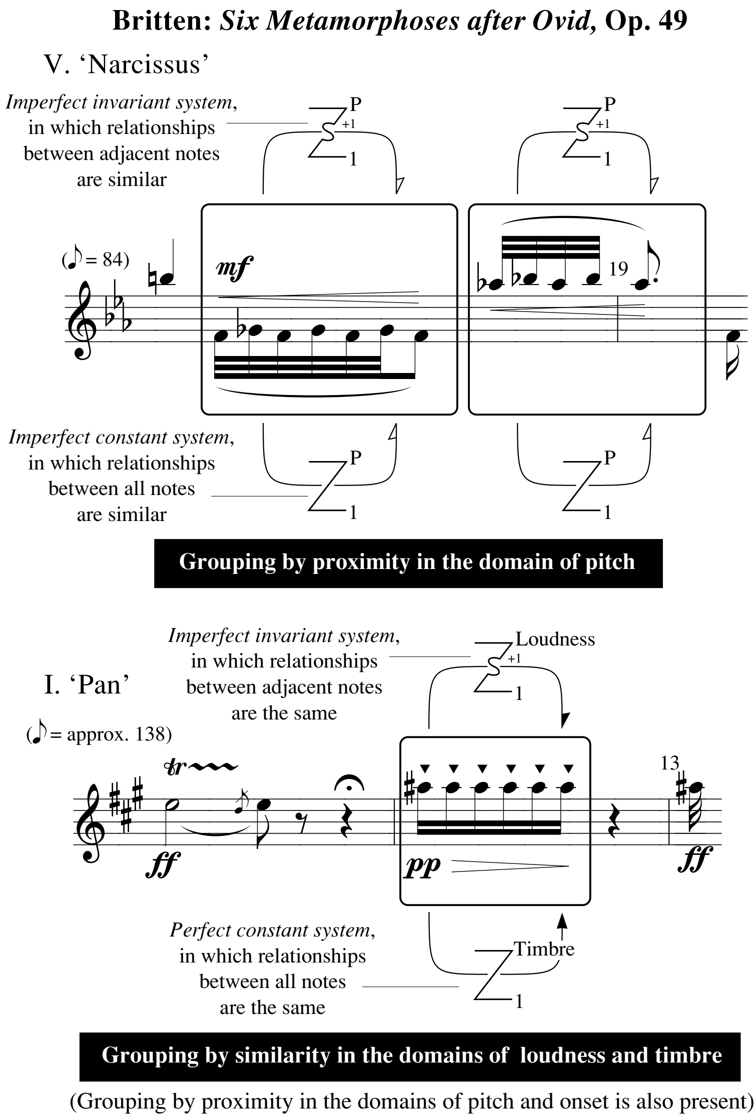

FIGURE 15 *The gestalt grouping principles of 'proximity' and 'similarity' shown in relation to zygonic organization.*

it and another that is similar or the same. This is one of a number of ways in which groups can be related – an issue to which we now turn our attention.

RELATIONSHIPS BETWEEN GROUPS

Relationships between groups are very diverse – an inevitable consequence of

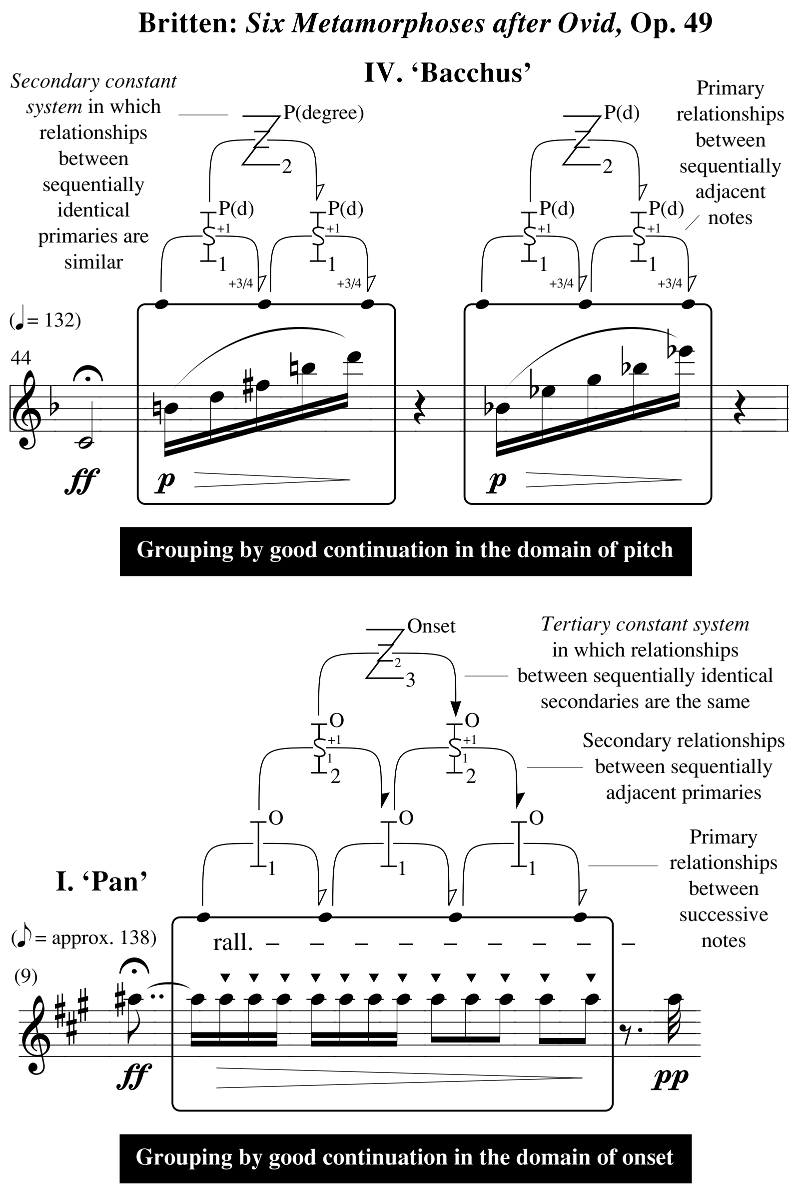

FIGURE 16 *'Good continuation' shown in relation to zygonic organization.*

the multifarious nature of music itself. However, just as the relationships between frames can be conceptualized as existing on a continuum which ranges from identity to complete dissimilarity, so it is possible to classify, in broad terms, relationships between groups. Such comparisons are, however,

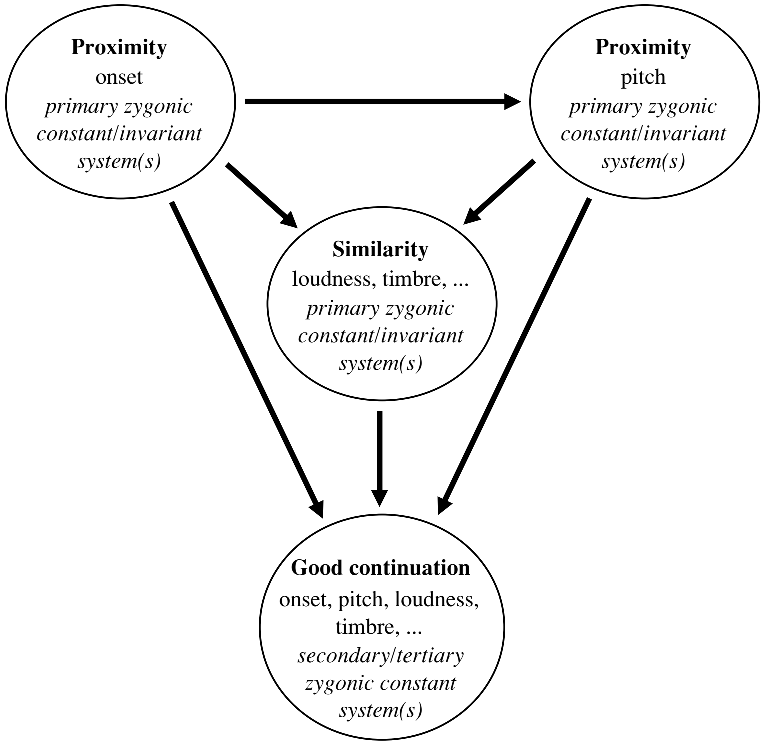

FIGURE 17 *Hierarchy of gestalt grouping principles and their common zygonic foundation.*

dependent on musical context, are liable to vary from listener to listener, and even (with the same listener) to differ from one occasion to another. It is hardly surprising, therefore, that a number of distinct classifications have been proposed, both by psychologists and music theorists. Serafine (1988: 81–3), for example, identifies three stages along the continuum of change: 'relative repetition' (ranging from identity to transposition, and changes in mode, tempo, accompaniment or dynamics); 'ornamentation' (involving the alteration of a musical event through the addition, overlay or superimposition of other events); and 'substantive transformation' (entailing, for example, the preservation of contour alone). Compare this with Reti's fourfold arrangement:

> . . . imitation, that is, literal repetition of shapes, either directly or by inversion, reversion, and so forth; varying, that is, changing of shapes in a slight, well traceable manner; transformation, that is, creating essentially new shapes, though preserving the original substance; indirect affinity, that is producing an affinity between independent shapes through contributory features. (1951: 240)

Other writers venture further along the continuum of change, acknowledging the possibility of contrast. LaRue (1970: 80–2), for instance, divides the spectrum between similarity and difference into 'recurrence', 'development' (embracing all changes that derive clearly from the preceding material), 'response' (including continuations that give an antecedent-consequent effect), and 'contrast' (complete change).

The wide variation in these taxonomies means that their validity is at least questionable, although it could be argued that, since the transformation of musical material is such a complex affair, all three models may be equally sound, with each reflecting a different analytical perspective. A problem common to all of them, though, is a lack of precision leading, inevitably, to a certain arbitrariness in their proposed divisions. In Serafine's model, for instance, would a change of mode combined with the addition of material be classed as 'ornamentation' or 'substantive transformation'? With Reti's categorization, is it possible to determine consistently when 'varying' becomes 'transformation'? Taking LaRue's version of affairs, is there a necessary difference between 'development' and 'response'?

Future empirical work may resolve these questions. In the meantime, zygonic theory at least offers a certain conceptual clarification, enabling relationships between groups to be defined and analysed precisely (see Ockelford, 1999), and offering in its own right a classification of relationships between groups. This suggests that three zones are distinguishable on the continuum of derivational possibilities, defined as follows:

(a) one group is perceived to derive as a whole from another;
(b) an aspect of one group is perceived to derive from another;
(c) there is no perceived derivation between groups.

Analysing relationships of type 'a' as zygonic invariants suggests that similarity between groups is ultimately dependent on one or more of three processes: the modification of material (which may occur in one perspective domain or more), its omission or addition (which typically affect all domains together) – cf. Schoenberg, 1967: 10. This is comparable to the pitch-error coding scheme used by Palmer and van de Sande (1993) and subsequently by Repp (1996) in classifying pianists' errors as 'substitutions', 'omissions' or 'intrusions', and similar also to the matching algorithm developed by Large (1993) and used by Crawford et al. (1998: 86ff), who identify equivalent forms of transformation ('replacement', 'deletion' and 'insertion') in their classification of string-matching techniques for detecting musical similarity through computer-assisted analysis. Similarity relationships between groups in music often entail complex combinations of these three processes. Consider, for example, the theme and first variation of Mozart's Piano Sonata in A major, K331. The opening bar of the variation utilizes the addition of material in the right hand (which is derived from modified fragments of the theme), balanced by the omission of material in the left. The result is a blend of similarities and differences in which appoggiaturas and neighbour notes, that characteristically function as expressive, ornamental features of the

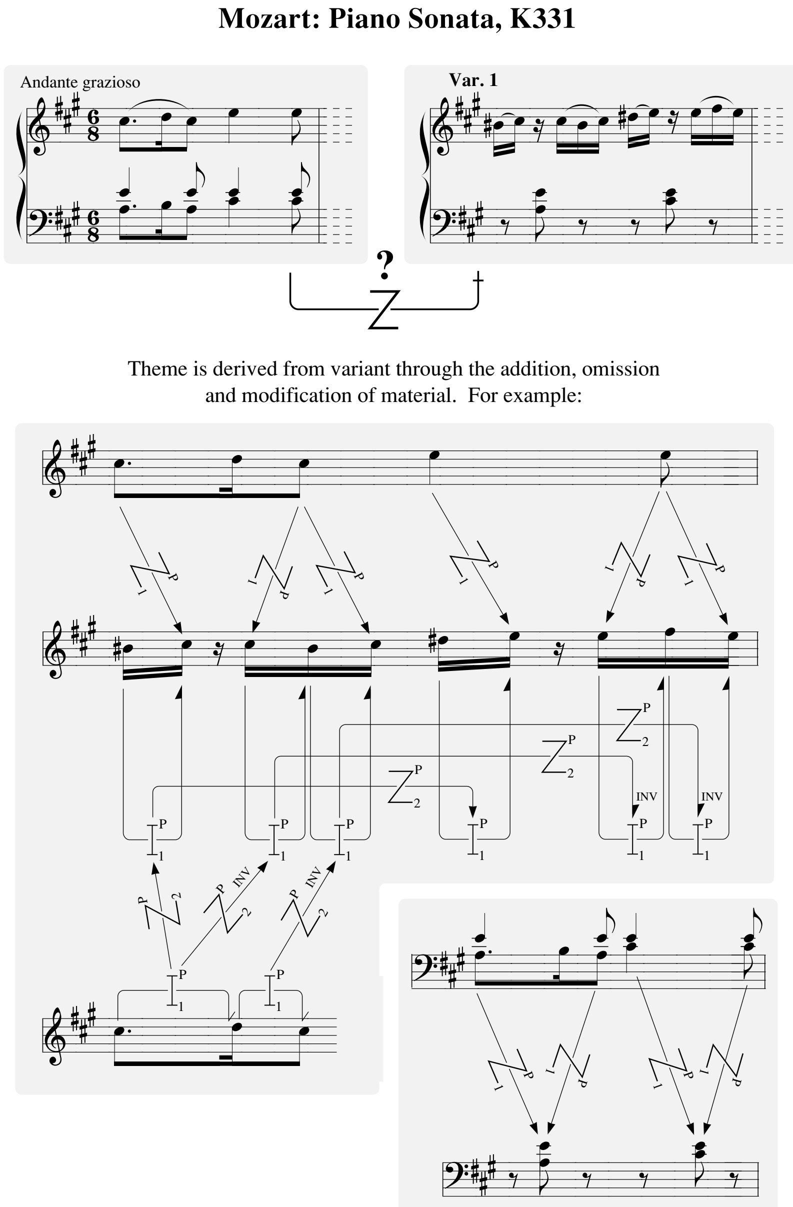

FIGURE 18 *The modification, addition and omission of material combine in thematic development.*

style, are structurally bound into the unfolding musical discourse. Zygonically, the complex of relationships between segments may be conceptualized as shown in Figure 18. This analysis affirms that it is not only the cognitive acknowledgement that the two passages fall into the same category that is

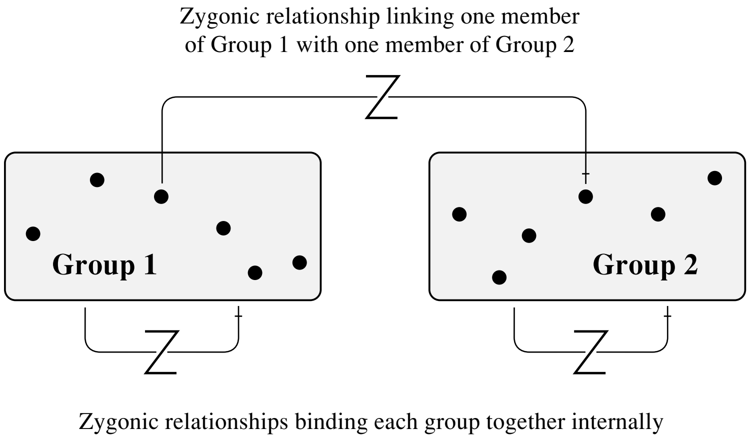

FIGURE 19 *Abstract representation of a situation in which one group is 'logically' related to another through the derivation of an* aspect.

important to musical understanding (à la the similarity perception/cue abstraction/categorization model) – clearly this is fundamental to the notion of the variation set – but the fact that one is derived from the other, and how it is derived. To reiterate points made earlier: all pieces comprise an intricate mix of identities, similarities and differences, and it is not any one of these characteristics but their perceived interaction that serves to define musical content and structure (Ockelford, submitted for publication).

The existence of perceived connections of type 'b' between groups (in which common aspects are zygonically related) indicates that it is not necessary for an entire musical chunk to be felt to derive from another to be perceived as being logically related to it. The only additional requirement is that both groups are internally coherent (as described above in relation to gestalt perception). Hence in abstract terms, type 'b' relationships may be represented as in Figure 19.

To illustrate this form of organization, two examples will again be taken from Mozart. Analytical reflection suggests that in the first (the opening theme of the Symphony in A major, K201), the octave descent comprising the opening gesture is, in aural terms, logically linked to the repeated quavers that follow through primary zygonic relationships of pitch, timbre and loudness. In the second example (from the Piano Sonata, K309), it is hypothesized that continuity between otherwise contrasting groups is achieved through a secondary zygonic relationship of pitch (scale degree), enhanced by timbral constancy. (See Figure 20.)

It is difficult to conceive of relationships of type 'c' (through which there is no perceived derivation between groups, and between which therefore, according to zygonic theory, no orderly connection exists) fulfilling a purposeful music-structural function. If there were no similarity whatever between

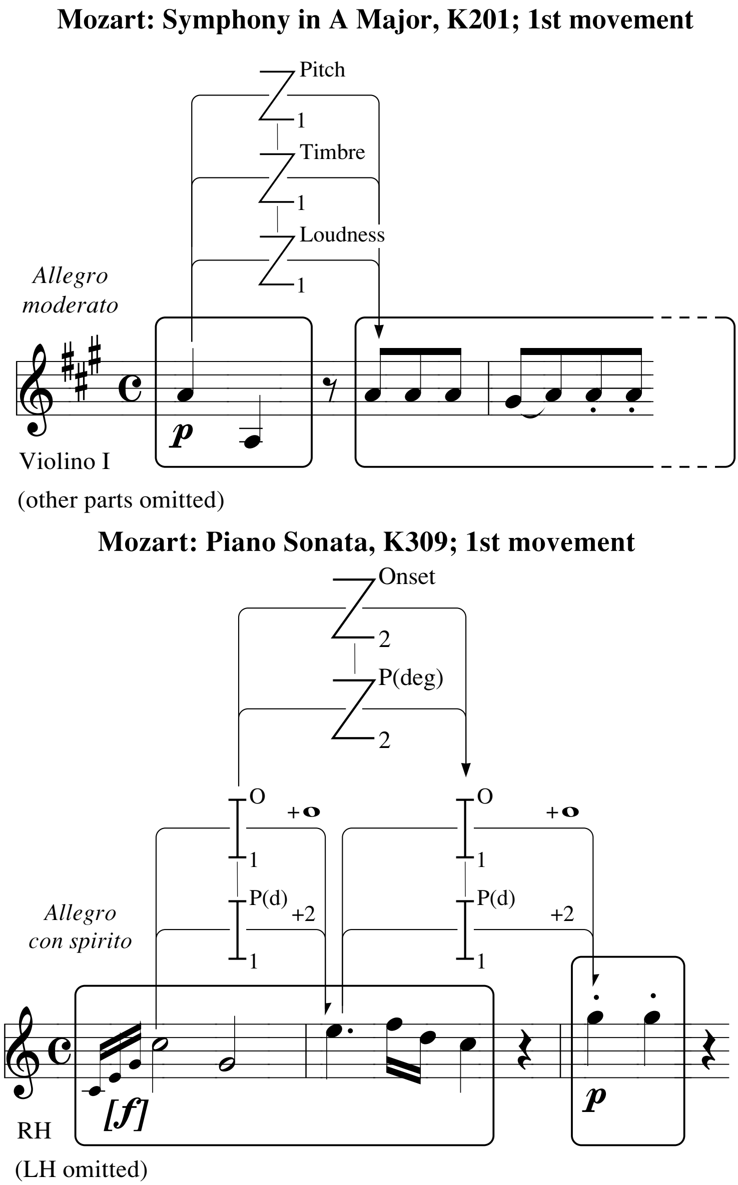

FIGURE 20 *Examples of* type 'b' *relationships (between* aspects *of groups).*

neighbouring groups – which would imply, at the most basic level, that they were separated by a significant perceived temporal interval – it seems unlikely that they could contribute to a larger coherent musical whole. Even juxtapositions such as that illustrated in Figure 21, which is characterized by a high degree of contrast, are underpinned in cognition, we may surmise, with secondary zygonic relationships of pitch-class and onset.

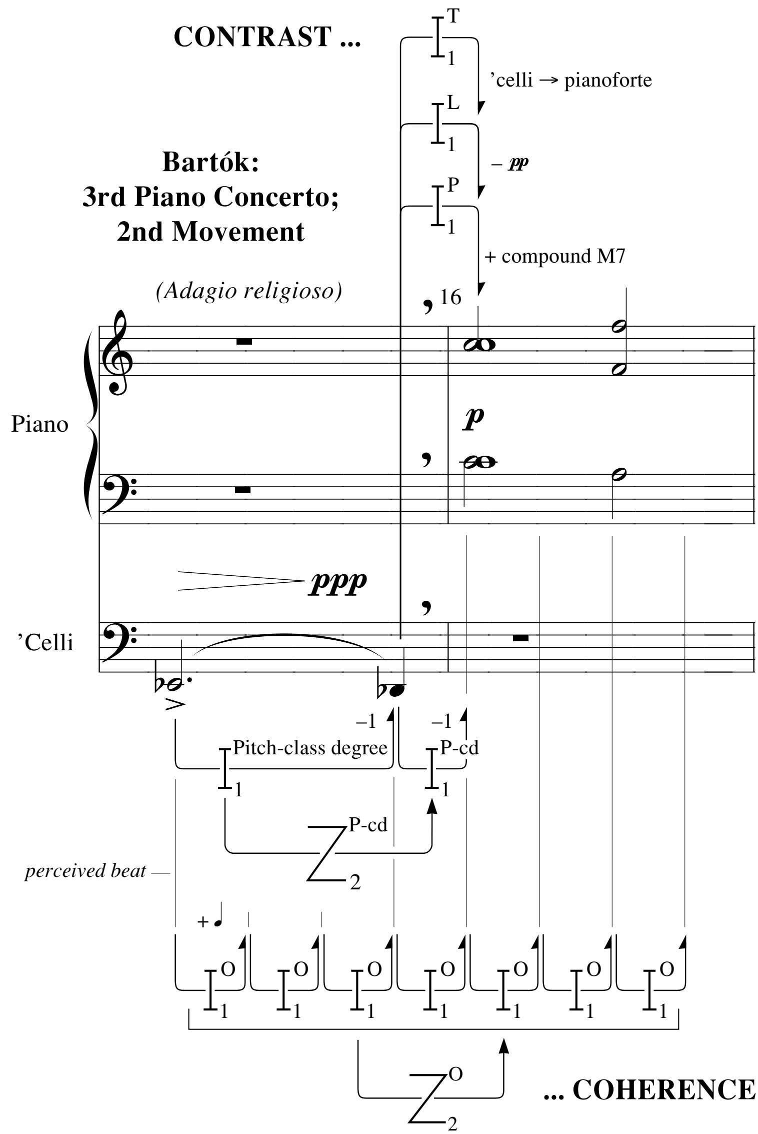

FIGURE 21 *Musical coherence in the juxtaposition of contrasting material is assured through secondary zygonic relationships of onset and pitch-class degree.*

7. A new model

We are now in a position to propose a new model of music-structural cognition, which will refine and extend the processing framework put forward and empirically tested by Deliège, her co-workers and others (set out in Section 2). A summary of this framework provides the starting point.

Deliège contends that, in listening to music, ongoing judgements of similarity and difference underpin the perception of music as 'chunks' (at the motivic/thematic level) from which salient features are abstracted as 'cues'. Using the cues, each chunk is compared as a whole to another or others, directly or via 'imprints' (prototypical representations stored in memory), and thereby assigned to a category, according to the similarities that may be discerned. The chunks thus encoded through cues and categories come to act as 'landmarks' on an evolving 'mental line' – the schematic representation of musical structure over time in cognition (see Figure 22).

Likewise, the zygonic model (described in Section 5) assumes that the unremitting search for similarity is fundamental to the cognition of musical structure, in all domains, between perspective values and the relationships between them. (Note that the identification of differences is postulated to be crucial to the understanding and appreciation of music too, as these comprise a key aspect of musical 'content' (Ockelford, submitted for publication) that work hand-in-hand with the syntactic, context-independent relationships that determine structure (Horton, 2001: 143).) Which of the myriad potential relationships of similarity are realized in cognition is principally governed by the salience of the events or features they connect, a characteristic which, as we have seen, is dependent upon a number of factors, including the presence of derivational relationships. It is hypothesized that similarity and salience work together to produce a sense in which one event is wholly or partly implied by another or, more persuasively, derives from it. This feeling of derivation can vary in perceived strength, and function directly or indirectly (the latter occurring via the imitation of other events or prototypical representations of them stored in memory). Where there are two or more routes through which derivation could be construed, the mind will tend to opt for that which entails least processing effort (according to the principle of parsimony). Generally speaking, greater degrees of similarity and salience are more likely to result in a sense of direct derivation, corresponding to strong elements in music-structural cognition – for example, interthematic relationships, which make a piece characteristically what it is – comprising the 'message'. Conversely, it is more probable that lesser degrees of similarity and salience will incur the impression of indirect derivation, associated with weak elements in structural cognition, such as timbral continuity, which make up the 'background' organization common to many pieces: the 'carrier'. Finally, it is postulated that a feeling of derivation is necessary to the cognition of structure, which, it is hypothesized, comprises an unfolding set of perceived

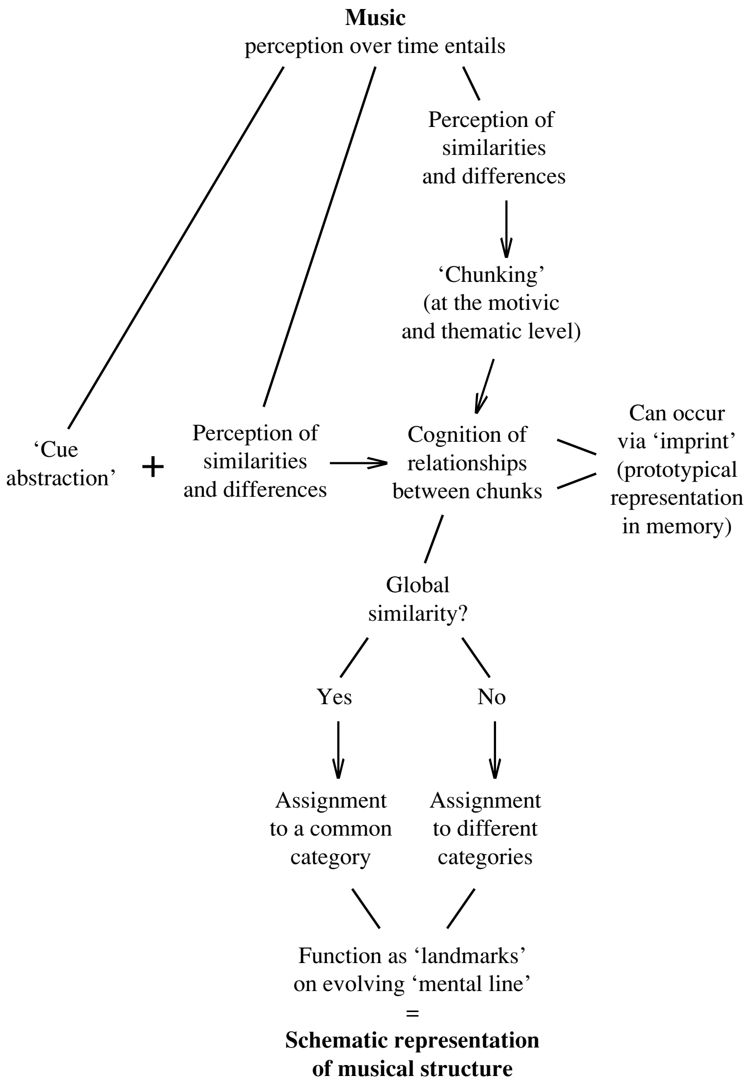

FIGURE 22 *Representation of the processes underlying Deliège's account of the cognition of musical structure.*

contingencies over time which in some wise fulfil a comparable function to the causal connections we imagine to link objects and events in the real world, imbuing them with a sense of coherence (Ockelford, submitted for publication) (see Figure 23).

Though distinct, these two models share important similarities, which make them compatible, and they may be combined to form a composite account of music-structural cognition which runs as follows. In listening to a piece, the mind automatically – and typically unwittingly – scans the

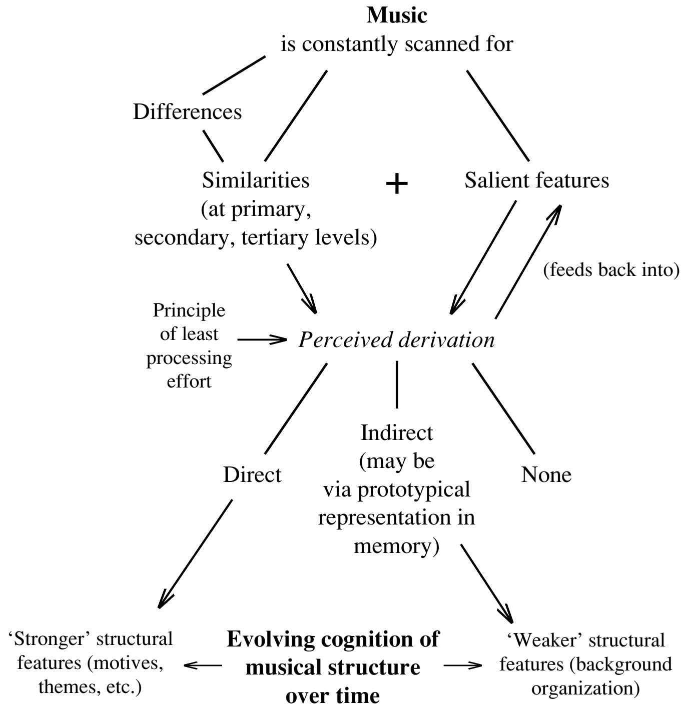

FIGURE 23 *Representation of the processes underlying the zygonic theory of the cognition of musical structure.*

incoming auditory information for similarity and salience which (according to the principles set out above) results in the sense that perceived sounds in whole or in part, and to a greater or lesser extent, derive from one another. It is hypothesized that this sense of derivation feeds into the 'chunking' process at the level of motives, themes and sections. It seems likely that the perception of chunks of smaller proportions – typically, notes of unexceptional length – is fed directly from similarity judgements, since, it is surmised, a feeling of derivation would not have time to 'kick in' on such short timescales; a rather different view from that put forward previously (for example, Ockelford, 1999: 120ff). However, the notion that derivation may play a part in the formulation of larger chunks such as motives and themes represents a subtle though important extension to the theory of gestalt perception as Deliège (and others) have applied it to music. That is to say, we are hypothesizing that a sense of contingency is necessary for events in music to be grouped at this level; similarity alone is insufficient. Evidence for this position may be adduced from the observation that grouping in music typically corresponds with salient patterns in the domains of pitch and rhythm (in terms of the current model, through direct relationships of derivation), and the fact that these patterns are usually superimposed on a generally continuous

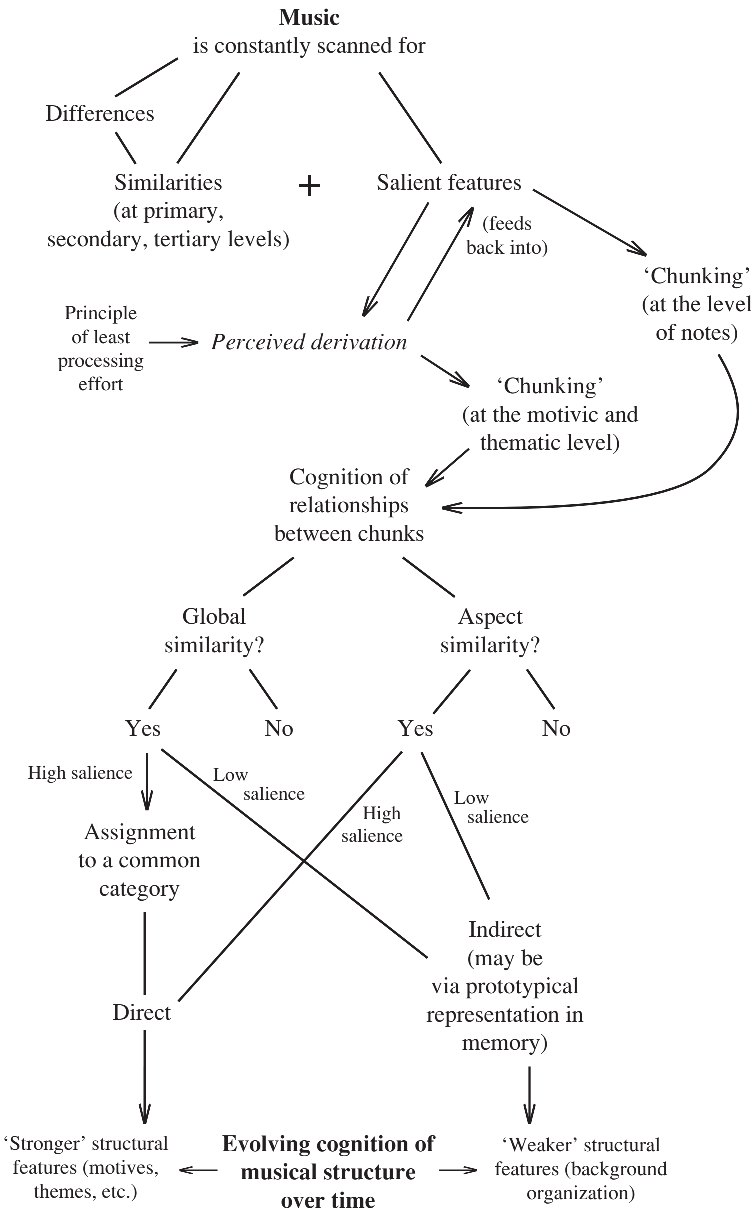

FIGURE 24 *Composite model of the processes underlying the cognition of musical structure.*

background of similarity in other domains such as timbre and loudness, which is only indirectly derivational (although change in these dimensions may be used to reinforce groups determined principally by features of melody and harmony) (see Figure 24).

Derivation also determines the structural significance of relationships between chunks. This implies a second important development of Deliège's model, for in addition to relationships between chunks as a whole, the composite framework allows for the possibility of relationships between aspects of chunks – the two frequently, though not necessarily, operating together. As in Deliège's model, global similarity leads to chunks being assigned to a common category, although, once more, the additional factor here is that derivation is hypothesized to be a necessary condition of categorization. The evidence for this view is similar to that cited above: two motives could be globally similar in a number of respects (for example, in relation to timbre) but unless, through salience, such a similarity relationship were to function in a perceived derivational capacity (typically in the domains of pitch and perceived time), then ascription to a common category would not occur. Such assignment may be be direct or indirect in nature, via an 'imprint' (to use Deliège's term). Each route has distinct structural consequences, as indicated in the zygonic model: direct relationships resulting in strong structural features (for example, the connection between the opening figure of the first movement of Beethoven's 5th symphony and the transposed version that occurs immediately afterwards), and indirect links pertaining to weak features (as exemplified by the many connections in Op. 67 between one appearance of the all-pervasive motive and others outside its immediate temporal ambit).

The second option, that just an aspect of one chunk is felt to have a derivational relationship with an aspect of another (as set out in Section 6) is where the new model significantly extends Deliège's thinking, since it provides for the possibility that segments of music assigned to different categories can be perceived as being coherently related. Again, such relationships may operate directly (as, for example, when a series of motives are linked through a common interval of transposition – see Figure 26 later) or indirectly (when an intermotivic relationship functions pervasively, as, for instance, in the first movement of Mozart's Symphony in A major, K201, where successive motive-pairs are insistently linked by a common pitch throughout first subject group; cf. Figure 20).

It is, of course, possible that chunks identified within a piece are not reckoned to be connected through a sense of derivation (in whole or in part), in which case it is postulated that they will not stand in a structurally significant relationship with one another. However, as observed above, it is highly unlikely that this would be the case for temporally adjacent chunks, since such a juxtaposition would imply a lack of coherence in the structural narrative of the music at that point (see Figure 21 earlier).

Finally, it should be noted that the process of formulating chunks and identifying relationships between them is potentially an iterative one, on account of the capacity of musical segments to form hierarchies, whereby smaller chunks group together to form larger ones, and so on. Hence, direct and indirect relationships may both operate at the same time at different hierarchical levels. For instance, with reference again to the example cited above of Mozart's Symphony K201, while the many relationships of common pitch linking motive pairs may generally function indirectly, both in the exposition and the recapitulation, the relationship between these two sections as a whole, which function as chunks on the highest formal level within the movement, is unique and direct.

So much for the mental processes that, it is proposed, underlie the cognition of musical structure, presented here purely at a hypothetical level. Clearly, future empirical work may, but need not, provide support for the postulated framework that has been set out. To conclude the present article, we return to the issues that were intially raised in relation to Deliège's model, and see whether the new proposals potentially offer solutions to the problems and anomalies that were identified then.

The first issue that was raised concerned the fact that the similarity perception/categorization/cue abstraction model appears not to take into account the structural significance of relationships between chunks in different categories, and the example was given of empirical work that had been undertaken in relation to Schubert's Ländler for piano, D145, No. 10. Here, the difficulty was that although subjects could usually categorize two-bar segments correctly, they were on the whole unable to recreate the 'mental line' of the piece from the eight chunks presented out of sequence. It was concluded that other structural data, not captured through categorization, and somehow degraded or even eradicated in the process of segmentation and randomization, were important too.

Comparing Deliège's framework with the composite model suggests that the missing information may pertain particularly to the derivation of aspects of chunks. It also yields the possibility that direct and indirect relationships may be the subject of confusion. Detailed analysis of the situation supports both these propositions. Since the design of the Ländler is based on an alternating motivic pattern ($A \ldots B \ldots A_1 \ldots B_1 \ldots A_2 \ldots B_2 \ldots A_3 \ldots B_3$), it is inevitable that coherence between successive segments is achieved through relationships linking only aspects of each. Moreover, given the limited range of material that is used, it is also the case that similar 'aspect connections' potentially exist between any of the 'A' segments and any of the 'B's. In the course of listening to the piece, we can anticipate that the salience of these relationships would vary according to temporal proximity and other factors pertaining to their sequence of presentation – indeed, some may function indirectly or not figure at all in the structural equation. However, when faced with an unordered set of segments, such contextual information is not available to the listener, and many juxtapositions are plausible. Indeed, zygonic analysis shows just how easy it is for subjects to be misled, since some intersegmental relationships (for example, that between A and B_2) offer continuations that are structurally just as strong, if not stronger, than those that Schubert actually employed (for instance, between A and B) (see Figure 25)!

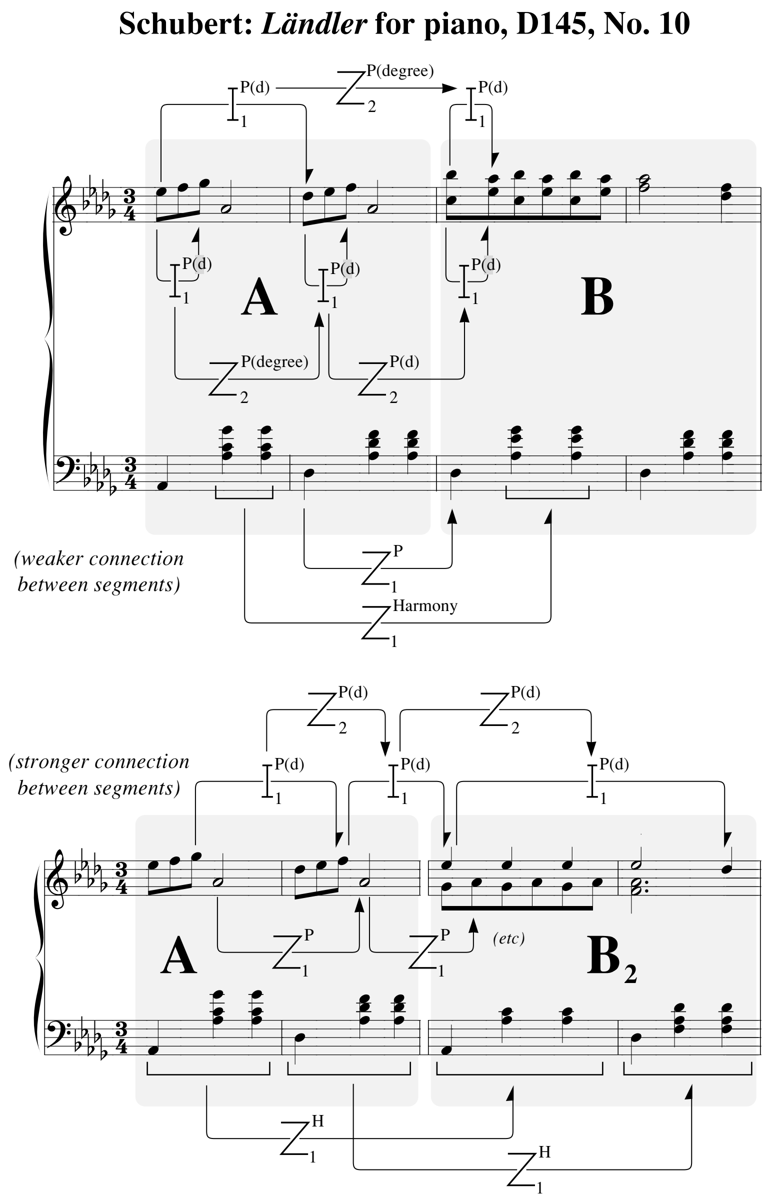

FIGURE 25 *Connections between aspects of groups, out of context, can display an apparent derivational logic not found in the original piece.*

The second issue raised at the beginning of the article was in relation to the opening of Beethoven's 5th Symphony, where it appeared that categorization alone was insufficient to account for the way that we model musical structure cognitively, since the alternative continuations that were proposed following the initial gesture, while all conforming to the same categorical organization ($A_1 \ldots A_2$), were self-evidently not structurally equivalent (see Figure 2). It was suggested that the melodic and harmonic differences between the opening chunks – characteristics which, it was noted, are taken up and developed in the ensuing material – were also of structural significance.

As we have seen, the composite categorization/derivation model recognizes such connections between motivic aspects, and accords them a parallel status in structural processing. Both structural strands may be realized in music-analytical terms through a zygonic approach (see Figure 26); future empirical work could gauge the extent to which these individual intuitions, here captured conceptually through a visual metaphor, form part of the 'typical' listening experience at the subconscious level.

The third issue concerned the challenge that iterative change poses to a purely categorical model of structure. A further example from the first movement of Beethoven's Op. 67 was presented (Figure 3), which showed how, to paraphrase Lerdahl and Jackendoff, the elements of a variant of the opening motive were successively deleted, until a single event (on its first appearance a chord of b♭ minor in first inversion) was able to stand for the original. Yet this solitary chord bears little (if any) resemblance to the opening motive, and, it was surmised, would not be assigned to the same category in the process of listening – indeed, it was noted that the appearance of a variant of the original motive following the succession of chords that occur from bars 210–27 would be likely to be construed as a contrasting event.

The composite model predicts that a passage such as this would be heard principally as successive changes to aspects of chunks, alongside which categorization may play a subsidiary or, indeed, an intentionally ambiguous role: the fact that the chords are evidently derived from the original motive-form, yet contrast with it, arguably provides the structural grounds for the shock of the reprise in bar 228. This hypothesis may be captured music-analytically in zygonic form as shown in Figure 27; its relevance to the 'typical' listening experience, future empirical work must determine.

The fourth and final issue that was identified pertained to the fact that some empirical work indicated modes of similarity judgement that appeared to be counterintuitive in music-theoretical terms. In Beethoven's Piano Sonata Op. 10, No. 1, for example, it was found that excerpts were rated as similar principally on account of their dynamics, articulation and texture. It was not clear how this finding could be reconciled with the numerous intermotivic and interthematic connections that music analysis suggested were present; what could their function be in the course of 'ordinary' listening? Pollard-Gott had earlier proposed that such relationships may play a part in structural cognition only after repeated exposure to a piece of music, and that listeners initially rely on the perception of similarity between more general features to understand the music. But, it was argued, this position is unsustainable, since eradicating coherent relationships in the domains of pitch and

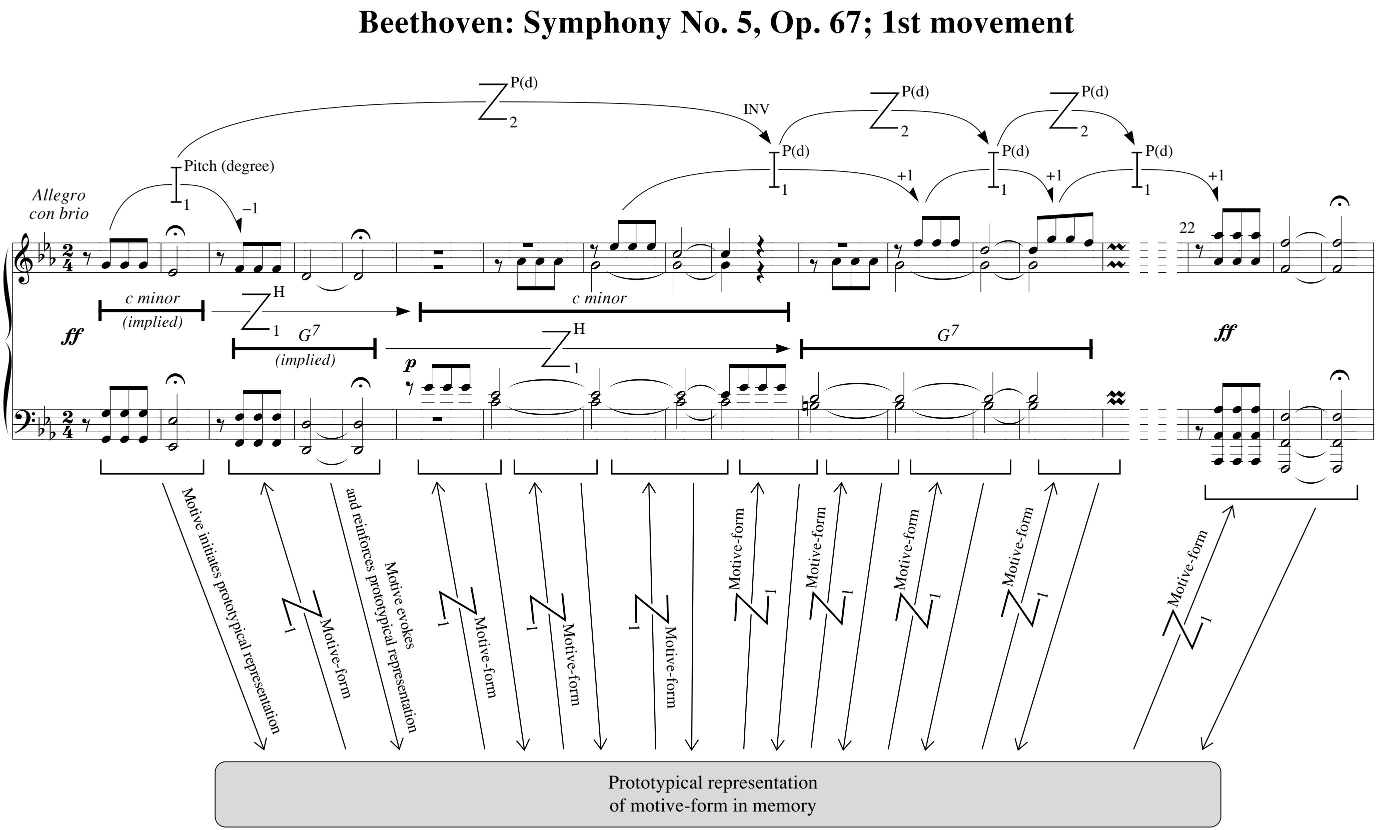

FIGURE 26 *Analysis showing how relationships between entire motives (via a prototypical representation) and aspects of them may function in the cognition of musical structure.*

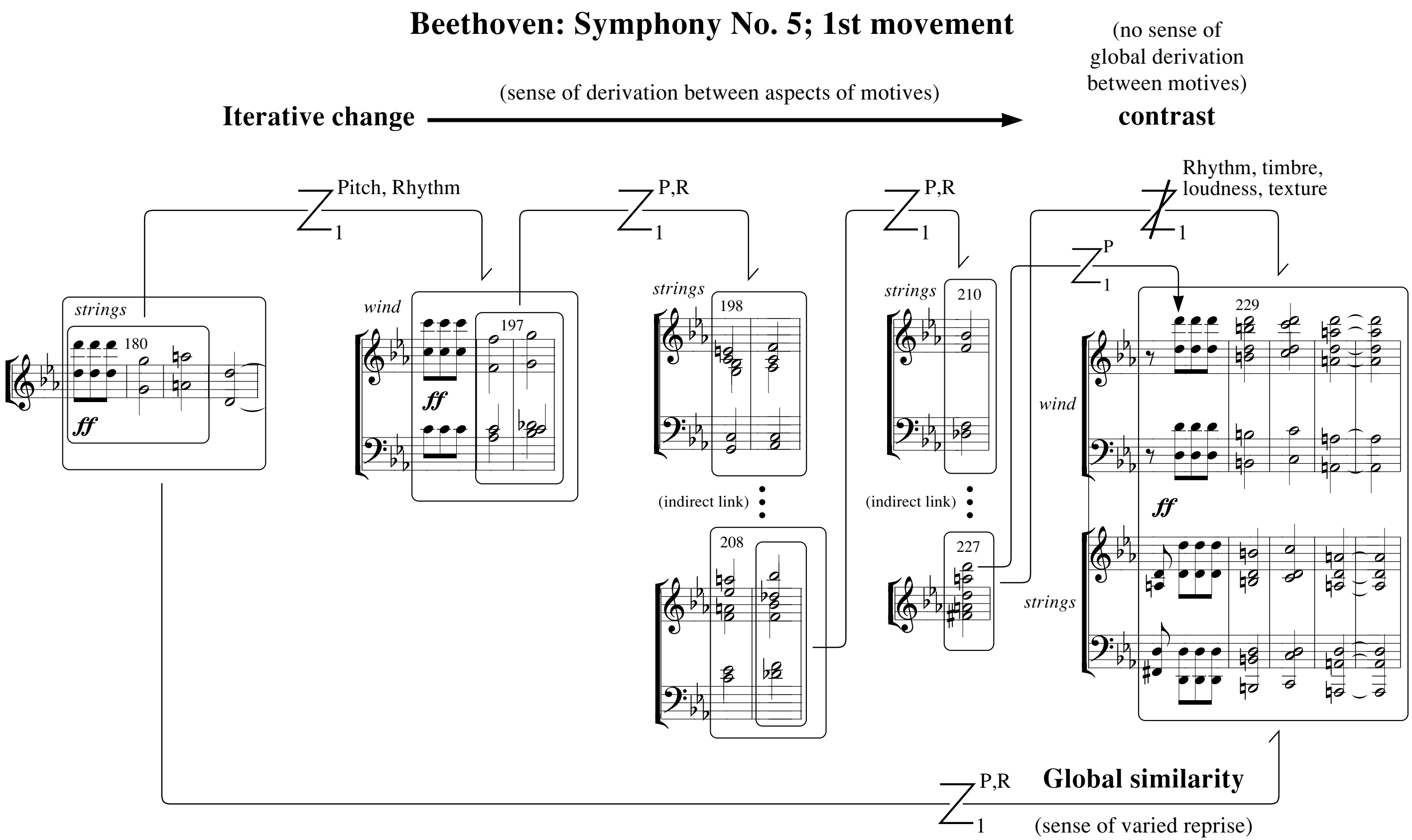

FIGURE 27 *Iterative change leads to contrast with the source.*

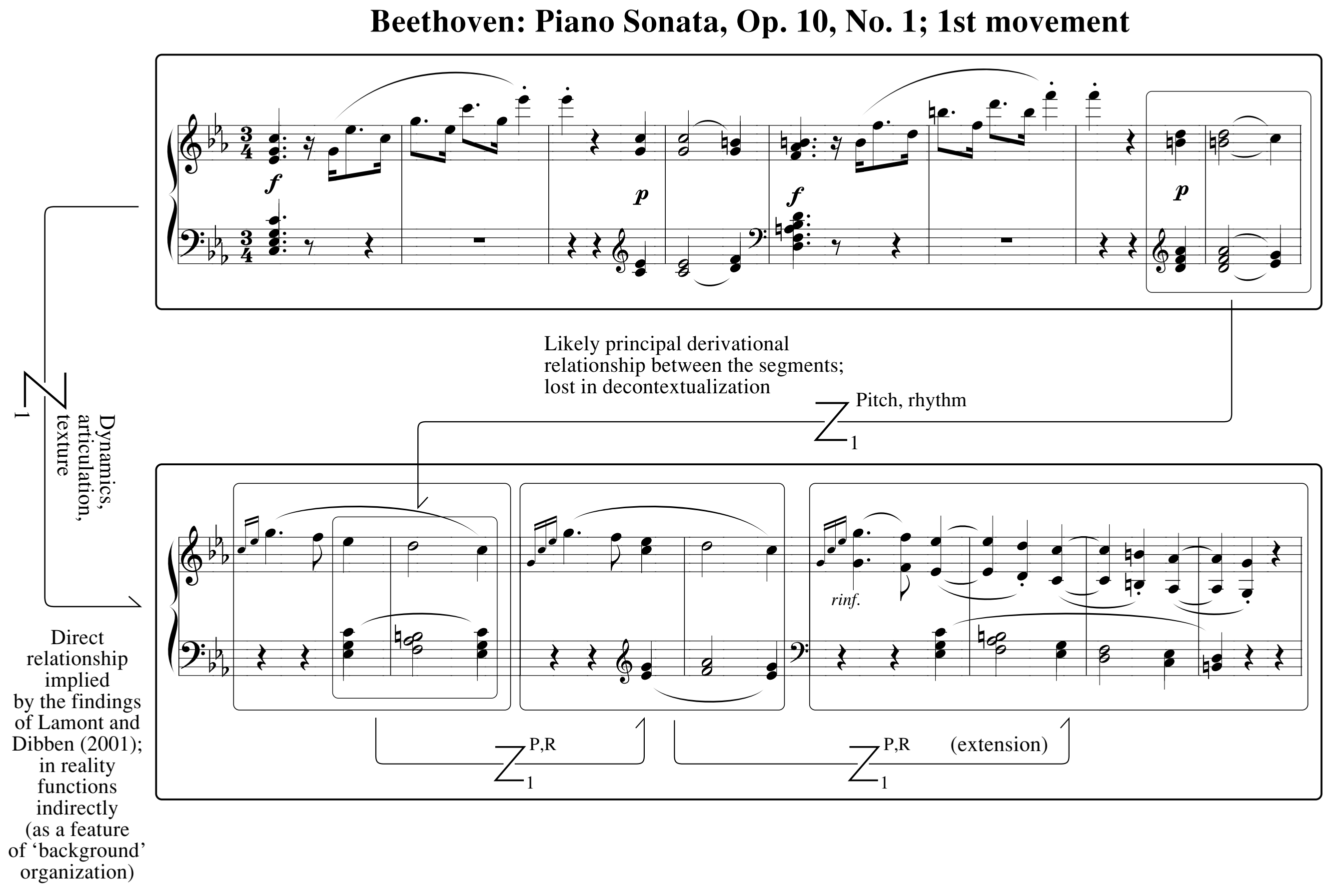

FIGURE 28 *Analysis of the findings of Lamont and Dibben (2001) using the composite model.*

perceived time while maintaining those pertaining, for example, to dynamics, articulation and texture would destroy the musical sense of a piece.

Analysis in terms of the composite model suggests where the confusion may lie. Initially, at least in music of the complexity of the Beethoven and Liszt sonatas cited, it is proposed that structural cognition occurs principally through direct relationships between aspects of chunks, offering coherent moment-to-moment connections within and between local areas of activity, largely in the domains of pitch and rhythm. These links may be supplemented by indirect relationships between whole chunks and parts of them, functioning in the 'secondary' domains of timbre, loudness, texture, etc. Gradually, with increasing familiarity, such data may be reinforced by direct pitch and rhythmic relationships pertaining to more substantial melodic and harmonic segments in their entirety. However, in the experiments described, subjects were asked to make global similarity judgements between excerpts taken out of their contexts within a piece – even those fragments that would have occurred contiguously in the normal course of events being intentionally decoupled. This meant that listeners were discouraged from perceiving the more immediate relationships of pitch and rhythm between aspects of the segments concerned, which they would typically have relied on to make judgements of similarity, salience and derivation (and so make sense of the music) – judgements that in any case were not recorded or taken into account. Therefore, as the data show, the listeners processed the similarity of the segments globally in terms of their general auditory features. The subsequent interpretation of the results wrongly ascribed the function of the relationships that were identified as being the principal link between motives or themes, directly connecting one with another in cognition, whereas (the composite model suggests) such relationships would typically fulfil an indirect and subsidiary role. In zygonic terms, this analysis may be illustrated as shown in Figure 28, which, again, future empirical work may support or refute.

8. Conclusion

This article, primarily using the concepts and methodologies of music theory, analyses the model of similarity perception, categorization and cue abstraction that has been formulated, developed and empirically tested by Irène Deliège and her followers over the last decade or so. The central hypothesis is that, alongside the cognitive processes Deliège identified as being essential to the perception of musical structure, the notion of perceived derivation is a key additional element. Evidence for this proposition is sought in the re-analysis of recent empirical findings pertaining to similarity perception and categorization in music, and through the identification of certain types of structure – those entailing iterative change, for example – that appear to challenge the sufficiency of Deliège's model. As a result, a new framework is set out, which suggests that the perception of similarity and salience may function together in cognition, underpinning and informing that aspect of cognitive processing whereby, in a musical context, we intuitively sense that a given auditory event or events or features pertaining thereto may seem to be derived from another or others. (It is further hypothesized that this feeling of contingency in some way acts as a metaphor for our perception of causation in the physical world, enabling the 'structural narrative' of a piece to be built up over time – a development of the concept of Deliège's 'mental line'.) A sense of derivation, it is surmised, lies behind both the 'chunking' of music at the motivic and thematic levels and beyond, and the relationships that are ideated between the segments so perceived, which may be direct or indirect (via prototypical representations which Deliège terms 'imprints'), and involve entire chunks (thereby entailing categorization) or parts of them.

Subsequent analysis, using the 'zygonic' concepts and terminology developed by Ockelford (for example, 2002, 2004), shows that the new, composite framework that, it is suggested, links the perception of similarity, salience, derivation, categorization and schematization, is capable – on a theoretical level – of accounting for the apparent anomalies and gaps that were identified in relation to Deliège's processing model. Empirical work is now required to test the validity of the new framework and the relevance of the assertions that derive from it to the 'typical' listening process.

NOTES

1. Based on papers given at two sessions of the 6th International Conference on Music Perception and Cognition held at Keele University during August, 2000.
2. To listeners familiar with the work; the implied harmonic structure is ambiguous on a first hearing.
3. Elsewhere (for example, Ockelford, 1999: 12ff) frames are taken to be the shortest imaginable instants of perceived sound, by which definition notes typically comprise a plurality of frames.
4. Beyond this, it is hypothesized that 'tertiary' relationships, linking secondaries, occur in some domains (Ockelford, 1999: 34, 2002). Note that interperspective relationships may be considered to model the way in which *any* musical aspects are compared in perception – not just those existing within the constraints of frames.
5. The fact that such expectations are liable to differ can be invoked to explain discrepancies between music–psychological and music–theoretical accounts of 'sameness' – see, for example, Cook's critique (1994: 67–70) of the empirical work of Wolpert (1990).
6. Contrast with the 'personal songs' described by Schneider (1957: 11) that exist in certain ancient cultures, whose individuality is considered to lie particularly in the timbre of the voice. Hence, what a listener brought up in the western classical tradition may consider to be the 'same' personal song sung by someone else would not be regarded in this way by a member of the tribe concerned (indeed, such transference would only be permitted after the owner's death).
7. In traditional western music theory the term is typically used to specify the replication of melodic contour, a limitation that does not apply here.

8. From the Greek term for 'yoke', implying a union of two similar things.
9. Here, the interperspective value is expressed in terms of the two perspective values that are compared (this being the most parsimonious form of expression, since relative values of loudness are not typically quantified).
10. The number of primary relationships between the salient values of 'n' frames, with 'x' different types of value = $^1/_2$ x.n(n–1). The number of secondary relationships = $^1/_8$ x.n(n+1)(n–1)(n–2).
11. A more direct form of imitation than that between interonset intervals (through secondary zygons), which the theory also suggests is present.

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