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The magical number two, plus or minus one: some limits on our capacity for processing musical information

ADAM OCKELFORD
Centre for International Research in Music Education,
University of Surrey Roehampton

• **ABSTRACT**

Like all fields of human artistic endeavour, music is constrained by our cognitive processing requirements and limitations (Swain, 1986; Lerdahl, 1988; Huron, 2001). This article considers particular forms of constraint pertaining to the relationships that the structure-seeking mind (subconsciously) fabricates between perceived musical events. It is proposed that 2±1 may be a universal limitation pertaining to the *level* of relationships so ideated. That is, in terms of Lewin's (1987) theoretical framework in which "intervals" can be intuited between the "elements" of musical "spaces", it is posited that the cognition of musical structure occurs either through intervals (level 1), through intervals between these (level 2), or — in some circumstances — through intervals between *these* (level 3). This proposition is explored through the psychomusicological model developed by Ockelford (1991, 1993, 1999), which too analyses musical structure in terms of the relationships that may be cognised between its discrete perceptual components. In particular, the model identifies a type of cognitive link through which events (at any level) are felt to imply others the same or similar — through so-called "zygonic" relationships. This theory suggests a further general principle: that the highest level of relationship in operation at any given point must be zygonic if the music is to be structurally coherent. Evidence for this, and for the limit on the level of relationships of 2±1, is offered through a series of musical examples, which illustrate a variety of musical organisation in action. Finally, empirical work is suggested to explore further the theoretical ideas that are presented here.

INTRODUCTION: COGNITIVE CONSTRAINTS ON MUSICAL STRUCTURE

Music, a product of the mind, is necessarily constrained by the cognitive processes through which it is created and apprehended; little wonder, then, that most work in the field of music theory acknowledges one or more such constraints, usually implicitly, although occasionally the matter receives direct attention.

Lerdahl (1988), for example, sets out some of the cognitive restrictions that appear to impinge upon compositional systems, and in so doing draws a distinction between "natural" and "artificial" grammars. The former (he asserts) arise spontaneously in musical cultures, dominating in those that emphasise improvisation and the active participation of the wider community; here, we may surmise, an intuitive music-structural understanding is shared by the composer and listeners. "Artificial" grammars, in contrast, are likely to materialise in cultures which utilise notation, are self-conscious and in which composers, performers and listeners fulfil discrete roles. Here, composers may create structures which quite simply pass most listeners by (and whose musical understanding therefore relies on "natural" grammatical features which are also usually present).

One could argue that the notion of a conceptual grammar, remote from the typical listening experience, is parallelled in theoretical models such as that devised by and summarised in Lewin (1987): his *Generalized Musical Intervals and Transformations.* This mathematical masterpiece consciously avoids undue concern with cognitive constraints; as Lewin says (*op. cit.*, p. 87), "One should not ask of a theory, that every formally true statement it can make about musical events be a perception-statement. One can only demand that a preponderance of its true statements be ***potentially*** meaningful in sufficiently developed and extended perceptual contexts". Contrast this with the approach adopted by Swain (1986) which, in bringing established psychological mechanisms to bear on musical situations, seeks to define "natural" grammatical features. Specifically, Swain contends that hierarchical theories of music should be limited by our finite capacity for taking in and processing information, and he invokes Miller's (1956) observations and those of subsequent studies (such as Atkinson, Campbell and Francis, 1976) to support his analytical findings. Certain principles of Gestalt perception are fundamental to Swain's thesis too, just as they are to some of the major theories of musical structure and understanding that appeared in the second half of the twentieth century, including, notably, Meyer (1956, 1967, 1973), Lerdahl and Jackendoff (1983) and Narmour (1990, 1992); most recently, Huron (2001) shows how Gestalt and other perceptual constraints, in the form of six core principles, can account for the majority of voice-leading rules presented in tracts on Western classical music theory.

In reviewing these approaches and others, it is evident that cognitive constraints are of two types: those that are structurally ***necessary*** for musical information to be processable, and those that represent a ***boundary*** to processability. In Lerdahl's (1988) terms, this distinction may be captured as those features that must be present in a listening grammar, as opposed to those that may exist beyond it (although they may have played a part in the process of composition). An example of the former is Lerdahl's "Constraint 1", whereby "the musical surface must be capable of being parsed into a sequence of discrete events" (*op. cit.*, p. 239). An instance of the latter is Swain's contention (*op. cit.*), that a structural level should contain a maximum of only three or four musical events. The purpose of this article (as indicated by the title, with its homage to Miller, 1956) is to propose the existence of similar constraints on the *level* of relationships that the mind constructs between perceptual events as it strives to make sense of musical input. The "level" of a relationship is defined as its adjacency to the perceptual surface. Relationships directly linking events are termed "primary" — the interval between two pitches, for example; while relationships linking these are referred to as "secondary" — the difference ***between*** two intervals, for instance. Examples of musically significant *tertiary* relationships are difficult to find (though, see, for example, Narmour, 2000, p. 364; cited below), while ***quaternary*** connections appear to have served no structural function at all. If this is the case, are musical structures conceivable that do rely on relationships at this level of abstraction, or do tertiary relationships represent a cognitive "ceiling"? And what of other domains of perceived sound, such as duration, timbre and loudness? Do comparable restrictions apply here, or do the levels of relationship that potentially operate in each domain differ?

It is questions such as these that are the central concern of the this paper. Seeking answers to them is, I believe, of general musicological value, since it contributes to our understanding of what can reasonably be deemed universal, bottom-up "givens" in music processing as against style-specific, top-down cultural constructs (*cf.* Narmour, 1990, pp. 55ff; see also, for example, Harwood, 1976; Rahn, 1983). Methodologically, the current article is theoretical in nature, drawing its evidence from conceptualised responses to music that are typically intuitive and making use of "zygonic" theory (Ockelford 1991, 1993). This metacognitive approach to examining how such structure "works" as an intellectual construct is based on the belief (as expressed by Bernstein) that music offers "a striking model of the human brain in action and as such, a model of how we think" (1976, p. 169). Inevitably, then, one outcome of what is presented is the proposal to undertake a range of further, empirical work.

Zygonic theory

Zygonic theory is a response to the observation that, just by listening, music makes sense; no special knowledge or skills are needed. The theory seeks to elucidate this phenomenon: how music, the ubiquitous, abstract medium for conveying human thought, is able to function as an asemantic language. The starting point is a reductionist one: music is considered initially as a system of perceived sonic variables. Some of these, such as duration, have a single axis of variability, while others, like timbre, are multidimensional in nature; some gauge qualities such as loudness, while others detail its perceived location in time or space; and some, like pitch, pertain to individual notes, while others, including tonality, are characteristic of a group. Each variable has many potential modes of existence, or "values", whose range represents the freedom of choice available to composers. Conversely, each may be deemed to be constrained or "ordered" to the extent that its value is reckoned to be subject to restriction. While some of the causes of perceived sonic constraint may lie beyond a composer's immediate control (the selection of timbre will be dictated by the availability of performers, for example, and a singer may be unable to reach a particular pitch), and while external influences (such as the cross-media effects of song-texts, for instance) often have a bearing, most — and certainly the most important — perceived sonic restrictions in fact function *intra*musically, through the process of repetition: in short, a value may be thought to be ordered if it is reckoned to exist in imitation of another. Since the vast majority of listeners are quite unaware of this type of cognitive activity, clearly it need not operate at a conscious level. Yet it must be universally present, if only subliminally, otherwise an orderly sequence of sounds would prove no more effective a means of musical communication than a random one, which is not the case.

Recognition of the essential role of repetition in musical structures is widespread, ranging from Schenker (1935/1979) to Cone, who claims (1987, p. 237), in relation to the derivation of musical material, that "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'". Such notions of repetition, imitation and perceived derivation are predicated on the existence of ***interperspective relationships***[1], mental constructs through which incoming perceptual data are compared (*cf.* Krumhansl, 1990, p. 3). Such relationships can exist between any aspects of any musical events, in any perceptual domain. Typically (it is surmised), they are formulated unthinkingly, and pass listeners by as a series of qualitative experiences. However, introspection enables them to be captured conceptually, and they may be symbolised as in Figure 1 (*cf.* Ockelford, 1991, pp. 133ff).

In this figure, the "I" stands for "interperspective", the superscripts indicate in each case the perspect concerned (represented by its initial letter — here "P" for "pitch", "L" for "loudness" and "O" for "onset"), and the level of relationship (primary, secondary or tertiary) is shown by the appropriate subscript. In the domain of pitch, two primary relationships are illustrated, the first comprising the interval of a descending major 3rd, and the second a minor 3rd. The secondary relationship between these values gauges the difference between them: a semitone. In the domain of onset, there are three primary relationships (spanning differences of ♩., ♩ and ♪), two secondaries (both of value - ♪), and a tertiary relationship which indicates that the two secondary differences are the same (shown through the use of a full arrowhead, as opposed to the half arrowhead, which represents a link

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

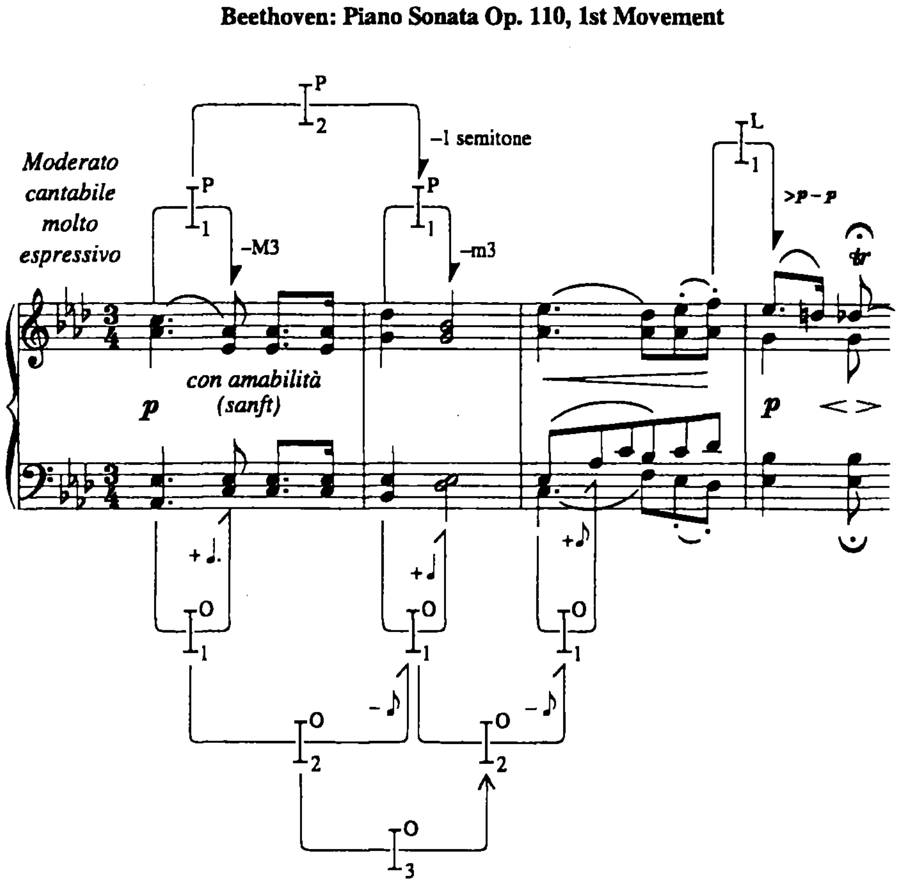


Figure 1.
Interperspective relationships.

between *different* values). In the domain of loudness, a single primary relationship reflects the difference in perceived levels between >***p*** and ***p***[2].

(2) Here, the interperspective value is expressed in terms of the two perspective values that are related (this being its most parsimonious form of expression, since relative values of loudness are not typically quantified). Observe that some arrowheads are open and some are filled — the former showing a link between *single* values, and the latter indicating a *compound* connection within or between "constants" (typically, values extended in time) — implying a network of relationships. For fuller explanation, see Ockelford, 1999.

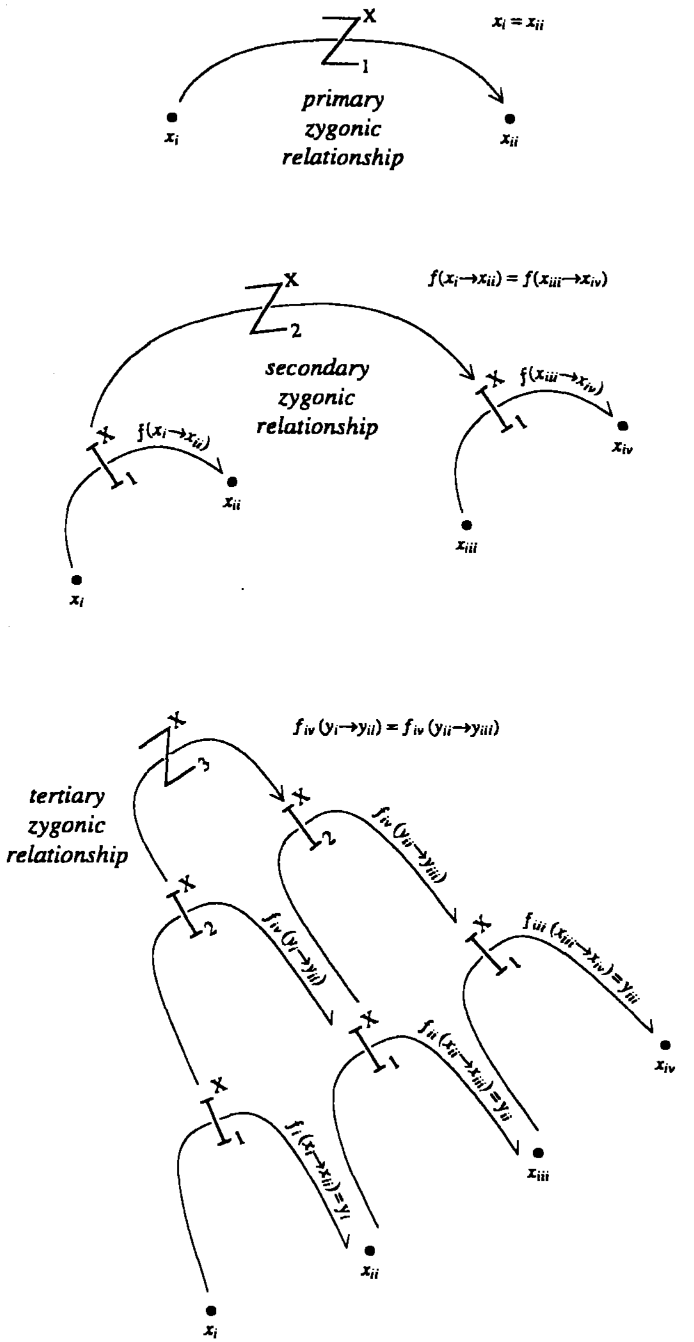


Figure 2.
Representation of primary, secondary and tertiary zygonic relationships.

The interperspective relationships through which imitative order is perceived are of a special type termed "zygonic" by Ockelford, 1991, pp. 140ff (from the Greek term "zygon" for "yoke", implying a union of two similar things). A primary zygonic relationship or "zygon" may be represented in abstract terms as in Figure 2 (with "X" standing for any perspect, and x_i, x_{ii} etc. representing appearances of perspective values).

Here, to reiterate, the second value is deemed to exist in imitation of the first, and so its value is felt to be constrained, and therefore ordered.

Clearly, a primary zygonic relationship such as that depicted in Figure 2 offers a highly simplified version of certain cognitive events that we may reasonably suppose take place during meaningful participation in musical activity. Moreover, the single concept of a zygon bequeaths a vast perceptual legacy, with many potential manifestations: potentially involving any perceived aspect of sound; existing over different periods of perceived time; and operating within the same and between different pieces, performances and hearings. Zygons may function in a number of different ways: reactively, for example, in assessing the relationship between two extant values, or proactively, in ideating a value as an orderly continuation from one presented. They may operate between anticipated or remembered values, or even those that are wholly imagined, only ever existing in the mind. (There is, of course, no suggestion that the one concept is cognitively equivalent in all these manifestations, but only that it is *logically* so.)

Just as perspective values may be ordered through primary zygonic relationships, so primary interperspective values may be ordered through imitation too, with secondary zygons functioning as shown in Figure 2. Similarly, tertiary zygonic relationships may be considered to order secondary values, and higher levels of zygon are also theoretically possible. The imitation of perspective and interperspective values may be approximate, resulting in "imperfect" ordering, in which case the full arrowhead shown is replaced by a half arrowhead (as explained in relation to Figure 1).

Even a short passage of music comprises a large number of perspective values, potentially linked through a vast network of relationships, whose effect would be perceptually overwhelming were it not for the fact that the mind seeks (and is able to find) groups of relationships that give the impression of acting together in co-ordinated fashion. This issue is taken up in the next section.

THE PERCEPTUAL AND CONCEPTUAL STATUS OF INTERPERSPECTIVE RELATIONSHIPS

The taxonomy of relationships set out above can be used to model various aspects of our capacity for processing patterns of abstract sound. In particular, it is pertinent to the central concern of this paper: what constraints apply to the levels and types of relationship that are typically used in the creation and cognition of musical structures? Answers to this question can be sought in two ways: empirically, through analysing subjects' responses to a range of passages whose differing structures are dependent on various levels of relationship; or through a music-analytical approach, which aims to show what forms of musical organisation composers have used, with the assumption that these provide some indication of their and listeners' cognitive limits (*cf.* Lerdahl, *op. cit.*). It is the latter, analytical, method that is adopted here.

However, the issue of deciding which relationships are of structural significance is not as straightforward as it may appear. For example, the fact that two perspective or interperspective values are the same may not necessarily be important in music-structural terms; any piece of music is replete with sameness and similarity in all dimensions. To understand why, consider Sloboda's (1985) observation that for music perception to "get off the ground" there is the fundamental requirement for sounds to stand in significant relation to one another, rather than in isolation (p. 154); and that there is the need for a framework of discrete and re-identifiable locations in pitch and time to enable the dialectics of tension/resolution and motion/rest to flourish (p. 259). That is to say: for our perceptual and cognitive processing capacities not to be overwhelmed, composers have to work within tight constraints, such that the number of 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, "background" restrictions of comparable severity typically apply to other perspects too, such as timbre and loudness. These almost invariably fulfil a secondary role as "carriers" of the main musical message, and as a consequence tend towards coherence based on uniformity or incremental change (*cf.* Boulez, 1963/1971, p. 37; Erickson, 1975, p. 12; Ockelford, 1999, pp. 277ff).

The fact that constraints underlie the creation of music, whereby many perspective and interperspective values are the same, regardless of the choices of the composer, poses a challenge for theorists and analysts, since relatively few identical or similar values give rise to a large number of potentially significant structural relationships between them. Consider, for example, Chopin's Prelude No. 6 in B minor, Op. 28, which consists of 403 notes. In just one domain — pitch-class — the number of potential primary zygons is around 13,000; the number of potential secondary zygons is in excess of 500 million, and the number of potential tertiary zygons is approximately 10^{18} (*cf.* Ockelford, 1999, pp. 458-9). Many other relationships are conceivable too, both between pitch-classes and within other perspective domains. Moreover, higher level relationships are theoretically feasible. Hence, even these vast figures account for only a tiny proportion of all the significant relationships that potentially exist. Manifestly, to move forward in analytical terms, clarification of the likely cognitive status of these relationships is required. This can be modelled through considering the relationships to exist on a continuum with three sectors, comprising those that are "imperceptible/non-cognisable" (Sector 1), "perceptible, but of no direct significance to perceived musical structure" (arising, for example, by chance, as a result of "background" organisation; Sector 2), and "subconsciously processed *and* of direct relevance to the perception of structure" (Sector 3). Sector 4, comprising relationships which are "consciously processed/ conceptualised" may be subject to even greater variation, having the potential to be overlaid anywhere on the other regions.

Inevitably, the boundaries between these sectors are fuzzy, since which of the potential relationships find a place in cognition, and the significance of these, will vary from listener to listener, and even with the same listener on different occasions. Nevertheless, the model offers a useful framework for distinguishing between different types of relationship. Specifically, it is in Sector 3 of the continuum, where subconsciously processed connections are likely to attain perceived structural significance, that relationships can be classed as zygonic: that is, when it is reasonable to assume that the mind will instinctively attribute a feature of one event as existing in imitation of a feature of another. *Consciously*-processed relationships (in Sector 4) may but need not be zygonic, the criterion again being to what extent imitation can reasonably be reckoned to be present, although, clearly, conceptualising a typically subconscious experience may well affect the way the mind reacts to it on subsequent occasions.

This model offers insights into how Lerdahl's compositional and listening grammars can relate to one another, since listening grammars can be equated with structural relationships pertaining to Sector 3, and compositional grammars with relationships in Sector 4 (which can embrace Sectors 1, 2 or 3); this affirms that the two need not be exclusive, although they may be[3]. The model also suggests a number of areas of further, empirical work. For example, criteria need to be developed according to which relationships may reasonably be assigned to one sector or another, since, it could be argued, the correct ascription of their status is fundamental to contextually valid music analysis. The following thoughts are offered here as starting points, which will be used to inform the analytical examples that lie at the heart of this paper. The question is, with so many potentially orderly relationships linking any two musical events, any of which may be significant, how does the brain know which will be of most value to attend to, to process, to remember and to compare? One way of addressing this issue is to work on the assumption that the mind instinctively adopts the principle of parsimony ("Ockham's razor") in seeking to make sense of musical structure, such that the simplest available "solution" is sought (*cf.* Fiske, 1990, p. x). This means that music will be modelled in cognition using the *fewest possible* of the *simplest available* mental processes, an assumption that can be broken down into a number of constituent principles. They are couched here in terms of "preference rules" (*cf.*

(3) Although, as Sloboda remarks (1985, p. 102): "It is [...] possible that certain features of a composition [...] were no part of the composer's intention, conscious or otherwise. In a system of inter-related sounds as large as, say, a symphony, there are bound to be some relationships discoverable by analysis which were neither noticed nor designed by the composer".

Lerdahl and Jackendoff, 1983), which take into account the *number* of relationships, their *nature* and *relative disposition*. Hence, the proposition is that we will tend to opt for structural interpretations whereby, *ceteris paribus*:

a) *lower* levels of relationship are preferred to *higher*;
b) *simpler* functions are preferred to *more complex*;
c) *perfect* zygons are preferred to *imperfect*;
d) a *lower degree* of imperfection is preferred to a *higher degree*;
e) *parallel* processing is preferred to *non-parallel*, both
  i) *within* perspective domains, and
  ii) *between* them; and
f) *fewer* relationships are preferred to *more*.

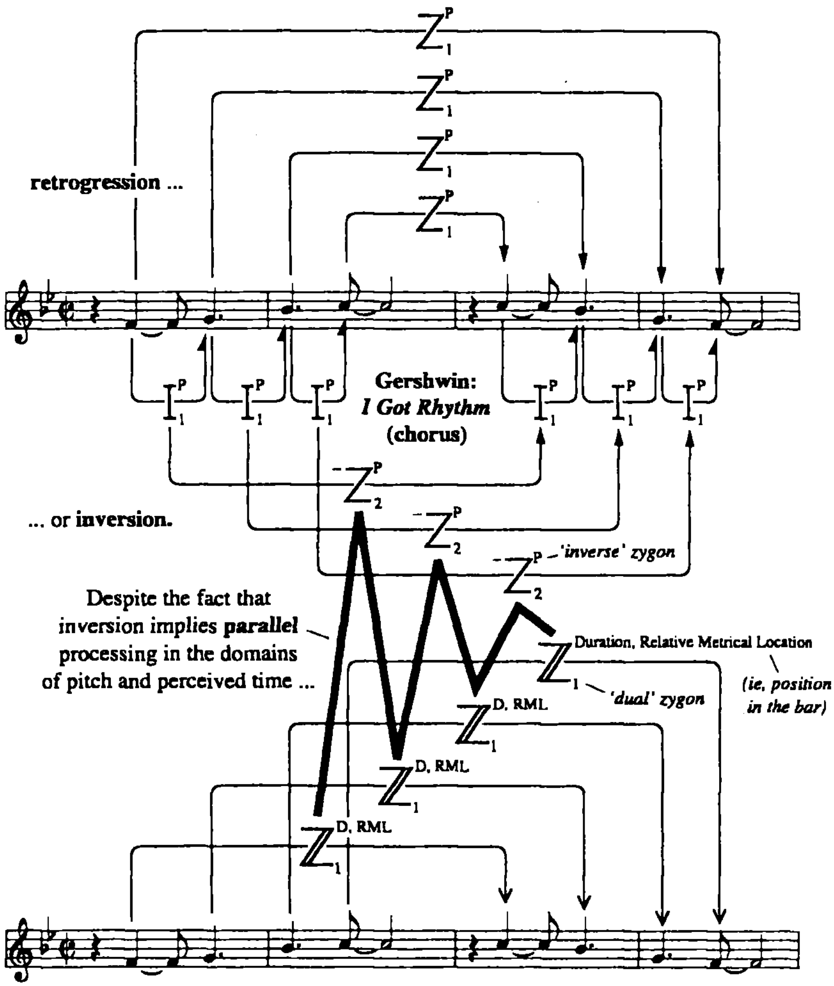
Consider, for instance, the opening phrases of the refrain of *I Got Rhythm* (Gershwin, 1930). In the domain of pitch, the relationship between the two can be interpreted principally in two ways, as inversion or retrogression. Which interpretation do the preference rules suggest is likely to dominate cognitively? Rule a) — "prefer lower level relationships to higher" and rule f) — "prefer fewer relationships to more" both indicate retrogression, since this transformation uses four (as opposed to nine) relationships, all of primary (rather than some being of secondary) level; Figure 3 spells out what is involved. Tentative as they are, these preference rules will be used to guide the analytical approach adopted in the rest of this article — with the aim of showing what levels of relationship typically exist in different music-structural contexts, and their zygonic status.

First, however, we need a taxonomy of the various combinations of relationships that may *potentially* exist at the different levels (from primary to tertiary). At each level a relationship may be zygonic or non-zygonic (designated here merely as "interperspective"; for a fuller discussion, see Ockelford, 1999, p. 75). Hence the main possibilities are as follows (see Figure 4). Other patterns are, of course, conceivable — for example, a secondary interperspective relationship may link a primary interperspective relationship and a primary zygon. However, such combinations do not affect the organisational principles outlined below.

PATTERNS OF RELATIONSHIPS: MUSICAL EXAMPLES AND DISCUSSION

The following examples are organised according to the patterns illustrated in Figure 4, and are restricted to the domains of pitch, onset, timbre and loudness since these are distinct and, in many respects, representative of other perspects. They are generally taken from pieces in the Western classical style, because of their presumed familiarity to readers of this article; however, there is no reason to think why the observations made in this context should not have more general applicability. Further work (analytical or empirical) could explore the position in relation to other aspects of perceived sound and other styles of music.

In the domain of pitch, two principal structural interpretations are possible:



... (whereas retrogression implies separate processing), retrogression will tend to dominate because of the relative strength of the primary zygons of pitch.

Figure 3.
Primary zygonic organisation in the domain of pitch preferred to secondary.

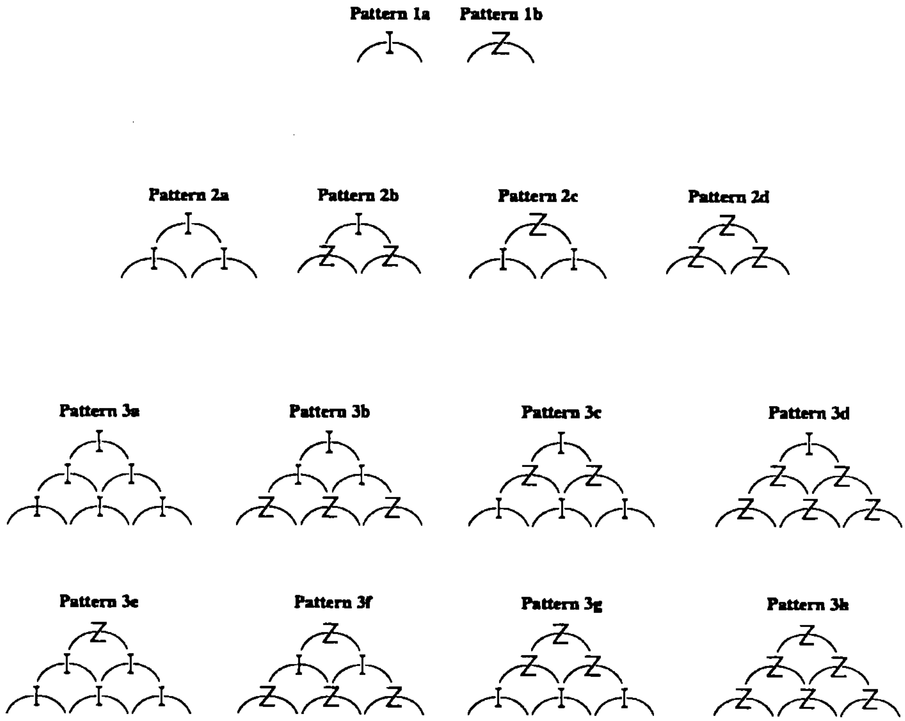
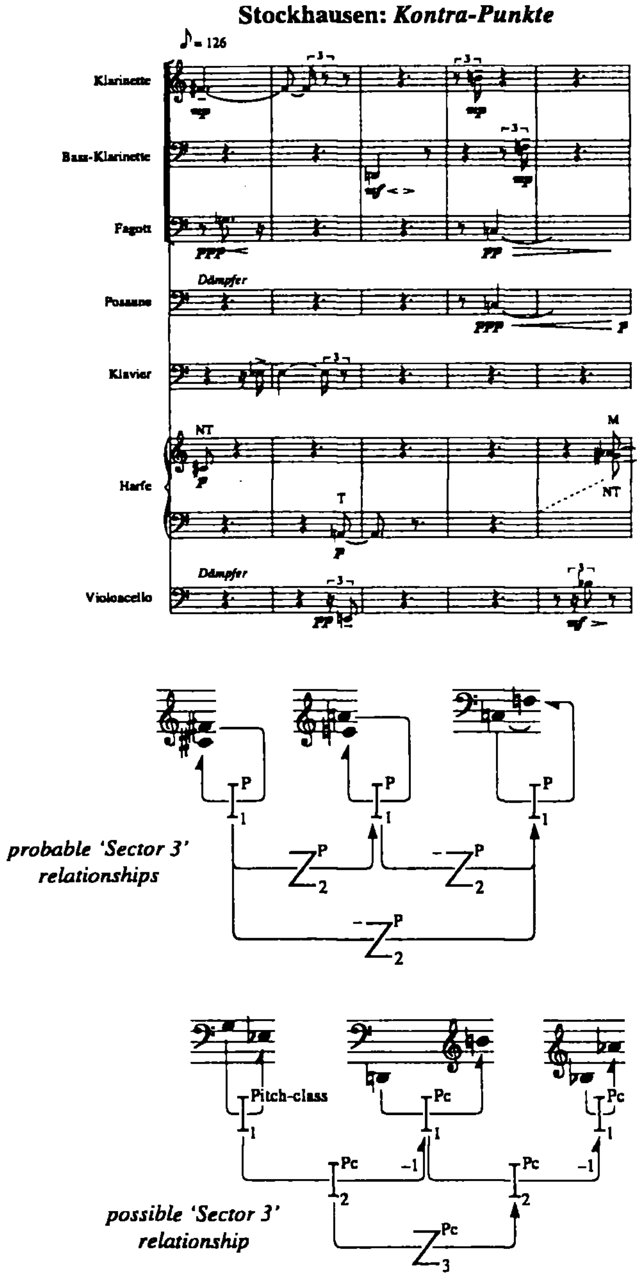


Figure 4.
Potential patterns of zygonic and non-zygonic (here shown as interperspective) relationships.

PATTERN 1A

Primary relationships linking one perspective appearance with another that is different are fundamental to music; without them, all sounds would be sucked, as it were, into the black hole of complete identity (*cf.* Ockelford, 1993, p. 107; Borthwick, 1995, pp. 29ff). Hence, as a general rule, every perceived sound has at least one non-zygonic connection with another or others. Consider, for example, Figure 5, the opening of Stockhausen's *Kontra-Punkte* (1952/1953), which the composer claims in his introductory notes to have "no repetition [...] One never hears the same thing". Certainly, it seems safe to assume that this passage is perceived through the subconscious formulation of many non-zygonic primary relationships. However, we may also surmise that these are not the only type nor the highest level that are in operation in the perception of this excerpt — nor, extensive analysis suggests, are comparable relationships *ever* the sole cognitive links active in the creation or recognition of musical structure: zygonic relationships and relationships of higher levels are invariably present. It is possible to demonstrate why this should be so by trying to conceive of a scenario where it was *not* the case. If no zygonic relationships were operational, then there would be no perceived causal connection



Karlheinz Stockhausen *Kontra-Punkte* PH 396/UE 12207

Figure 5.
Examples of relationships of possible and probable perceived structural significance (in the domain of pitch) occurring in the first five bars of Kontra-Punkte.

between any perspective or interperspective value — the present theory suggesting that each therefore had to be different (or, at least, not recognisably the same). The effect would be one of amusical chaos, insofar as music is defined as coherent patterns of abstract sound, whose organisation is intuitively shared by the composer, performers and listeners (*cf.*, again, Lerdahl, 1988). In fact, even a short passage devoid of repetition is extremely difficult to create: a cursory analysis of the passage shown in Figure 5, in the domain of pitch alone, reveals a structure of great intricacy. For sure, in these early stages of the piece, none of the pitch-classes that makes up the 12-tone row is repeated[4] (although from bar 6 they all are). However, the intervallic symmetry inherent in the chromatic scale means that the opening twelve notes are potentially linked through 345 secondary zygons of pitch-class. Of course, the great majority of these will be in Sectors 1 and 2, being either imperceptible, or only theoretically perceptible and of no direct structural significance; however, there are some, which by their perceived temporal disposition (whereby simultaneity or sequence is maintained), do seem likely to be in Sector 3, and so of structural relevance.

Hence it is evident that while non-zygonic primary relationships are a ***necessary*** element in the cognition of musical structure, they are not in themselves ***sufficient*** to perceive or understand how sounds are organised. Therefore, we must extend our investigation to other patterns of relationships.

Pattern 1b

Primary zygonic relationships are typically fundamental to structure in all perspective domains, and, we may surmise, our mental modelling of music is unwittingly replete with them (for, as the discussion in relation to Pattern 1a suggests, the absence of primary zygons would imply the musically inconceivable siuation in which all pitches, durations, loudnesses, timbres and other perspective appearances differed significantly from one another, and none was felt to be logically related to another). Primary zygons offer the most immediate form of perceived sonic organisation, whereby one direct perceptual experience is felt to imply another the same, through the repetition of a feature or features at the musical "surface". At the most basic level, we can assume that primary zygons play a role in the cognition of the internal structure of notes, which are typically perceived as constant in the domains of pitch and timbre, and frequently so in the domain of loudness (although the physical variation present in the course of many notes is indicative of considerable perceptual simplification taking place — see Ockelford, 1999, pp. 120ff). That is, around every period of perspective constancy, a web of potential relationships exists, reactively acknowledging the organisation that is present, and proactively anticipating its continuation (*cf.* Husserl, 1905-1910/1964; Miller, 1984, pp. 117ff; cited in Lewin, 1986, p. 329). Evidence for this is found, for example, in the

(4) Leaving aside the repetition implicit in sustained notes (see below).

research of Bregman (1978), who found that if a portion of a constant pitch was interrupted with a burst of noise sufficient to mask it, then the steady sound would continue unabated in the listener's imagination (pp. 70 and 71)[5].

Beyond this, in the domain of pitch, primary zygonic relationships play a crucial role in formation of melodies. A major factor in this is the almost universal tendency for tunes to be constructed using limited frameworks of pitch and pitch-class (a constraint that is often reinforced through the use of instruments that are capable of producing only certain values). However, primary zygonic constraints on pitch extend beyond these "background" considerations. Consider, for example, that of the 10,000 or so musical themes catalogued by Barlow and Morgenstern (1948/1983) from the Western classical tradition, 68% repeat a pitch-class within the first four notes (significantly higher than the probability of a value being repeated by chance under these conditions, which is 43%). Moreover, the work of Levitin (for example, 1994) on the prevalence of absolute pitch memory among the population as a whole indicates that primary zygons may be of consequence ***between*** performances too.

Timbre is typically consistent within phrases and sections (timbral change often being used to reinforce the demarcation between between melodic "chunks"); indeed, many entire pieces use just one timbre (for example, piano sonatas) or a family of timbres (for example, string quartets). Moreover, pieces often use the same or similar instrumental or vocal combinations, indicative of primary zygonic relationships functioning between pieces. Series of different timbres are frequently repeated in conjunction with the repetition of melody and harmony (for example, in the recapitulations of symphonies of the classical period) — the similarity of tone colour reinforcing the feeling of "return" primarily afforded by the patterning in the domains of pitch and perceived time. Occasionally, timbre attains greater status as an independent or at least influential organisational feature: a striking example occurs in Brahms's 4th Symphony, Op. 98; 1st Movement, bars 227ff, where a series of timbral "blocks" are organised through successive primary zygonic constants (Figure 6, next page)[6].

Although dynamic contrast is a significant affective component in some styles of music, successive values of loudness within and between notes are typically perceived to be the same or similar. Indeed, extended periods of music, ranging from notes to phrases, sections and even movements may be performed at the same dynamic level, or within a relatively narrow dynamic envelope. Sometimes, this constancy is dictated by the limitations of a particular instrument (such as the harpsichord); on

(5) See also, for example, Warren, Obusek and Ackroff (1972), who played listeners series of faint sounds alternated with louder sounds. The quiet sounds continued unabated in the imaginations of the listeners.

(6) A "constant" is a group of relationships linking a series two values the same (at any level); see Ockelford, 1999, pp. 125ff.

Brahms: Symphony No. 4, Op. 98; 1st Movement

(Allegro non troppo)

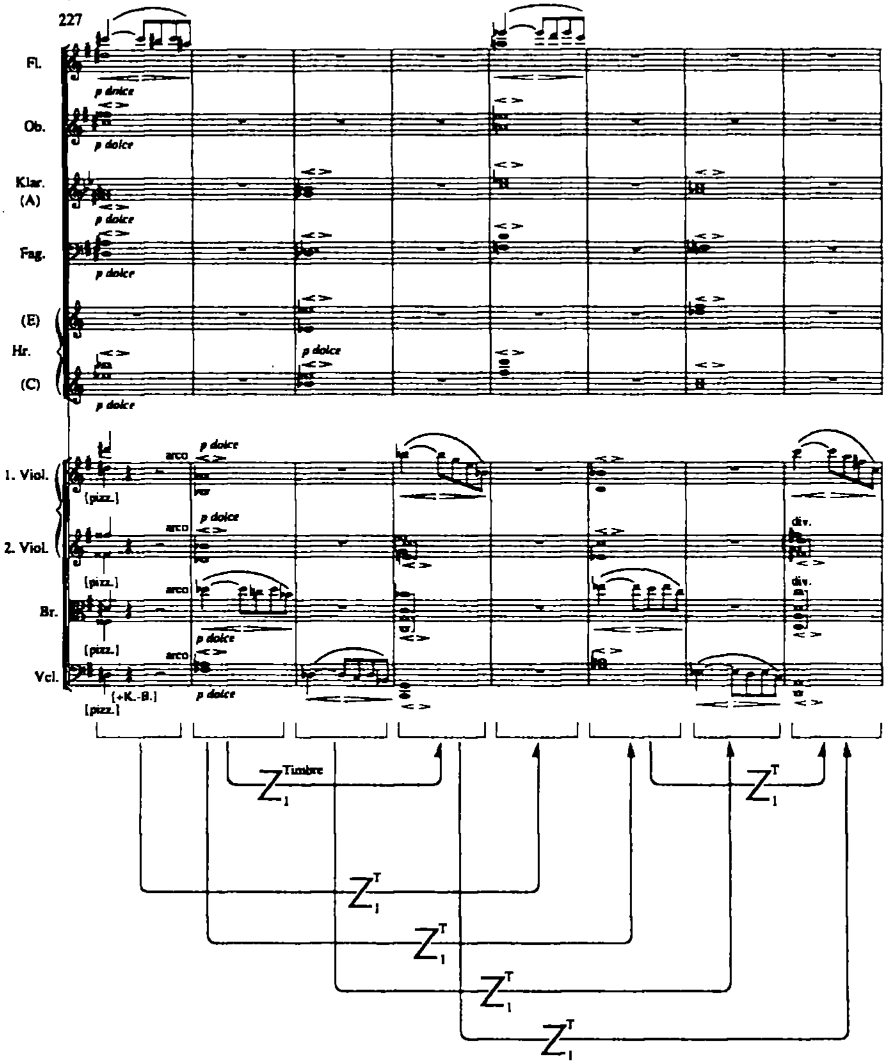


Figure 6.
Series of different timbres repeated in parallel with melody and harmony.

other occasions stylistic forces alone are at work, implying primary zygonic control. Series of dynamics are often repeated in conjunction with the repetition of pitch and rhythm, implying the operation of parallel primary zygonic relationships where this organisation is created or cognised.

In the domain of onset, primary zygons produce the effect of simultaneity. In these circumstances there is no perceived temporal basis for ascertaining which value is the model and which its imitation, since this is typically — though not invariably — determined by the order in which events occur (see Cone, 1987, pp. 249ff). The ordering effect can be given a specific bias only through appropriate contextual implication (Ockelford, 1999, p. 80), which may involve a further zygonic relationship (Figure 7).

Stamitz: Six Duets for Two Violas; II

Andante moderato

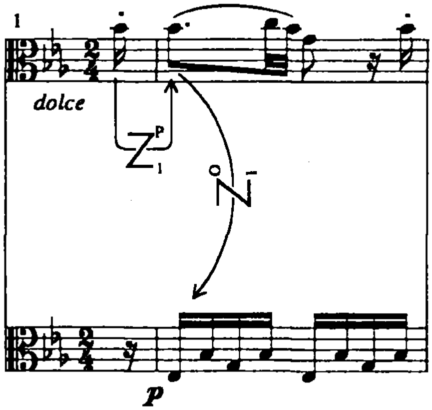


Figure 7.
Example of primary zygon of onset polarised through preceding zygon of pitch.

PATTERN 2A

As we have seen, even a relatively short piece of music bears the potential of billions of non-zygonic secondary relationships linking primaries, but it is unlikely that the great majority of these will attain structural significance. In the absence of empirical data it is difficult to gauge what role, if any, such formulations in the domain of pitch typically play in cognition (see Figure 15), but in the domains of loudness and timbre, things are more clear cut: Pattern 2a does not appear to have been utilised. In the domain of onset, by contrast, secondary differences or ratios between onsets are fundamental to music perception: as Figure 8 (next page) shows, they are the building blocks of rhythm. Hence, they are functionally comparable to *primary* pitch relationships, and are invariably not the only type nor the highest level of relationship that are in operation in coherent musical structures (see comments in relation to Pattern 3e).

Haydn: String Quartet, Op. 20, No. 2; 2nd Movement

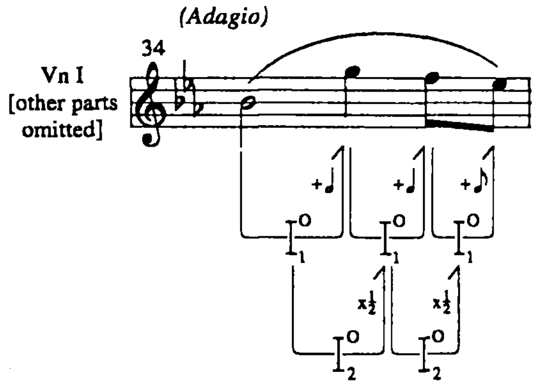


Figure 8.
Secondary ratios of onset — the building blocks of rhythm.

PATTERN 2B

It seems inconceivable, in any perspective domain, that two primary zygons could be linked through a non-zygonic secondary relationship in a way that was structurally significant. Consider, for example, the following pattern of repeated notes in the right hand that opens Haydn's keyboard sonata in B♭, Hob. XVI:2 (Figure 9). Clearly, the second pitch in each pair owes its derivation to the first, and there is a sense in which this very repetition is itself emulated from one pair to another. This implies the operation of secondary zygons (Pattern 2d) however, rather than non-zygonic secondary relationships (Pattern 2b), since the latter scenario would imply that, while the repetition of repetition was cognitively acknowledged, no implicative link was inferred, which would make no sense in music-perceptual terms.

PATTERN 2C

This pattern of relationships is significant in the creation and cognition of structure pertaining to a number of perspects. In the domain of pitch, its fundamental importance is shown by the fact that the melodies remain invariant under transposition. More specifically, the preponderance of similar, small intervals is confirmed by a number of studies, particularly of various Western genres, ranging from folksongs (Dowling, 1978, pp. 351-2), to many styles of classical music (Fucks, 1962) and to popular music of the twentieth century (Jeffries, 1974, p. 904). Ockelford's (1999) analysis of the first movement of Mozart's piano sonata K. 333 shows that 85% of the intervals between successive notes in the melody are unisons, seconds or thirds; major seconds alone account for 39% of all the intervals used, and similar proportions are found in other of Mozart's works (Figure 10, p. 204). This suggests that Pattern 2c will figure in cognition in a number of ways: for example, to inform general expectancy during the first — and any subsequent — hearing of the work (since the distribution of intervals in K. 333 is a broader stylistic trait; see Ockelford, *op. cit.*, p. 736); within a melody, between specific elements — both prospectively and retrospectively — particularly where these are highlighted through parallel ordering in other domains (*cf.* preference rule e); and between repeated melodies or melodic contours.

Haydn: Piano Sonata in B♭, Hob. XVI:2; 1st Movement

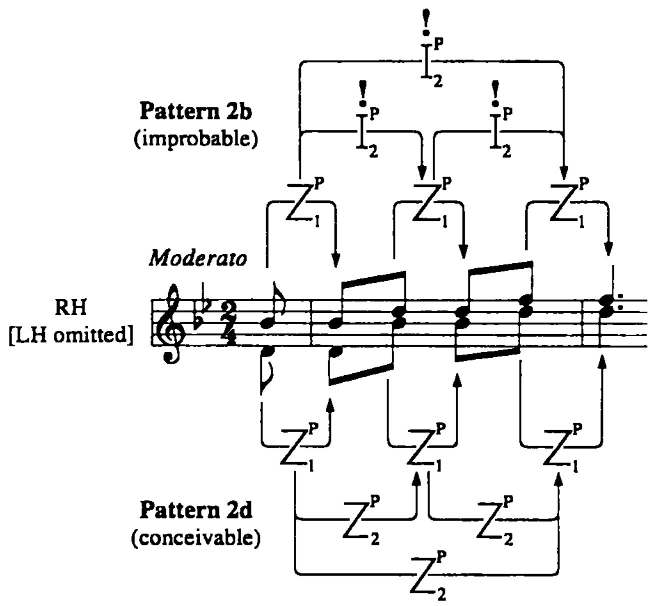


Figure 9.
Primary zygonic relationships linked through secondary zygons (rather than secondary interperspective relationships).

In the domain of loudness, this pattern of relationships is found where a series of dynamics is arranged in regular steps; more commonly, it is implicit in *crescendi* and *dimunendi*, to the extent that these are perceived or reckoned to constitute uniform change (Figure 11, p. 205). The pattern is rarely found in the domain of timbre, but occasionally occurs when the variation is in effect unidimensional as, for example, in the successive addition of mutes in Bartók's *Music for Strings, Percussion and Celesta*, 1st Movement, bars 66ff. The perceived temporal intervals between successive onsets are frequently similar or, very often, the same: in the first movement of K. 333 (Figure 12, p. 205), for example, 78% of inter-onset ratios between successive notes are 1:1 — a feature that is typical of the style (Ockelford, 1999, p. 724). From this we may surmise the extensive operation of Pattern 2c in creating and cognitively modelling perceived temporal structures in music.

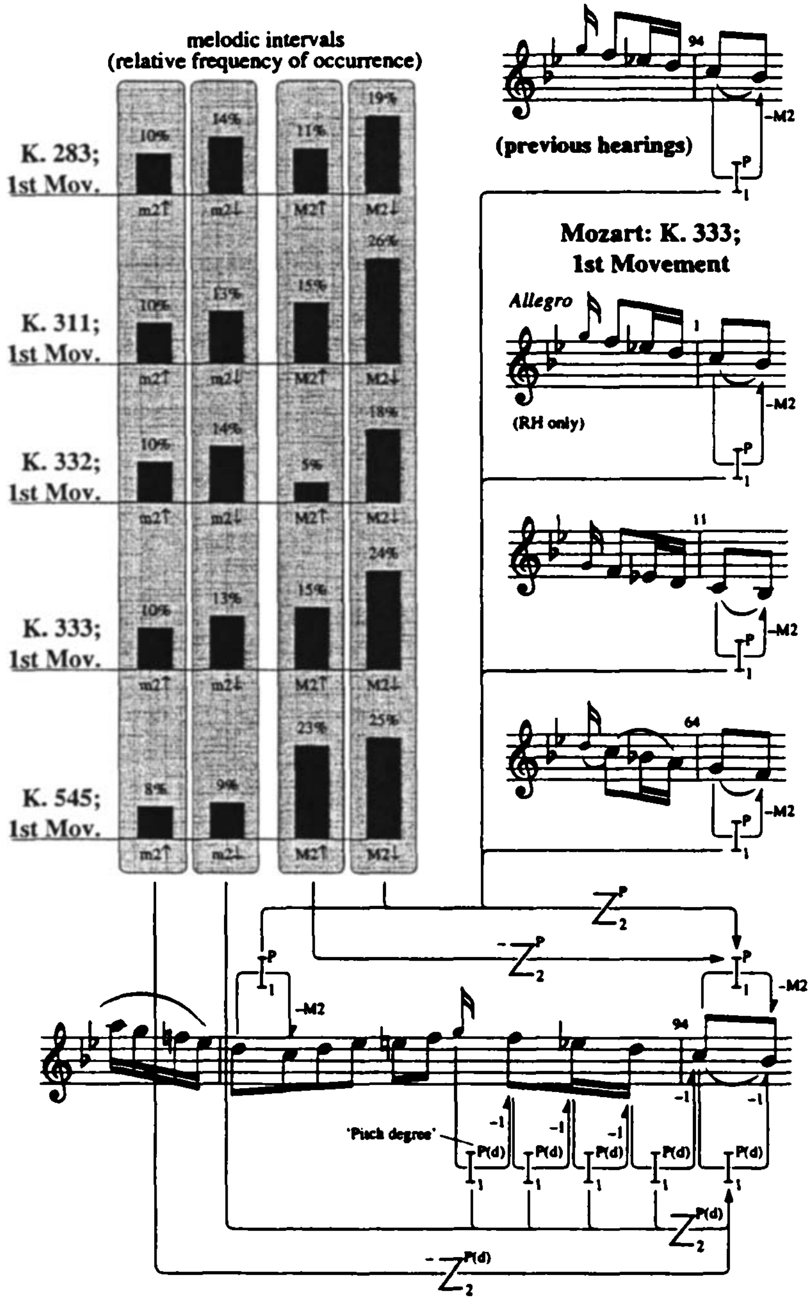


Figure 10.

Secondary zygonic relationships potentially linking primary interperspective relationships in the domain of pitch in a number of contexts: within a melody; between melodic fragments (within the same hearing and between different hearings); and in terms of general stylistic probability.

Mendelssohn: 'Cello Sonata No. 1, Op. 45; 1st Movement

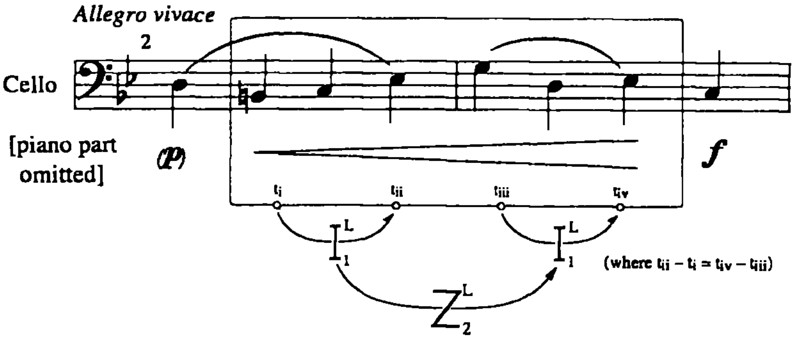


Figure 11.
Pattern 2c operating in the domain of loudness — underlying a crescendo *(assumed to be uniform).*

Mozart: K. 333; 1st Movement

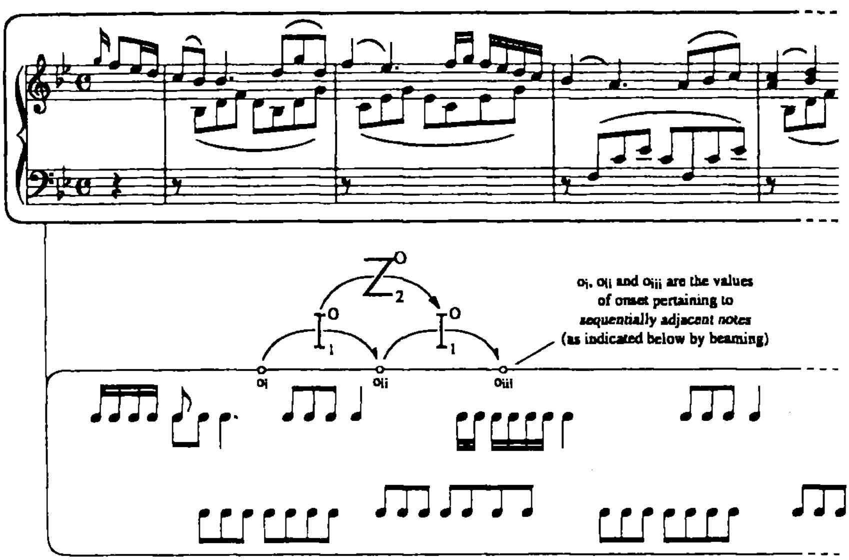


Figure 12.
Pattern 2c functions extensively in the domain of onset; in K. 333, 78% of inter-onset intervals between successive notes are in the ratio 1:1.

PATTERN 2D

The implication of this pattern of relationships is that imitation at the primary level is replicated at the secondary level. This feature is ubiquitous in musical structures; the very orderliness of one thing being reflected in that of another. A common construction in the domain of pitch is shown in Figure 9 (in the context of Pattern 2b); less familiar forms are also possible — in Figure 13, for example, the sheer constancy of one note (in the context of the *portamenti*) may be felt to emulate that of others. The imitation of perspective constancy is often found in the domains of loudness and timbre too, typically coupled with the repetition of pitch and rhythm. With regard to onset, since simultaneity implicates primary zygonic organisation (see the discussion of Pattern 1b above), imitative relationships between chords present instances of Pattern 2d — an effect which can be especially marked where chords alternate with single lines.

Xenakis: *Phlegra* (1975)

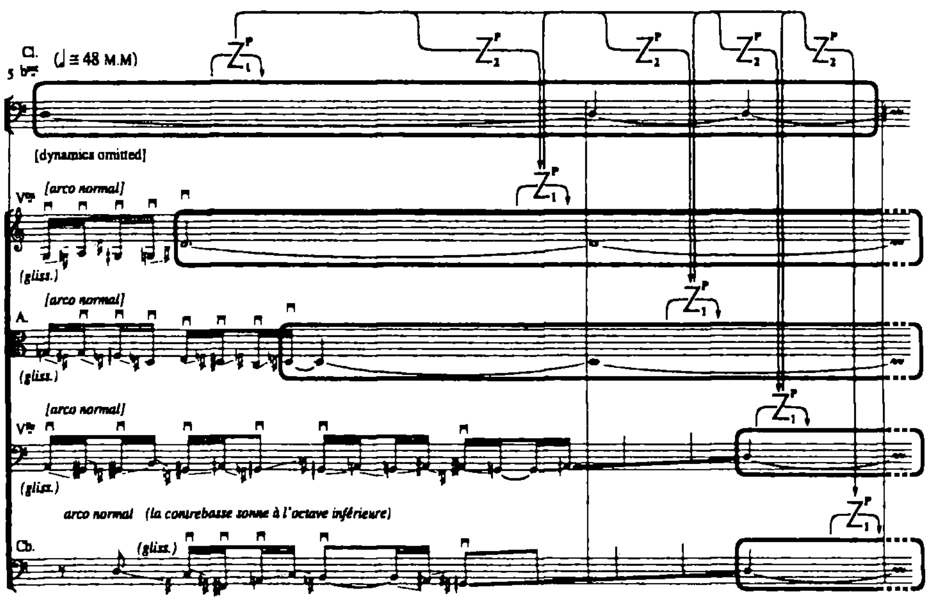


Figure 13.
Constancy of pitch the subject of imitation.

PATTERNS 3A, 3B, 3C, 3D, 3F, 3H

While such patterns of relationships exist in their theoretical quintillions, it appears that none has attained music-structural significance in *any* perspective domain. Significant tertiary relationships may however be found in the case of Patterns 3e and 3g.

PATTERN 3E

This pattern is cognitively significant in the creation and cognition of some forms of organisation in the domain of onset, including *accelerandi* and *ritardandi*, and in structures such as that shown in Figure 14, in which the interval between the onset of the *appoggiatura* and its resolution is doubled on each appearance (for further examples see Ockelford, 1999, pp. 389-92).

Mozart: K. 333; 1st Movement

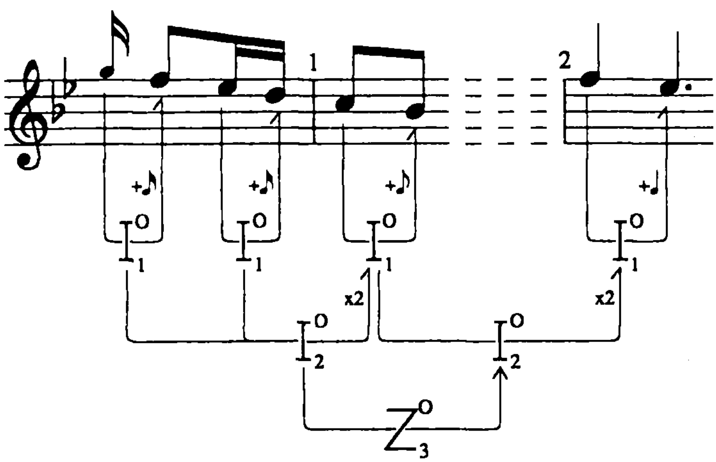
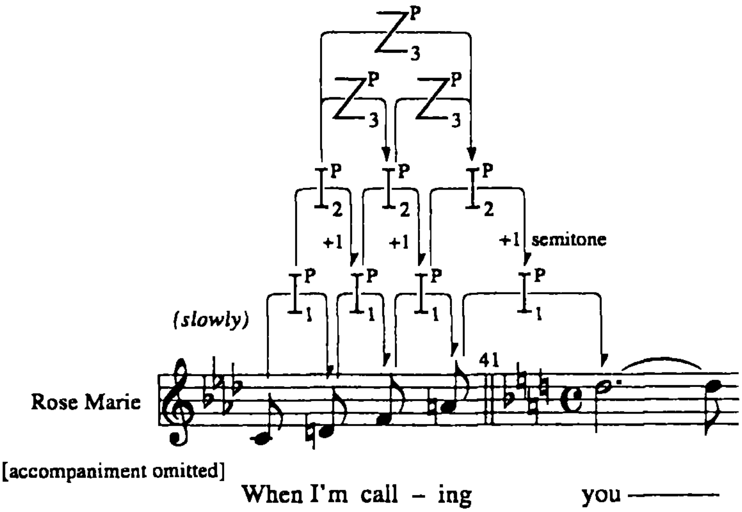


Figure 14.

Pattern 3e functioning in the domain of onset between a series of appoggiaturas, *successively augmented.*

In the domain of pitch, things are less clear cut. Although the occasional potential example can be found, such as the opening of the melody by Friml shown in Figure 15 (*cf.* Ockelford, 1999, p. 517; also cited by Narmour, 2000, p. 364) in which intervals grow successively by a semitone, the perceived effect is likely to be one of general melodic expansion allied to the harmonic series rather than of tertiary zygonic organisation. Such a finding is in accordance with preference rule a) — which suggests that lower levels of relationship will take cognitive precedence over higher. However, having once conceptualised the passage in terms of regular intervallic expansion (and therefore organisation at the tertiary level), it is possible to hear it in this way. That is, Pattern 3e, which in this context would typically be located in Sector 2, could, through conscious reflection, reasonably be deemed to have a place in Sector 3. Finally, note that Pattern 3e appears not to have played in part in the structuring of loudness and timbre.



Friml: *Indian Love Call* from *Rose Marie* (1924)

Figure 15.
Regular intervallic growth potentially ordered through tertiary zygonic relationships — though only through conscious reflection.

PATTERN 3G

This pattern of relationships appears to be relevant only in the domain of onset, where it underlies the prevalence of the ratio 1:1 between successive inter-onset intervals in certain styles (see Figure 12) and, even more generally, is the means through which the very consistency of a regular beat can be considered to be imitated within and between pieces. This is illustrated in Figure 16.

Debussy: *Douze Etudes* (1915); I—*pour les "cinq doigts" (d'après Monsieur Czerny)*

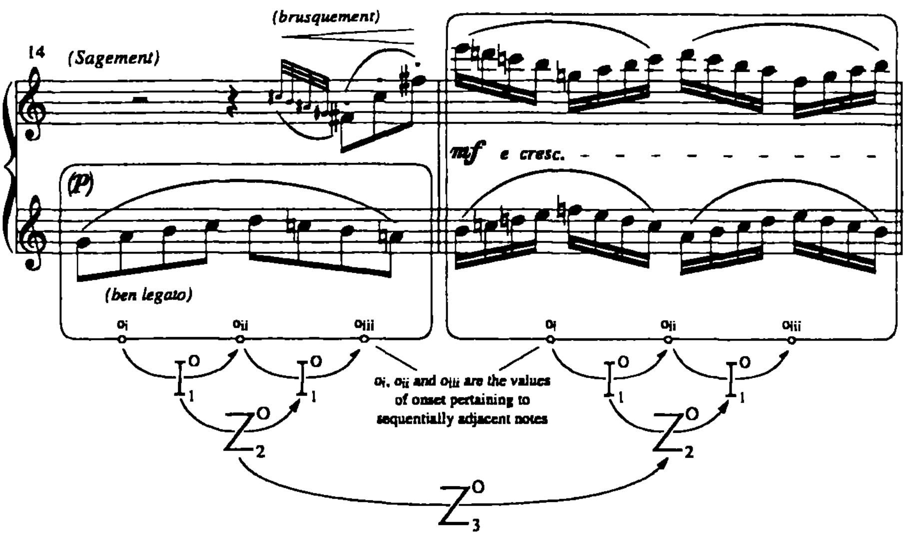


Figure 16.
Pattern 3g functioning in the domain of onset, through which the very regularity of one series of onsets is emulated by that of another.

QUATERNARY RELATIONSHIPS

There appear to be no musical structures in existence whose cognition is reliant on quaternary relationships of any type.

CONCLUSION

In summary, then, the analysis of a number of pieces from the Western classical repertoire (a few examples of which are cited above), suggests that the underlying patterns of relationships occurring in the domains of pitch, onset, loudness and timbre are those shown in Figure 17 (pp. 210-212, where the density of the shading is intended to give some indication of the prevalence of the patterns shown).

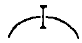
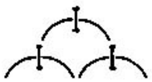
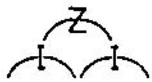
Pattern	**1a** 	**1b** 
General comments	***Perceptual acknowledgement of how one value stands in relation to another.***	***Cognitive acknowledgement that one value exists in imitation of another. This mental act typically occurs intuitively in the course of listening; however, it may be conceptualised in composition or analysis. Music would be inconceivable without the ubiquitous operation of primary zygons in every domain.***
Pitch	Differences in pitch are fundamental building blocks of melody and harmony—found in all music except monotonic chants. Conceptualised in Western classical tradition as 'intervals'. Invariably not the highest level of relationship	Primary zygons play a crucial role in musical structure—from the perceived constancy of notes, to the fact that this domain is typically structured using highly constrained frameworks of pitch and pitch-class. 68% of melodies in the Western classical tradition repeat a pitch-class in the first four notes.
Onset	The perceived temporal intervals between the onsets of discrete sonic events are fundamental to the creation and perception of almost all musical structures.	In the domain of onset, primary zygons produce the effect of perceived simultaneity—fundamental to almost all music comprising more than one part or 'stream' of sound.
Timbre	Differences in timbre are characteristic of some (though not all) music. They are very rarely of intrinsic stuctural significance (and where they are they are invariably not the highest level of relationship active in this domain), typically being used to reinforce the organisation present in the domains of pitch and rhythm.	Constancy of timbre is typical of almost all styles—ranging from entire sets of pieces to short phrases, where constancy is almost invariably used to reinforce organisation in the domains of pitch and rhythm.
Loudness	Differences are found in much (though not all) music. They are hardly ever of intrinsic stuctural significance (and where they are they are invariably not the highest level of relationship active in this domain), but are typically used to reinforce the organisation of pitch and rhythm.	Although dynamic contrast is significant affective component in some styles, successive values of loudness within and between notes are typically perceived to be the same or similar. Extended periods may occur at same dynamic level or within a relatively narrow dynamic envelope.

Figure 17

Summary of the pattern of relationships used in the

Pattern	2a 	2c 	2d 
General comments	***Perceptual acknowledgement of the difference (or ratio) between the differences (or ratios) between perspective values.***	***Cognitive acknowledgement that one interperspective value exists in imitation of another.***	***Cognitive acknowledgement that imitation at the primary level is replicated at the secondary level; a feature that is ubiquitous in musical structures—the very orderliness of one thing being reflected in that of another.***
Pitch	**Empirical work required to ascertain the role this formulation may play in the domain of pitch; examples of potential utilisation indicate tertiary zygonic ordering (Pattern 3e).**	*Of fundamental importance* and ubiquitous: through the widespread distribution of similar intervals; as an essential aspect of coherent melodic and harmonic structure; and between repeated (notably transposed) passages.	*The pattern of relationships* through which the sheer constancy of pitch of one note is felt to exist in imitation of others. Moreover, the fact that repeated pitches are a feature of so many melodies is indicative of its widespread operation.
Onset	Secondary differences or ratios of onset are fundamental to the creation and perception of rhythm: invariably ordered at the tertiary zygonic level (Pattern 3e).	The extensive operation of this pattern in the creation and cognitive modelling of perceived temporal *structures may be surmised*, since inter-onset ratios between successive notes are frequently the same or similar (eg. around 80% 1:1 in Mozart piano sonatas).	*The simultaneity that* characterises the onsets of the notes in many chords indicates the widespread operation of this pattern of relationships in creating and perceiving musical *structures of more than one* part or 'stream' of sound.
Timbre	**[Not found]**	**This pattern is rarely found in the domain of timbre, but occurs occasionally when the differences occur in effect unidimensionally (as with the successive addition or removal of mutes, for example).**	The very constancy of timbre that is characteristic of so many pieces and passages suggests the widespread operation of this pattern of relationships.
Loudness	**[Not found]**	**Implicit in *crescendi* and *diminuendi* (to the extent that these are perceived or reckoned to constitute uniform change).**	The very constancy of loudness that is typical of many pieces and passages suggests *that this pattern of* relationships functions widely in music cognition.

(parts a and b).

domains of pitch, onset, timbre and loudness.

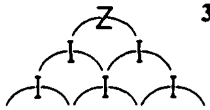
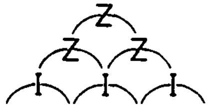
Pattern	 3e	 3g
General comments	***Cognitive acknowledgement of the imitation at tertiary level of secondary differences (or ratios) between primary values.***	***Cognitive acknowledgement of the imitation at tertiary level of secondary imitation between primary differences (or ratios).***
Pitch	**The place of this pattern in the creation and cognition of pitch structures is not clear: while potential examples can be found, imperfect secondary zygonic organisation appears to be a more likely interpretation of the cognitive processing that occurs.**	**[Not found]**
Onset	**Cognitively significant in the creation and recognition of some forms of organisation in the domain of onset, including *accelerandi* and *ritardandi*, and augmentation and diminution.**	This pattern underlies the prevalence of the ratio 1:1 between successive inter-onset intervals in some styles, the means through which the very consistency of regular beats can be considered to be imitated within and between pieces
Timbre	**[Not found]**	**[Not found]**
Loudness	**[Not found]**	**[Not found]**

Figure 17 (part c).
Summary of the pattern of relationships used in the domains of pitch, onset, timbre and loudness.

Clearly, given the methodological limitations of this study, it is reasonable to draw only preliminary conclusions. However, it does appear that composers have (unwittingly) respected limits on the levels and types of interperspective relationship through which musical structures are created — constraints that apparently accord with the perceptual and cognitive processing abilities of most listeners (insofar as music in familiar style intuitively "makes sense" to the majority of people). Thus:

- in the domain of *pitch*, Patterns 1b, 2c and 2d (which utilise primary and secondary zygonic relationships) are fundamental to the creation and cognition of structure;
- in the domain of *onset*, Patterns 1b, 2c, 2d, 3g and, to a lesser extent, 3e (involving primary, secondary and tertiary zygons) are used;
- in the domain of *timbre*, Patterns 1b and 2d (entailing primary and secondary zygonic relationships) predominate, although Pattern 2c is encountered occasionally; and
- in the domain of *loudness*, Patterns 1b, 2c and 2d (utilising primary and secondary zygons) prevail.

Quaternary relationships (and those of higher levels) do not seem to have played a part in the creation or cognition of structure. Hence "2 ± 1" does indeed appear to be a constraint universally respected by composers — and, therefore, by listeners — to date, implying a convergence between Lerdahl's listening and compositional grammars in this respect.

Two subsidiary findings are also worth mentioning. The first is that at any point, the highest level of relationship of music-structural significance appears invariably to be zygonic (were this not the case, the passage or aspects of the passage in question would not be orderly, and would not therefore be coherent or comprehensible to listeners); this explains why non-zygonic relationships are not to be found at the tertiary level. Second, it seems that zygons only "stack two high". That is, secondary zygons may well order primaries, and, occasionally, tertiaries order secondaries, but there appear to be no extant cases of tertiaries ordering secondaries which in turn order primaries. It may be that the cognitive processing demands of such patterns are simply too great.

Many questions remain. For sure, a good deal more work needs to be undertaken on aspects of the theory outlined here; for example, in relation to the "preference rules" which model how the musical mind deals with the plethora of relationships that are of potential structural significance. Again, there is clearly a need to verify or modify the findings presented here through undertaking comparable analyses in other perspective domains, examining further pieces in different styles, and tapping into the musical intuitions of a wide range of people; experiments could also be developed to test, empirically, the hypotheses formulated here through individual reflection. Only then would we be in a position to know with reasonable certainty whether 2 ± 1 does indeed represent an ultimate perceptual or cognitive limit on the levels of relationships that link aspects of the perceived sounds used in music, or whether it is a consequence of the styles that have evolved to date — which could therefore be extended in carefully constructed musical contexts. For example, using electronically synthesised sounds, which hold out the prospect of continuous change in any perspective domain, could the increasing rate at which a perspective value was changing be grasped perceptually, and be compared with other such change (implying the recognition of quaternary zygonic organisation)? Could the capacity for making such judgements be improved through practice? Could the tertiary zygonic control that is occasionally encountered in the domains of pitch and perceived time be extended to, for example, loudness, timbre or perceived location (*cf.* Boulez, 1963/1971, pp. 66ff; Slawson, 1985)? Would it ever be conceivable for zygons to stack for three (or more) levels in a hierarchy of relationships in a music-structurally significant way? Finally, are the issues raised here in the context of music cognition relevant in other arenas (such as the visual perception of changing patterns of motion, for example)? These questions, and others, await the outcome of future research[7].

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Address for correspondence:
Dr Adam Ockelford
Visiting Research Fellow
Centre for International Research in Music Education
University of Surrey Roehampton
64a Princes Way
Wimbledon Park
London SW19 6JF
Phone: +44-(0)20 7391 2149 / +44-(0)20 8789 1816
e-mail: adam.ockelford@rnib.org.uk

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• El número mágico 2, más o menos uno: algunos límites sobre nuestra capacidad para procesar información musical

Como todos los campos del esfuerzo artístico humano, la música es constreñida por los requerimientos y limitaciones de nuestro proceso cognitivo. (Swain, 1986; Lerdahl, 1988; Huron, 2001). Este artículo considera algunas formas particulares de constricción teniendo en cuenta las relaciones que la estructura de búsqueda mental (subconsciente) fabrica entre eventos musicales percibidos. Se propone que 2±1 *puede ser una limitación universal relacionada con el nivel de relaciones*. En términos de la propuesta teorética de Lewin (1987), en la cual los "intervalos" pueden ser intuidos entre los "elementos" de "espacios" musicales, se propone que la cognición de la estructura musical se desarrolla bien a través de intervalos (nivel 1), a través de intervalos entre éstos (nivel 2), o – en ciertas circunstancias – a través de intervalos entre éstos (nivel 3). Esta propuesta es explorada a través del modelo psicomusical desarrollado por Ockelford (1991, 1993, 1999), que también analiza la estructura musical en términos de relaciones que pueden ser consignadas entre sus componentes perceptivos discretos. En particular, este modelo identifica un tipo de enlace cognitivo a través del cual los eventos (de cualquier nivel) se sienten como implicación de otros, los mismos o similares, también llamados relaciones "zygónicas". Esta teoría sugiere un principio general que va más allá: que el nivel más alto de relación de operación en cualquier punto dado debe ser *zygónico si la música es estructuralmente coherente*. La evidencia de esto y del límite del nivel de relaciones de 2±1 se ofrece a través de una serie de ejemplos musicales que ilustran una variedad de organización musical en acción. Finalmente, el trabajo empírico sugiere llevar a cabo una exploración más profunda de las ideas teóricas aquí presentadas.

• Il magico numero due, più o meno uno: alcuni limiti della nostra capacità di elaborare l'informazione musicale

Come tutti i campi dell'umano sforzo artistico, la musica è vincolata dalle esigenze e dai limiti dei nostri processi cognitivi (Swain, 1986; Lerdahl, 1988; Huron, 2001). Il presente articolo prende in considerazione particolari forme di limitazione attinenti alle relazioni che la mente bisognosa di struttura costruisce (subconsciamente) fra due eventi musicali percepiti. Si propone che 2±1 possa costituire una limitazione universale attinente al *livello* delle relazioni così ideate. Ossia, nei termini del quadro teorico di Lewin (1987), secondo il quale gli "intervalli" si possono intuire fra gli "elementi" dello "spazio" musicale, poniamo che la cognizione della struttura musicale avvenga mediante intervalli (livello 1), mediante gli intervalli fra questi intervalli (livello 2), oppure — in alcune circostanze — mediante gli intervalli fra *questi ultimi* intervalli (livello 3). Tale asserzione viene esaminata con l'ausilio del modello psicomusicologico sviluppato da Ockelford (1991, 1993, 1999), il quale analizza a sua volta la struttura musicale in termini di relazioni che possono venire riconosciute fra le sue componenti percettive discrete. In particolare, il modello identifica un tipo di collegamento

cognitivo mediante il quale gli eventi (a qualsiasi livello) sembrano implicarne altri uguali o simili — tramite relazioni cosiddette "zigoniche". Questa teoria conduce ad un ulteriore principio generale: il massimo livello di relazione operativa in un qualsiasi punto dato dev'essere zigonico se la musica vuole essere strutturalmente coerente. Una prova a favore di questo, nonché del limite di 2±1 nel livello delle relazioni, viene offerta da una serie di esempi musicali che illustrano una varietà di organizzazioni musicali in atto. Infine, si suggerisce alla ricerca empirica di esplorare ulteriormente le idee teoriche qui presentate.

• Le nombre magique deux, plus ou moins un : de quelques limites de notre capacité à traiter l'information musicale

Comme tous les domaines de l'activité artistique humaine, la musique souffre des exigences et des limites de notre traitement cognitif (Swain, 1986; Lerdahl, 1988; Huron, 2001). On étudie ici les formes particulières de contrainte inhérentes aux relations que le mental, à la recherche d'une structure, tisse (subconsciemment) entre les informations musicales perçues. A notre sens, 2±1 pourrait être la limite universelle du niveau des relations ainsi mises en œuvre. Autrement dit, en se plaçant sous l'angle du cadre théorique de Lewin (1987) où des "intervalles" peuvent être intuitivement placés entre les "éléments" des "espaces" musicaux, on postule que la cognition de la structure musicale est dérivée des intervalles (niveau 1) ou des intervalles entre ces intervalles (niveau 2), voire — dans certaines circonstances — des intervalles entre *ces derniers* (niveau 3). Cette hypothèse est explorée à l'aide du modèle psychomusicologique développé par Ockelford (1991, 1993, 1999), où la structure musicale est également analysée sur la base des relations dont la cognition se forge entre les composants perceptifs discrets. Autrement dit, le modèle identifie un type de lien cognitif qui conduit à percevoir des manifestations (à quelque niveau que ce soit) comme étant à l'origine d'autres manifestations, identiques ou similaires — par le biais des relations dites "zygoniques". Cette théorie fait l'hypothèse d'un autre principe général : pour qu'il y ait cohérence structurelle en musique, il faut que, en quelque point donné que ce soit, le niveau de relation le plus élevé mis en œuvre soit zygonique. Cette hypothèse, comme la limite du niveau des relations de 2±1, est étayée par une série d'exemples musicaux illustrant diverses organisations musicales en action. On propose ensuite une recherche empirique afin d'approfondir les idées théoriques présentées ici.

• Die magische Zahl 2 plus oder minus 1: Grenzen der Verarbeitungskapazität von Musik

Wie alle Bereiche menschlichen künstlerischen Tuns unterliegt auch Musik den Bedingungen und Beschränkungen unserer kognitiven Verarbeitung (Swain, 1986; Lerdahl, 1988; Huron, 2001). Dieser Beitrag betrachtet besondere Formen der Zwänge bei der Beziehungsbildung zwischen wahrgenommenen musikalischen

Ereignissen im Rahmen der (unterbewußten) Struktursuche. Es wird an eine Beziehungsebene gedacht, in welcher 2±1 eine universelle Begrenzung sein könnte; d. h. es wird entsprechend der Theorie von Lewin (1987), nach der "Intervalle" zwischen den "Elementen" musikalischer "Räume" erlebt werden *können, postuliert, daß die Kognition von musikalischer Struktur durch* Intervallbildung entweder auf zwei oder (unter bestimmten Umständen) auf drei Ebenen abläuft. Diese Annahme wird mit dem musikpsychologischen Modell von Ockelford (1991, 1993, 1999) untersucht, welches ebenfalls musikalische Strukturen auf der Basis der Beziehungen analysiert, die zwischen den diskreten strukturellen Wahrnehmungskomponenten erkannt werden können. Im einzelnen identifiziert das Modell eine Art kognitiven Link, wodurch gefühlt wird, daß Ereignisse (auf jeder Ebene) durch zygonische Beziehungen einen Bezug auf andere gleich oder ähnlich erscheinende Ereignisse herstellen. Diese Theorie nimmt ein weiteres allgemeines Prinzip an, nämlich daß der höchste Beziehungsgrad an jedem Punkt der Operation zygonisch sein muß, wenn die Musik strukturell kohärent sein soll. Hinweise hierfür sowie für die Grenze auf der Ebene der 2±1-Beziehungen werden durch eine Reihe von Musikbeispielen geboten, welche das Wirken einer Vielfalt musikalischer Organisation illustriert. Abschließend werden empirische Untersuchungen vorgeschlagen, um die hier vorgestellten theoretischen Ideen weiter zu untersuchen.