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Society for Education, Music and Psychology Research

Article

Psychology of Music
41(2) 139–174

DOI: 10.1177/0305735612442582
pom.sagepub.com
SAGE

Musical expectancy in atonal contexts: Musicians' perception of "antistructure"

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Abstract

Two exploratory studies examine how 12-tone rows are processed cognitively. Tone-rows use each pitch-class once, and were devised by the composer Arnold Schoenberg as a way of structuring music in the absence of tonality, an approach subsequently known as "serialism". One form of "antistructure" implied in the design of tone-rows – eschewal of pitch repetition – is explored using the "probe-tone" method, where subjects rate how well a pitch stimulus fits in a given context. The results support the finding of Krumhansl, Sandell and Sergeant that listeners can detect – and come to expect – the avoidance of pitch repetition. This cognitive strategy is modelled using Ockelford's "zygonic" theory of music-structural understanding. A further study examines the second form "antistructure" implicit in serialist thinking (though not always adhered to in practice): the avoidance of patterns of intervals that give rise to a sense of key in suitably encultured listeners. Here, the discrepancies between the outputs of the zygonic model and the probe-tone ratings suggest that, despite the structural atonality, tonal schemata may also feature in the listening experience. These are evaluated using supplementary data gathered in a task where subjects were asked to identify potential "tonal flecks" in tone-row segments.

Keywords

cognition, expectation, probe-tone, serial music, structure, zygonic

Introduction

Zygonic theory and antistructure

The notion of "antistructure" in music was posited by Adam Ockelford in the first main exposition of his "zygonic" theory (Ockelford, 1993). This asserts that musical structure stems

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from a sense of derivation, whereby musical elements, whatever their perceptual domain, are (typically nonconsciously) heard as existing in imitation of another or others. The relationships – hypothesized cognitive constructs – through which such derivation is held to occur are said to be "zygonic" (from the Greek word for "yoke," implying the union of two similar things). "Zygons" constitute a special type of "interperspective relationship," through which perceived aspects or "perspects" of musical sounds are compared. The perspects pertaining to individual notes include pitch, scale-degree, onset, duration, loudness, and timbre. Intersperspective relationships can be represented parsimoniously in graphical form as shown in Figure 1.1

The proposition of "antistructure" is this: just as a given musical event has the quality of being what it *is*, since in perceptual terms the event comprises a set of features that can exist in a number of potential states, the event also has the quality of being what it *is not*. It is postulated that this quality of *not being* may also be imitated, thereby forming what may be termed "antistructure" (Ockelford, 1993, p. 101). This is not the *absence* of structure, but, rather, its *obverse*, or opposite.

Examples from western classical music – in the domain of timbre – are to be found in those concerti where composers have consciously omitted the soloist's sound from the main body of players. For instance, Richard Strauss's *Oboe Concerto* (1945) uses a small orchestra of two flutes, cor anglais, two clarinets in B♭, two bassoons, two horns in F, violins, violas, 'celli and basses. In the context of the concerto, the tone colours of these instruments are united in sharing the quality *not being* an oboe. Hence they are linked *anti*structurally. This notion can be represented schematically as follows (see Figure 2; cf. Ockelford, 1993, p. 49).

According to Ockelford's (2005) analysis, an example of antistructure in the domain of pitch occurs in the first of Arnold Schoenberg's *Drei Klavierstücke*, Op. 11. In the opening section ('Mäßige', bars 1–11), all pitch-classes are used except E♭. However, this value is particularly prominent in the first melodic gesture of the section that follows ("viel schneller," bars 12ff.), forming the lowest note in the texture up to that point, and providing the springboard from which a new, rapidly ascending, arpeggiated figure is launched. Arguably, then, this first appearance of the E♭ pitch-class adds to the sense that "here is something different."

The ontological status of antistructure

For music theorists, propositions such as these are, at least in principle, unproblematic. They would consider it reasonable to argue that the reading of the first Klavierstück shown in Figure 3 may act as an "ear-opener" (Dubiel, 1999, p. 274), pointing listeners towards an antistructural feature (that is, pitch-classes in the first section sharing the quality of not being E♭) that subsequently assumes structural significance in Section 2 (through an E♭ in the second octave being repeated in the bass).

For music *psychologists*, however, concerned more with "typical" listeners (rather than individuals with a high degree of expertise or score-specific knowledge – see, for example, Margulis, 2005, pp. 334 and 335), the value of observations like these is less clear. For them, the significant issue is likely to be whether the identified "antistructure" has any perceptual (albeit nonconscious) reality. The challenges of testing conjectures of this kind empirically lie at the heart of this article, and are considered in some detail below.

There is a third perspective that *musicologists* may wish to take into account: that of the composer. What were Schoenberg's intentions in relation to this aspect the piece? While there is no documentary evidence that he fashioned Op. 11, No. 1 with the initial omission of the E♭ in mind, it may have been a feature of his thinking, though the antistructural procedure

Figure 1. Examples of interperspective and zygonic relationships

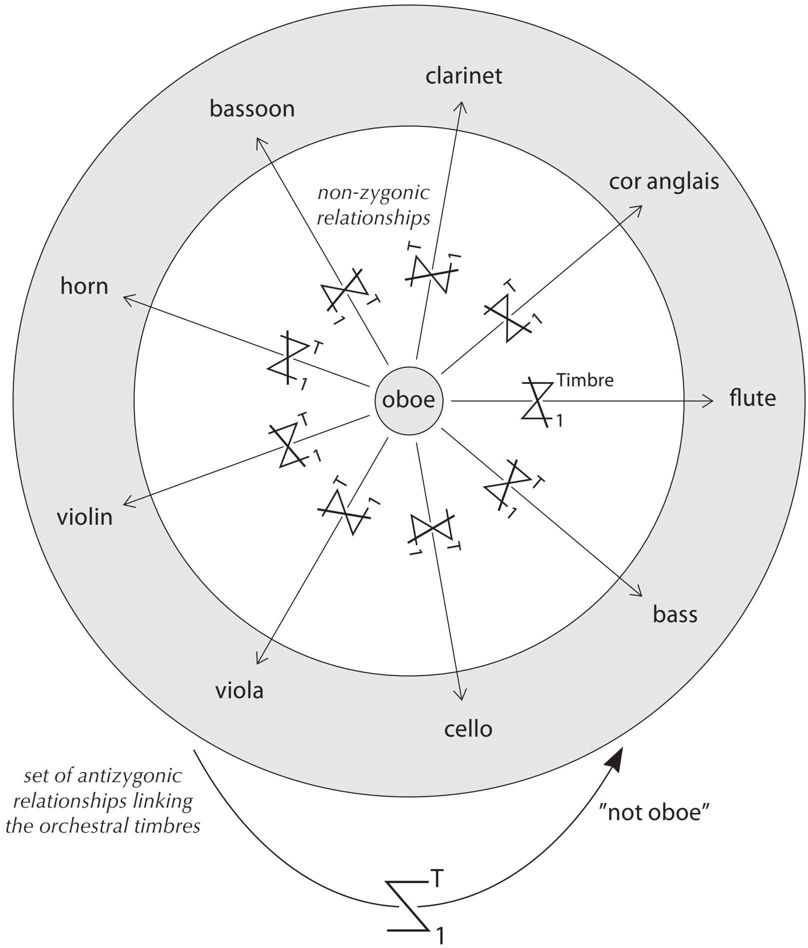


Figure 2. Example of antistructure in the domain of timbre in Strauss's Oboe Concerto

identified here arguably foreshadows the principle of avoiding of pitch-class recurrence that characterized the composer's subsequent "serial" writing (Schoenberg, 1948/1975, p. 247).

In summary, then, though the ontological status of the antistructure we identify in the first *Klavierstück* is unclear (see Figure 4), it is also non-contentious: Ockelford's (2005) analysis highlights a feature that makes no general claim to be part of listeners' conceptual awareness (though it could conceivably exert a subliminal effect).

Serialism, atonality[2] and antistructure – the perspectives of composers, theorists and music psychologists

However, there are other instances of antistructure whose ontological status is a matter of some debate; for example, the property of tone-rows that no pitch-class may be repeated until all 12 have been presented, as described above. Schoenberg's position is this (1948/1975, p. 246):

Figure 3. Antistructure purported to operate in the domain of pitch in Schoenberg's first *Klavierstück*, Op. 11

> The construction of a basic set of twelve tones derives from the intention to postpone the repetition of every tone as long as possible … [since] the emphasis given to a tone by a premature repetition is capable of heightening it to the rank of a tonic. But the regular application of a set of twelve tones emphasizes all the other tones in the same manner, thus depriving one single tone of the privilege of supremacy.

From the *composer's* point of view, zygonic analysis shows how this antistructural rule unfolds as a (synthetic) row is (re)created (Figure 5).

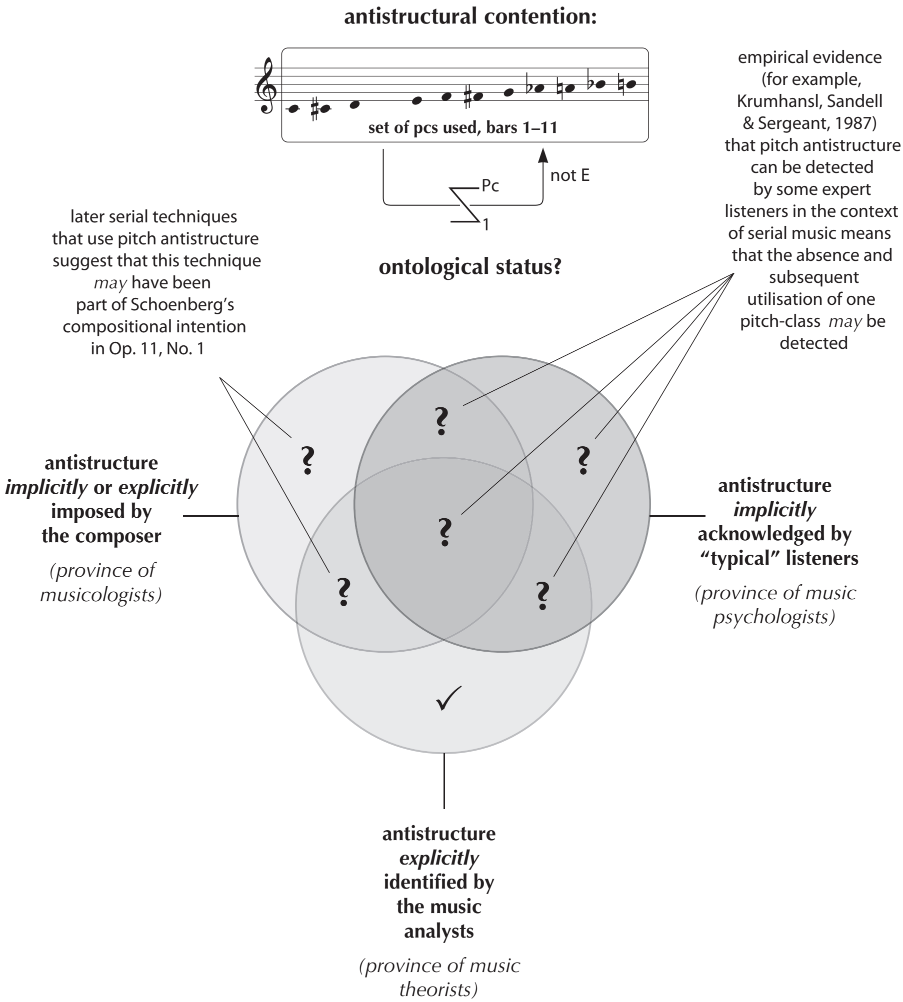


Figure 4. The ontological status of the pitch-class antistructure postulated to exist in the opening section of Schoenberg's Op. 11, No. 1

There is a further implication in Schoenberg's remarks: that, by having a sequence of musical events that advances antistructurally – through avoiding the reiteration of any pitch-class – the impression of tonal hierarchy is avoided. As we shall see, though, this is not actually the case: the repetition of notes is neither necessary nor sufficient for the tonally encultured ear to assign a series of pitches to a probabilistically weighted intervallic framework.

The verity of such assumptions aside, there can be little doubt that Schoenberg intended the compositional principles encapsulated in serialism to be detected by listeners; for example, two decades after the appearance of his first serial compositions, he endorsed the possibility of digression from the sequential order of a 12-tone series "in the later part of a work, *when the set had already become familiar to the ear*" (italics added; Schoenberg, 1941/1975, p. 226). His view of just what type of people such listeners were likely to be seemed to vary, however. For instance,

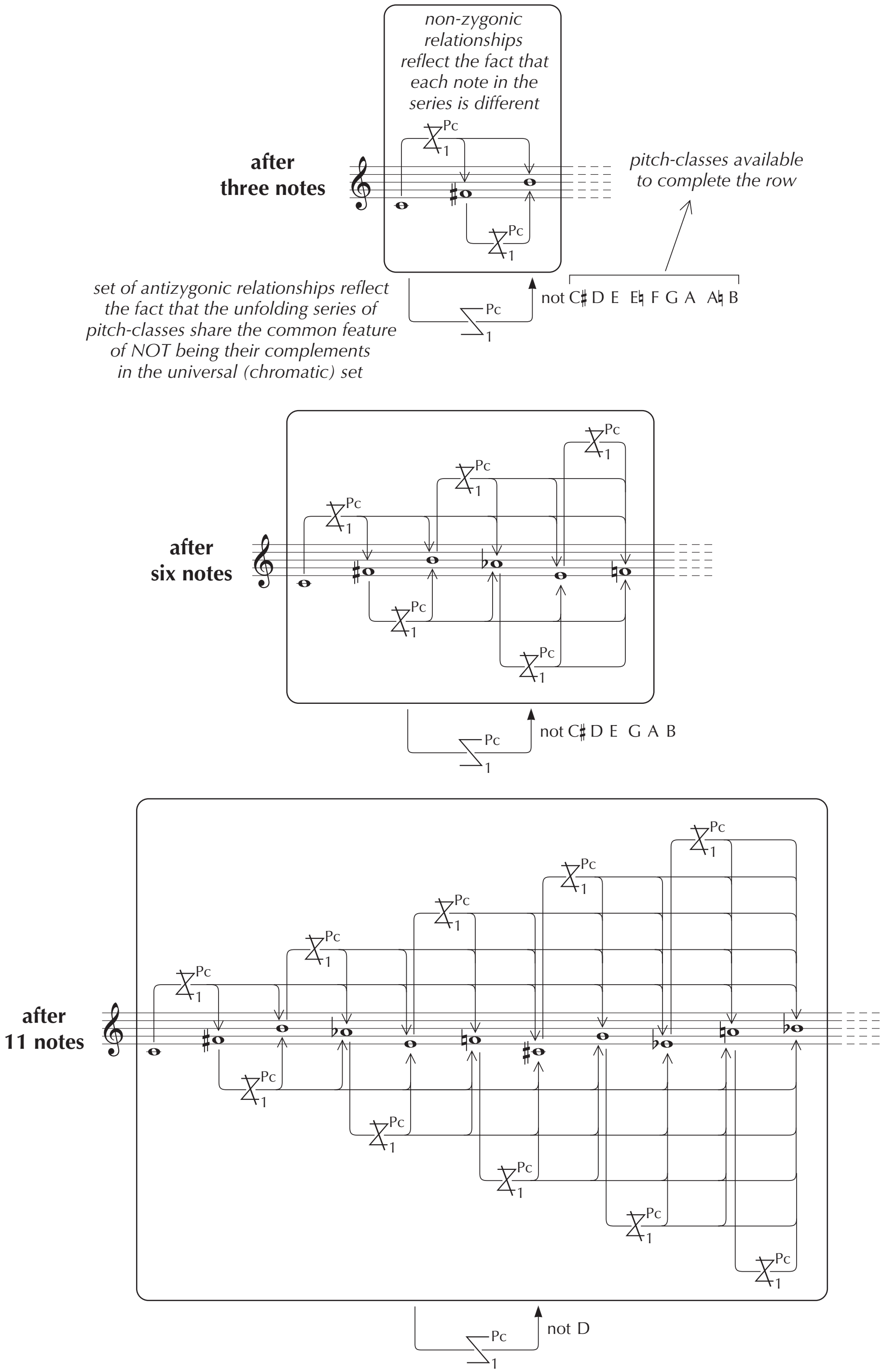


Figure 5. The non-zygonic and antizygonic relationships implied in the unfolding structure of a 12-tone row

in 1947, he wrote to the conductor Hans Rosbaud that an understanding of his music "*still* goes on suffering from the fact that the musicians do not regard me as a normal, common-or-garden composer ... but as a modern dissonant twelve-note experimenter." However, "there is nothing I long for more intensely ... than to be taken for a better sort of Tchaikovsky – for heaven's sake: a bit better, but really that's all. Or if anything more, then that people should know my tunes and whistle them" (Schoenberg, 1947/1987, p. 243). Only a year earlier, though, it had been the elitist in him that had come to the fore: "if it is art, it is not for all, and if it is for all, it is not art" (Schoenberg, 1946/1975, p. 124).

Still, the principles of serialism were taken up – in distinctive ways – by a number of other composers, including Alban Berg, Anton Webern, Ernst Krenek, Luigi Dallapiccola, Luigi Nono, Roger Sessions, Milton Babbitt, Olivier Messiaen, Igor Stravinsky, Karlheinz Stockhausen and Pierre Boulez. And, through the work of academics such as Allen Forte (1973), Schoenberg's ideas gave rise to a new branch of music theory ("set-theoretical analysis"), whose initial aim was to describe and explain the pitch structures of atonal music (Dunsby, 1998). This mathematical approach borrowed several propositions from serialist thinking, including the assumed equivalence of pitches transposed at the octave, the correspondence of intervals related through inversion, and the notion of "complementarity" (the idea that a privileged relationship exists between those pitch classes present in a given set and those that are *not* members), which, in terms of the thinking presented in this article, offers a compelling instantiation of the antistructural principle (cf. Figure 5).

In the late 1950s, Robert Francès (1958/1988, pp. 122–127) sought to ascertain whether listeners could continue to identify a series when it was subject to the isomorphic transformations characteristic of the 12-tone approach (inversion, retrogression, and retrograde inversion; see Schoenberg, 1941/1975, p. 225). His findings were clear, that "serial unity lies more on the conceptual than on the perceptual level," and that "when thwarted by melodic motion, rhythm, and the harmonic grouping of tones, it remains very difficult to hear" (Francès, 1958/1988, pp. 126 and 127). In Fred Lerdahl's terms (1988, pp. 233–237), serialism constitutes an "artificial" compositional grammar rather than a "natural" one, which listeners of a shared culture can intuitively comprehend. Or, to extend the set analogy presented in Figure 4, the connection between the *explicit* structures consciously imposed by composers and deciphered by analysts with the assistance of visual resources (scores), and the *implicit* musical organization that mere auditory exposure enables listeners to grasp, is fragile.

Other studies followed, including those by Christiaan de Lannoy (1972), which explored the detection and discrimination of dodecaphonic series; Cheryl Bruner (1984), which tested the perceptual reality of Robert Morris's (1979–80) similarity index of pitch-class sets; and Don Gibson (1993), which examined the effects of pitch and pitch-class content on the aural perception of dissimilarity in complementary hexachords. None of these enquiries found that listeners – even those with a high level of music education – had the capacity to hear the theoretical structures concerned. However, an investigation by Carol Krumhansl, Gregory Sandell and Desmond Sergeant (1987) *did* find evidence of antistructural perception in 12-tone-rows among expert listeners who had received intensive training to become familiar with the materials that were used.

Listeners were exposed to sequences of 3, 6, 9, or 12 tones from Schoenberg's Opp. 26 and 37, and were asked to rate how well a "probe tone" (Krumhansl & Kessler, 1982; Krumhansl & Shepard, 1979) fitted, "in the musical sense of the atonal idiom, with the series that preceded it" (Krumhansl et al., 1987, p. 41). Four experiments were conducted in total. The first used partial or complete statements of the rows in isometric form, presented as series of "Shepard" tones (Shepard, 1964). In the fourth study, the rows' original compositional properties were restored. The second and third tests, which employed the same two (artificial and natural) conditions, were designed to gauge listeners' ability to process row transformations (inversion, retrogression, and retrograde inversion). On the basis of the results that were obtained, the researchers classified their subjects into two groups, which exhibited diametrically opposed patterns of response. Within groups, however, there was strong intersubject agreement, which was taken as further justification of the binary categorization. Information from a musical background questionnaire showed that the listeners in Group 1 "tended to have more academic training in music and more experience with atonal music, in particular, than Group 2" (Krumhansl et al., 1987, p. 49).

Two findings are of particular interest in the current context. First is the sensitivity of listeners to recency effects – but in opposite ways. Group 1's probe-tone ratings favoured pitch-classes that were *not* present in the stimulus, with particularly *low* ratings being assigned to those values that had just been heard. In contrast, Group 2's ratings showed a *preference* for the most recently sounded tones that were contextually prominent, through having been sounded more recently, for example. Second, is listeners' sensitivity to the possible tonal implications in the series. For example, Krumhansl et al. (1987) suggest that the prime form of the row that Schoenberg used in his fourth string quartet has the potential tonal trichords shown in Figure 6.

For Group 2, these local key implications had a positive effect on their ratings (albeit a weak one). In Group 1, listeners tended to respond systematically in a manner that may be termed "contra-tonal" (Huron, 1992), in that they preferred tones that were tonally remote from the implied key. That is to say, Group 1 perceived the antistructure implied in 12-tone rows (see Figure 5), in which successive tones are constrained by non-recurrence. But they also seemed to *extend* this principle into the realm of atonality by preferring continuations that were *other than* confirmatory of a tonal centre. Group 2, on the other hand, "missed the antistructural point" and perceived tonal "solutions" when these were available.

The current investigation

The availability of new data

Following his collaboration with Krumhansl and Sandell, Sergeant designed and ran a subsequent series of nine experiments (2012, in preparation), which again used the probe tone approach to test the perceptibility of various aspects of Schoenberg's serial techniques further, including the "verticalization" of "horizontal" lines (and vice versa), the notion of "octave equivalence," and the effects of the cyclical rotation of pitch series against repetition of

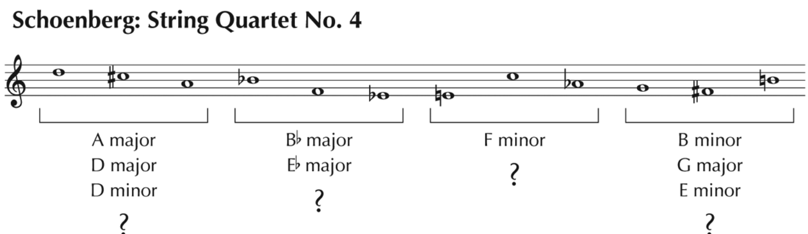


Figure 6. Local tonal implications in the prime form of the tone-row used in Schoenberg's String Quartet No. 1, after Krumhansl et al., 1987

rhythmic features. As well as providing additional evidence of the perceptual challenges that these procedures pose for listeners, the experiments also offer more empirical data that potentially shed light on the apprehension of antistructure – both in relation to the avoidance of pitch repetition ("not R," written "¬R" and the absence of implied tonal function "not T," written "¬T").[3] It is these two effects that are analysed here.

Hypotheses

First, we consider the ways in which listeners may have reacted in relation to ¬R and ¬T. In this regard, their expectations "*e*," as gauged via the probe tone technique, would have derived from the way in which these two elements were cognized "*c*." That is to say, if a listener detected both forms of antistructure in judging which pitch was likely to follow next – and given that "∗" represents an undetermined interrelational function – then:

1. $$e\,(\mathrm{S}) \leftarrow c\,(\neg \mathrm{R} * \neg \mathrm{T})$$

This reads, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition of NOT pitch repetition (¬R) and NOT implied tonal function (¬T)."

This scenario is not the only possibility, however, as the listeners in Group 2 of Krumhansl et al.'s (1997) study indicate. Here, expectations were based on repetition "R" and tonal implication "T" as structural forces. That is:

2. $$e\,(\mathrm{S}) \leftarrow c\,(\mathrm{R} * \mathrm{T})$$

This reads, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition of pitch repetition (R) and implied tonal function (T)."

Extending this principle, it is theoretically conceivable that a listener may detect antistructure of one type but not another – that is, tonal function but not repetition,

3. $$e\,(\mathrm{S}) \leftarrow c\,(\neg \mathrm{R} * \mathrm{T})$$

or repetition but not tonal function:

4. $$e\,(\mathrm{S}) \leftarrow c\,(\mathrm{R} * \neg \mathrm{T})$$

Hence, given a set of probe-tone data from a 12-tone series, we postulate that

5. $$e\,(\mathrm{S}) \leftarrow c\,((\neg \mathrm{R} \text{ or } \mathrm{R}) * (\neg \mathrm{T} \text{ or } \mathrm{T}))$$

or, "expectations (*e*) pertaining at the end of a 12-tone series (S) derive from (←) an unspecified interaction (∗) between the cognition of NOT pitch repetition (¬R) or repetition (R) or NOT implied tonal function (¬T) or tonal function (T)."

But how can we disaggregate the potential influence of the four factors *c* (R), *c* (¬R), *c* (T) and *c* (¬T), since the nature of any interaction between them is unknown? To put it another way: given a set of expectational data pertaining to a series, it would not be possible to assign cause and

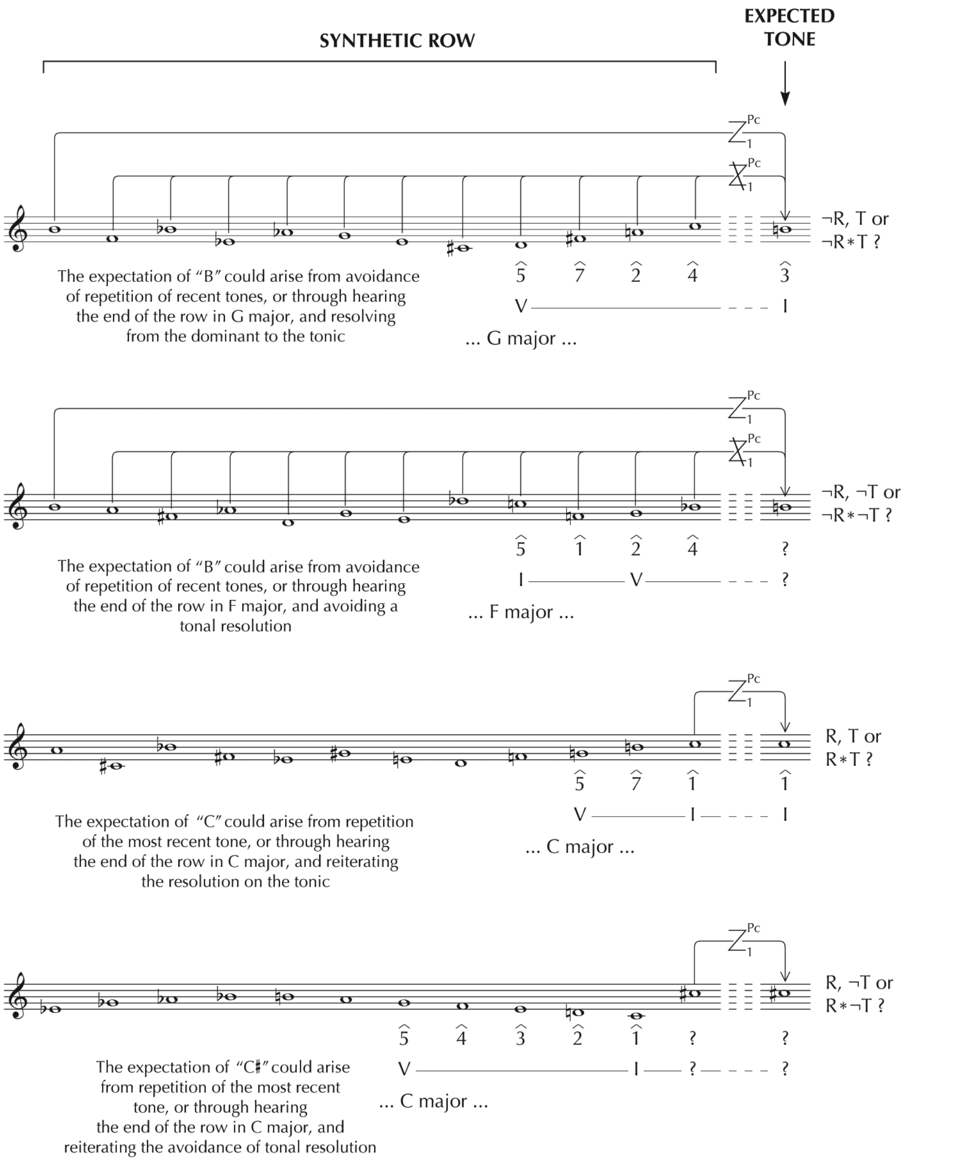


Figure 7. Ambiguity in the structural (R or T) or antistructural (¬R or ¬T) derivation of tones following a 12-tone row

effect to the separate antistructural elements, as a single outcome may result from different combinations of R, ¬R, T and ¬T. See, for example, the hypothetical examples shown in Figure 7.

However, given data from a number of different rows, it may be possible to gauge the distinct impact of R, ¬R, T, and ¬T, because, it is suggested, the avoidance of pitch repetition in some sense represents a "deeper structure" that operates consistently throughout all series, whereas implied tonal functions tend to exist as fleeting and idiosyncratic "surface perturbations." That

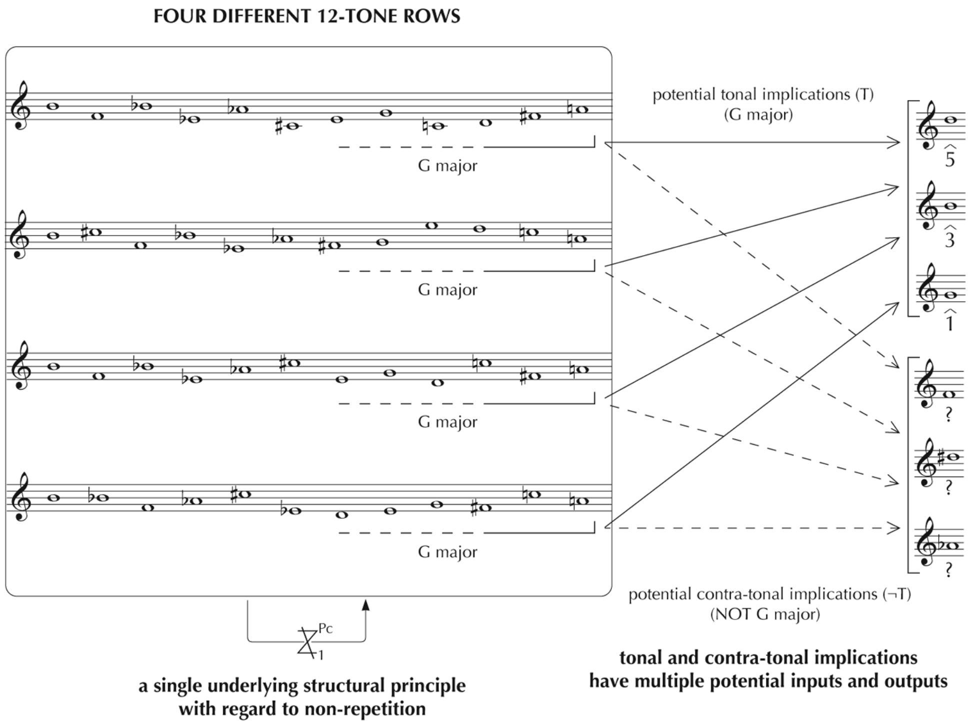


Figure 8. Non-repetition functions as a "deeper" structural principle in 12-tone rows than tonality and non-tonality

is to say, as far as expectation is concerned, in relation to each tonal centre, there are many different potential "inputs" (means through which a given key can be signalled) that correspond to a range of possible "outputs" (musically logical ways in which the suggested tonality can be reinforced) – see Figure 8.

Hence it is axiomatic that, in relation to a number ("n") of 12-tone series, the means of ¬R or R (symbolized respectively as $\neg\overline{R}$ and $\overline{R}$) will tend to what may be termed "general" values of NOT repetition or repetition ($\neg\mathbb{R}$ or $\mathbb{R}$), whereas the means of ¬T or T (symbolized as $\neg\overline{T}$ and $\overline{T}$) will tend to 0. That is:[4]

6. $$\neg\overline{R} = \frac{1}{n}\sum_{i=1}^{n} \neg R_i \rightarrow \neg\mathbb{R} \quad \text{and} \quad \overline{R} = \frac{1}{n}\sum_{i=1}^{n} R_i \rightarrow \mathbb{R}$$

whereas

7. $$\neg\overline{T} = \frac{1}{n}\sum_{i=1}^{n} \neg T_i \rightarrow 0 \quad \text{and} \quad \overline{T} = \frac{1}{n}\sum_{i=1}^{n} T_i \rightarrow 0$$

This implies that expectations (*e*) occurring in relation to "n" 12-tone series ("S") will tend to the cognition (*c*) of $\neg\mathbb{R}$ or $\mathbb{R}$ alone:

8. $$e\,(S_{1\ldots n}) \leftarrow c\,(\neg\mathbb{R} \text{ or } \mathbb{R})$$

In order to use this expression to gauge the import of Sergeant's data, it is necessary to make it function predictively, so that comparisons can be drawn between the values forecast by the model and listeners' actual expectations. If the predicted and actual figures are found to be similar or the same, this could be taken as evidence that the underlying assumptions used to the build the model are correct. Conversely, differences between expected and observed responses would suggest that changes may need to be made (and may indicate the nature of the modifications required). To quantify $e\ (S_{1\ldots n}) \leftarrow c\ (\neg\mathbb{R} \text{ or } \mathbb{R})$, we will adapt the methodology developed by Thorpe, Ockelford and Aksentijevic (in press), which itself sought to operationalize the zygonic model of expectation set out by Ockelford (2006).

The zygonic model of expectation

The zygonic model of expectation holds that anticipation in music arises from the projection of zygonic relationships into the imagined future, using what the phenomenologist Edmund Husserl (1905–10/1964) referred to as "protentions" – the anticipation of what is to come, enauralized in the conscious present. Such relationships stem from two potential sources:

(a) "current" structures, derived from the aural data of a work currently being heard, and forming part of the hearing process in train at the time, are encoded in working memory, and operate either:
  (i) *within* groups of notes or
  (ii) *between* them (Ⓐ in Figure 9); and
(b) "previous" structures, which are retained from aural data of past hearing processes, and therefore necessarily operate only *between* groups. These may be encoded "schematically" Ⓑ (generalized principles of musical behaviours) or "veridically" Ⓒ (more or less intact representations), to use the terminology adopted by Bharucha (1987, 1994).

It is hypothesized that, since all musical events have a plurality of potential logical continuations, current "within-group" structures can offer only a more or less *general* indication of what is to come ①. Conversely, "between-group" expectation provides a *specific* indication of what is likely to happen next ③. Such prognostication may be prompted by features that are particularly salient, incurred, for example, through the recency of groups or their frequent repetition. Schematic information derived from structures heard previously offers a *general* picture of what the future may hold ②, according to heuristics based on past trends and tendencies. That is to say:

$$A \rightarrow 1$$

$$B \rightarrow 2$$

$$A \text{ and/or } C \rightarrow 3$$

Expectations pertaining to the internal pitch structure of 12-tone rows derive from "current structures," "within groups" Ⓐ ①, because each "Grundgestalt" (the basic musical material from which a serial composition constructed) is different. Zygonic theory predicts that two cognitive forces are at work here – deriving from adjacency and recency – such that an expected value will be influenced most strongly by that which has just occurred, less by the one preceding, still less by the one preceding that, and so on; and, in each case, pitches that are "closer" to

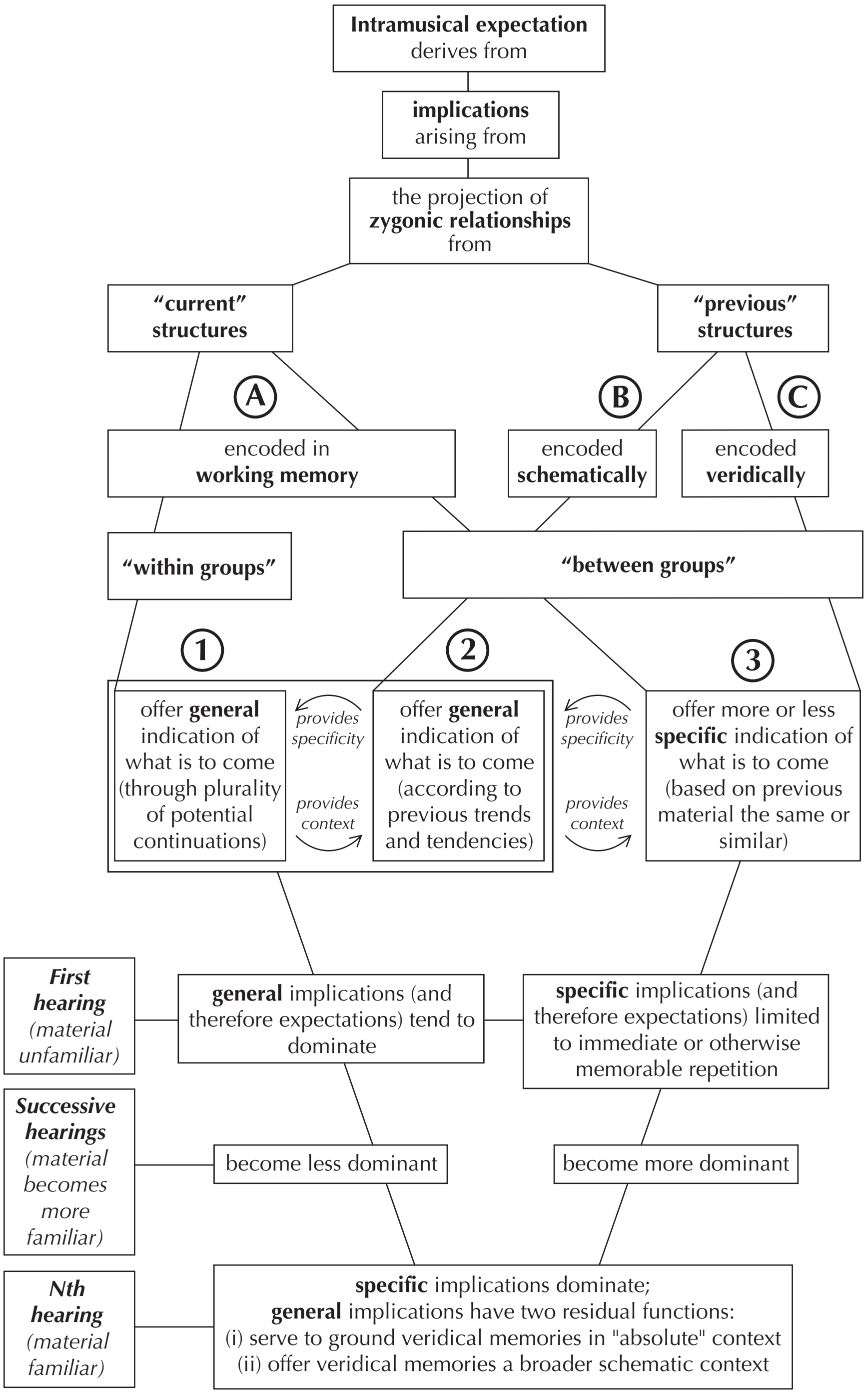


Figure 9. Zygonic model of expectation in music (after Ockelford, 2006, p. 127)

those that have already been heard are postulated to exert a stronger effect than those that are less similar in terms of pitch "height." It is hypothesized that there is a cumulative interaction between these two effects – resulting in a sense of "interagency" – whereby the probabilities associated with each pitch heard in the recent past combine additively. This means that, within the resulting *general* sense of what may follow, each potential future value is felt to have a different probability of occurrence. Visually this thinking can be represented as follows (see Figure 10).

There is evidence that this model reasonably represents one ingredient in the expectational mix – see Thorpe et al. (in press) – although in *tonal* music (with which that study is concerned), the available data pertaining to the melodic intervals occurring between successive notes in a range of styles and genres (see, for example, Huron, 2001, p. 25 and Ortmann, 1926, p. 30) suggest certain refinements to the model. For example, exact repetition tends to be used less frequently than intervals of a major or minor second (the desire for similarity apparently outweighing the wish for duplication), and the interval of an octave arises more often than major or minor sixths and sevenths (arguably because of the influence of the harmonic series; see Ortmann, 1936, p. 31). Comparable empirical data are not available for *a*tonal music,

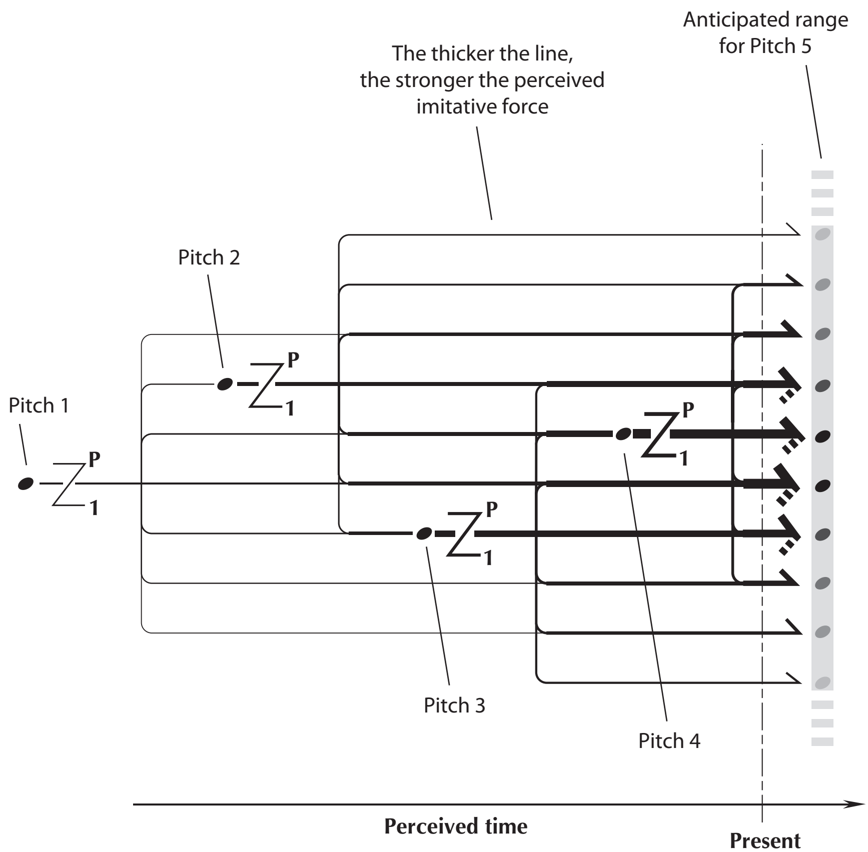


Figure 10. Schematic representation of zygonic "adjacency + recency" = "interagency" model of expectation in music

however, and so in the absence of evidence to the contrary, a version of the model that is linear both with respect to adjacency and recency will be used here. With regard to adjacency, given a chromatic intervallic range extending over an octave (up or down) from a given pitch p_{n-1} (a span that suffices to encompass the empirical data reported below), the predicted probability P of a further given pitch p_n being expected to occur can be taken to diminish in a linear fashion in proportion to the size of the interval between pitch p_{n-1} and pitch p_n . As the sum of the probabilities of all values must equal 1, this can be expressed as follows:

9. $$P(p_n) = \frac{13 - |p_n - p_{n-1}|}{13 + 2 \bullet \sum_{i=1}^{12} i} = \frac{13 - |p_n - p_{n-1}|}{13^2}$$

where $|p_n - p_{n-1}|$ is the difference in semitones between the two notes concerned. This yields the following set of probabilities (Table 1).

Apropos recency, for the "structural" listener, the predicted probability of an *n*th pitch, p_n, occurring after n – 1 events, is given by the equation:

10. $$P(p_n) = (n-1) \bullet \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_{n-1}) + (n-2) \bullet \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_{n-2}) + \ldots \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_1)$$

However, for a listener processing a 12-tone row antistructurally – see Figure 5 – this effect is reversed, so that the most recent pitch exerts the least effect, the next most recent more influence, and so on.

11. $$P(p_n) = \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_{n-1}) + 2 \bullet \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_{n-2}) + \ldots (n-1) \bullet \left(\sum_{i=1}^{n}(i-1)\right)^{-1} \bullet P(p_1)$$

Clearly, an important factor in applying this formula to model cognition is the number of pitches a listener can be assumed to hold in working memory. Although there are currently no relevant empirical data pertaining directly to atonal series of notes, other evidence is available that suggests listeners' capacity for storage and recall in the domain of pitch in the absence of structure (which would have permitted more economical encoding) may be very limited. For example, re-analysis of Diana Deutsch's (1980) findings of listeners' capacity to process sequences of pitches shows an average accuracy of recall of unstructured 12-note sequences (each comprising an average of just five different pitch classes) of only 52%. And it is important to bear in mind that Deutsch's stimuli were cast within a tonal framework (G major), providing coding cues in terms of scale degree not available from 12-tone rows.

Given this cognitive constraint, it seemed prudent, at least as a first step, to model the antistructure pertaining only to portions of 12-tone series – short enough to be manageable in working memory – and it was decided initially to work with the last six notes of each row (a number that also corresponds to the number of different pitch categories that a listener without absolute pitch can store in working memory – see Miller, 1956, after Pollack, 1952, and Krumhansl, 1987, p. 34). It was felt that this figure could in subsequent studies be increased or reduced or left unchanged in the light of the preliminary findings reported below. Anticipated probabilities of probe-tone responses pertaining to notes 7, 8, 9, 10, 11 and 12 were calculated

Table 1. Anticipated probabilities modelled through adjacency

Interval (semitones)		Predicted probability
12	up/down	0.0059
11	up/down	0.0118
10	up/down	0.0178
9	up/down	0.0237
8	up/down	0.0296
7	up/down	0.0355
6	up/down	0.0414
5	up/down	0.0473
4	up/down	0.0533
3	up/down	0.0592
2	up/down	0.0651
1	up/down	0.0710
0	—	0.0769

using formulae 9 and 11, and are shown in Table 2 and Figure 11. The method of utilizing these data is shown Figure 13.

Study 1

Materials

Thirteen of the rows were selected from Sergeant's original materials (which he had taken or adapted from the serial repertoire), which fulfilled the following three criteria: that they should be isometric (comprising notes equally spaced in time and of equal duration), contain no octave displacement and have no deliberately constructed "tonal" endings (Figure 12).

Sergeant presented the rows to his listeners using a Synclavier synthesizer; tones were 500 ms in duration, with a symmetrical spectral envelope, providing similar rise and decay times. The tones were harmonically rich – each approximating to a quiet diapason pipe sound.

Subjects

Fourteen musicians participated in Sergeant's study, of whom not less than 12 took part in any one task. Each was paid a fee commensurate with the then current hourly rate for rehearsal sessions. All had undertaken advanced musical study, either at conservatoire or university. They included people who were eminent in their sphere of musical endeavour (e.g., principal chairs in established UK orchestras, the conductor of a national choral festival, and a member of a professional string quartet). Some had extended experience of 20th-century music.[5]

Procedure

Subjects heard a 12-tone context sequence, followed after a two-second interval by a probe-tone. Probe-tones randomly and exhaustively sampled each of the pitches heard in the context sequence. The task was to rate "how well the probe-tone followed, or blended, with the preceding

Table 2. Anticipated probabilities modelled through adjacency + recency = "interagency"

"Recency" factor ...								
	Interval (semitones)		Pitch 7 **0.2857**	Pitch 8 **0.2381**	Pitch 9 **0.1905**	Pitch 10 **0.1429**	Pitch 11 **0.0952**	Pitch 12 **0.0476**
"Adjacency" factor ...	12	up/down	0.0017	0.0014	0.0011	0.0008	0.0006	0.0003
	11	up/down	0.0034	0.0028	0.0023	0.0017	0.0011	0.0006
	10	up/down	0.0051	0.0042	0.0034	0.0025	0.0017	0.0008
	9	up/down	0.0068	0.0056	0.0045	0.0034	0.0023	0.0011
	8	up/down	0.0085	0.0070	0.0056	0.0042	0.0028	0.0014
	7	up/down	0.0101	0.0085	0.0068	0.0051	0.0034	0.0017
	6	up/down	0.0118	0.0099	0.0079	0.0059	0.0039	0.0020
	5	up/down	0.0135	0.0113	0.0090	0.0068	0.0045	0.0023
	4	up/down	0.0152	0.0127	0.0101	0.0076	0.0051	0.0025
	3	up/down	0.0169	0.0141	0.0113	0.0085	0.0056	0.0028
	2	up/down	0.0186	0.0155	0.0124	0.0093	0.0062	0.0031
	1	up/down	0.0203	0.0169	0.0135	0.0101	0.0068	0.0034
	0	—	0.0220	0.0183	0.0147	0.0110	0.0073	0.0037

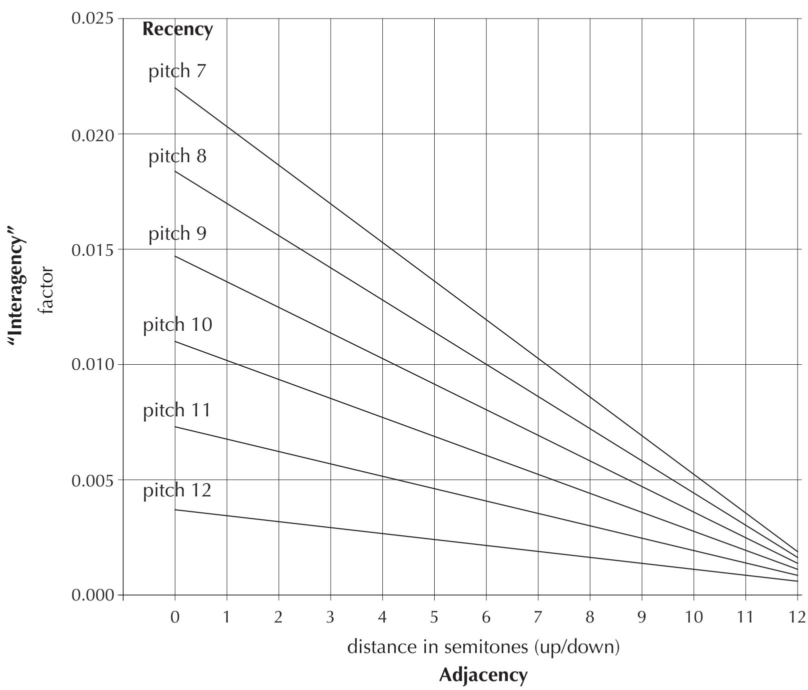


Figure 11. Visual representation of the relationship between recency, adjacency, and "interagency"

Figure 12. The rows from Sergeant (2012, in preparation) used in the current study

sequence" using a 7-point scale ranging from 1 = "fits poorly" to 7 = "fits well." Subjects were given the advice that "some listeners have found it helpful to listen to the whole sequence, then judge how surprising the following probe-tone sounded – a tone that was surprising would have a low rating; one that was unsurprising a high rating." To prevent over-learning, leading to practice effects and listener boredom, series were arranged in blocks of either three or four presentations. Rest intervals were provided after each block of 18 test items.

Results

The probabilities of each of the last six tones in the series occurring again, as predicted (a) through zygonic modelling of antistructure (using Formula 11) and (b) through probe-tone responses, are compared in the following tables and graphs. Differences of over 10% are noted for further discussion.

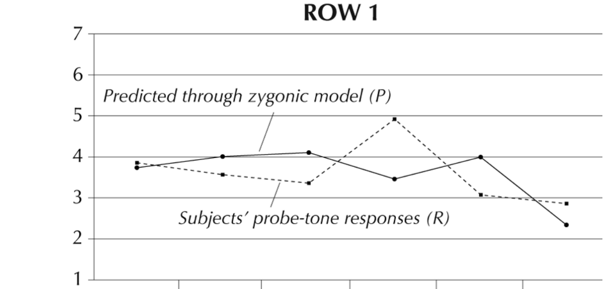
In Figure 13, the method of calculating the predicted probabilities of responses is shown in detail in relation to Row 1. The results are scaled up (by a factor of 65.3) to ensure equality of means, and facilitate comparison with listeners' probe-tone judgements. Figure 14 summarizes the remaining findings, in relation to Rows 2–13.

Analysis and discussion

Formula 11 provided a means of predicting antistructural cognition through a combination of adjacency and recency effects, while Formula 8 expressed the hypothesis that the *means* of expectations would tend to ¬R or R alone. Hence the degree to which the mean probe-tone results correlate with the mean predicted results is a measure of the strength with which listeners cognized antistructure in the manner predicted by the zygonic model. The two series of data are shown in Figure 15.

The degree to which the two series of values (observed and predicted) correspond can be assessed statistically in a number of ways, of which two will be used here. One approach is to calculate by how many standard deviations the observed values depart from the mean of the predicted population. The data in Figure 15 show that, in every case, the "z-score"[6] for the observed value falls within one standard deviation of the mean of the predicted value, and, with one exception, lies very close to it. Therefore, it is reasonable to argue that the observed values conform to those that are predicted. The second method is to run a multiple regression by treating the mean predicted values as the dependent variable and the observed values for pitches 7–12 of the series as six independent variables. The results are $F(6, 6) = 23.41$, $p < .001$, with $R = 0.98$, and $R^2 = 0.96$, showing the model to account for 96% of the total variance, with only 4% remaining unexplained.

But what of the discrepancies pertaining to individual rows? Formulae 1 and 2 suggest that differences could be ascribable to the impact of tonal or "anti-tonal" cognition. Specifically, with a cognitive approach that recognized and respected the conventions of tonality, one would expect pitches that accorded with the prevailing tonal context to be enhanced in terms of their probe-tone ratings (implying that they would be higher than the zygonic model predicted), while those that were incompatible would be rated lower. Conversely, given a cognitive style functioning *anti*-tonally, one would anticipate that pitches that did not conform to the current tonal frame of reference would receive elevated ratings, in contrast to those that presented a good tonal fit, whose scores would be relatively depressed (see Table 3).[7]



	F♯	B	A♯	C♯	G♯	D
Responses	3.86	3.57	3.36	4.93	3.07	2.86
Predicted	3.74	4.01	4.11	3.46	4.00	2.34

Pitch	F♯	B	A♯	C♯	G♯	D	**SUMS**	
C♯6				0.0008				
C6				0.0017				
B5		0.0014		0.0025				
A♯5		0.0028	0.0011	0.0034				
A5		0.0042	0.0023	0.0042				
G♯5		0.0056	0.0034	0.0051	0.0006			
G5		0.0070	0.0045	0.0059	0.0011			
F♯5	0.0017	0.0085	0.0056	0.0068	0.0017			
F5	0.0034	0.0099	0.0068	0.0076	0.0023			
E5	0.0051	0.0113	0.0079	0.0085	0.0028			
D♯5	0.0068	0.0127	0.0090	0.0093	0.0034			
D5	0.0085	0.0141	0.0101	0.0101	0.0039	0.0003		
C♯5	**0.0101**	**0.0155**	**0.0113**	**0.0110**	**0.0045**	**0.0006**	**0.0530**	3.46
C4	0.0118	0.0169	0.0124	0.0101	0.0051	0.0008		
B4	**0.0135**	**0.0183**	**0.0135**	**0.0093**	**0.0056**	**0.0011**	**0.0614**	4.01
A♯4	**0.0152**	**0.0169**	**0.0147**	**0.0085**	**0.0062**	**0.0014**	**0.0628**	4.11
A4	0.0169	0.0155	0.0135	0.0076	0.0068	0.0017		
G♯4	**0.0186**	**0.0141**	**0.0124**	**0.0068**	**0.0073**	**0.0020**	**0.0611**	4.00
G4	0.0203	0.0127	0.0113	0.0059	0.0068	0.0023		
F♯4	**0.0220**	**0.0113**	**0.0101**	**0.0051**	**0.0062**	**0.0025**	**0.0572**	3.74
F4	0.0203	0.0099	0.0090	0.0042	0.0056	0.0028		
E4	0.0186	0.0085	0.0079	0.0034	0.0051	0.0031		
D♯4	0.0169	0.0070	0.0068	0.0025	0.0045	0.0034		
D4	**0.0152**	**0.0056**	**0.0056**	**0.0017**	**0.0039**	**0.0037**	**0.0358**	2.34
C♯4	0.0135	0.0042	0.0045	0.0008	0.0034	0.0034		
C3	0.0118	0.0028	0.0034		0.0028	0.0031		
B3	0.0101	0.0014	0.0023		0.0023	0.0028		
A♯3	0.0085		0.0011		0.0017	0.0025		
A3	0.0068				0.0011	0.0023		
G♯3	0.0051				0.0006	0.0020		
G3	0.0034					0.0017		
F♯3	0.0017					0.0014		
F3						0.0011		
E3						0.0008		
F♯3						0.0006		
D3						0.0003		

Adjusted (x 65.3) so that Mean Responses = Mean Predicted

Figure 13. Method of comparing the results of zygonic modelling with the probe-tone tests for the last six notes of Row 1

But, as the same difference between a given probe-tone rating and its corresponding score predicted by the zygonic model could arise from opposing cognitive strategies (see Figure 8),

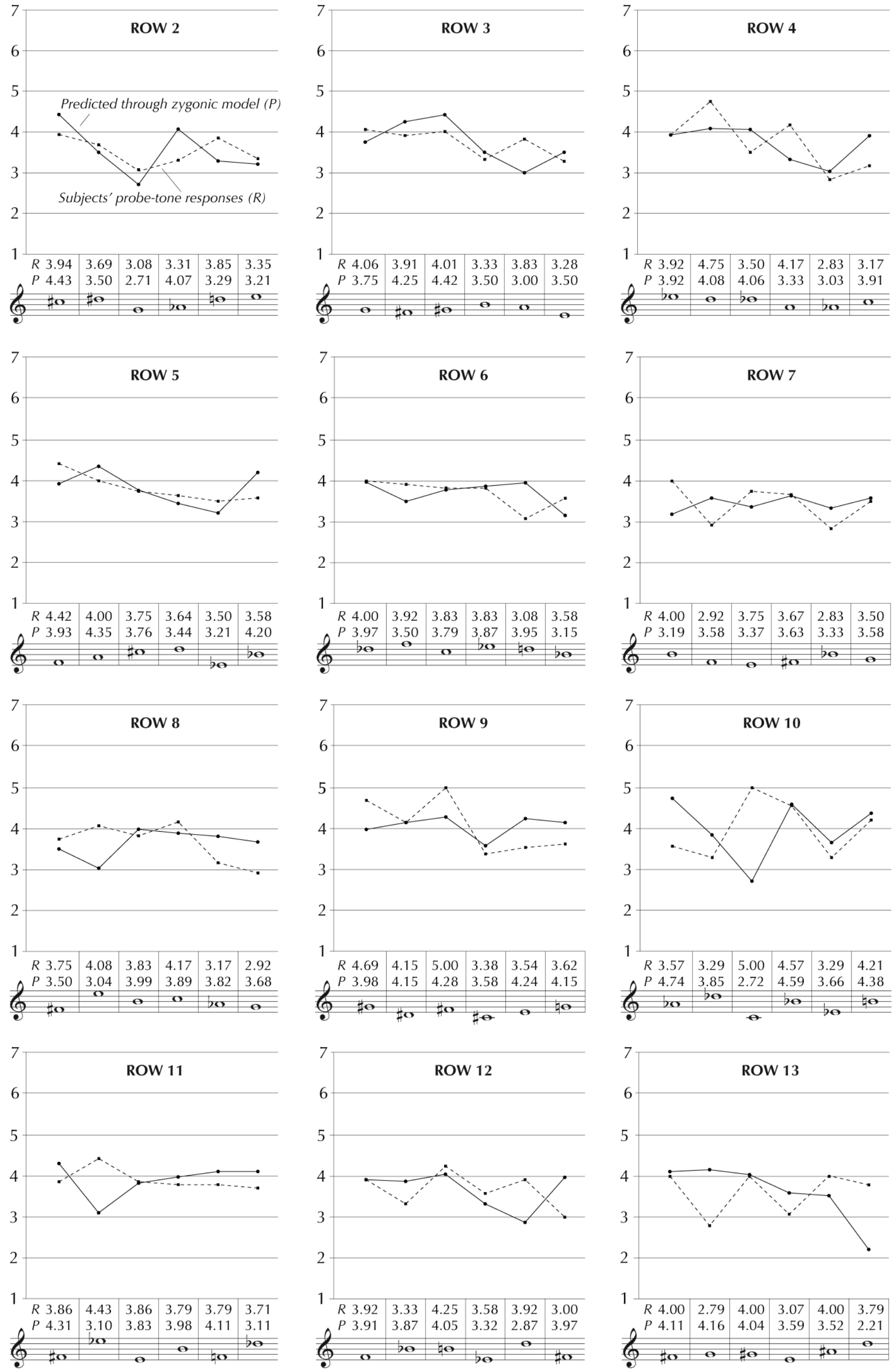
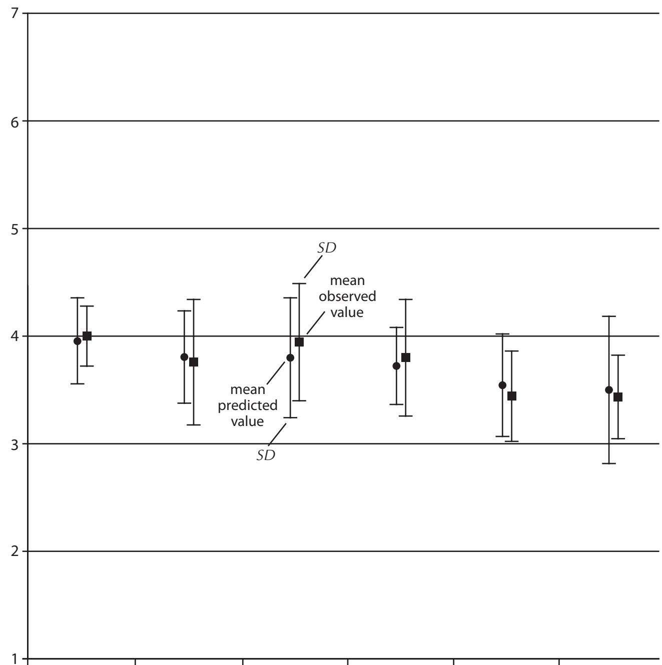


Figure 14. Results from zygonic modeling and the probe-tone tests for Rows 2–13



			7	8	9	10	11	12
position of note in row			7	8	9	10	11	12
observed ■		*mean*	4.00	3.76	3.94	3.80	3.44	3.43
		SD	0.28	0.57	0.56	0.53	0.42	0.38
		z-score	0.10	0.09	0.19	0.25	0.22	0.09
predicted ●		*mean*	3.96	3.80	3.78	3.71	3.54	3.49
		SD	0.40	0.43	0.54	0.36	0.46	0.68

Figure 15. Means and standard deviations of predicted values and observed responses

Table 3. How probe-tone ratings are likely to vary according to cognitive approach

Cognitive approach	Probe-tone ratings for:	
	tonally compatible tones	tonally incompatible tones
Tonal	higher	lower
Anti-tonal	lower	higher

how is one to know which approach the listener was taking, and, therefore, how to analyse the data?

Study 2 was devised in an initial attempt to answer this question, and is frankly more speculative in nature. Nonetheless it sets out a line of theoretical thinking that may be further developed in the future through a range of empirical work.

Table 4. Musicians' assessments of the tonality of the 13 tone–row segments used in Study 1.

Segment	*C major*	*A minor*	*G major*	*E minor*	*D major*	*B minor*	*A Major*	*$F^{\#}$ minor*	*E major*	*$C^{\#}$ minor*	*B major*	*$C^{\#}$ minor*	*$G^{\flat}$ major*	*$E^{\flat}$ major*	*$D^{\flat}$ major*
1	–	–	–	–	1	**4**	–	–	–	2	**5**	1	2	–	–
2	5	1	–	–	–	–	1	–	1	1	–	2	–	–	–
3	–	**4**	–	–	1	–	**10**	–	1	–	–	–	–	1	–
4	–	1	–	–	–	–	–	–	1	1	–	–	–	–	4
5	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	**3**	1	1	–	–	–	–	–	–	–	–	–	–
8	**6**	–	3	2	–	–	–	1	–	–	–	–	–	–	–
9	1	–	–	2	4	2	–	–	2	1	–	3	–	–	1
10	–	–	–	–	–	–	–	–	2	2	2	5	–	–	1
11	–	–	–	–	–	2	–	–	–	–	5	–	6	–	1
12	–	–	1	–	–	4	–	–	2	–	4	–	–	–	1
13	2	–	–	–	–	6	–	–	2	–	2	–	–	–	–

$N = 15$

Study 2

Procedure

A short series of notes (such as those at the end of a tone-row) can be deemed to exist in one of three states with regard to tonality: the fragment may evoke one key, more or less unambiguously; it may suggest two tonal regions or more (although the ear will probably be able to focus on only one at once); or it may induce no impression of tonality at all. In order to get a sense of the tonality perceived to be in play at the ends of Sergeant's rows (the points at which listeners were asked to rate probe tones), 15 musicians – all advanced performers or experienced teachers, who were familiar with tonal and post-tonal western classical music and had a good grasp of music theory, but who had not participated as listeners in Sergeant's study – were asked to undertake a further rating task. They were emailed a copy of the second halves of the 13 rows explored in Study 1 (see Figure 12), and asked what key or keys (if any) they heard each of the passages as ending in. They were told to assume enharmonic equivalence if necessary (whereby notes that sound the same within the system of equal temperament can be labelled differently according to tonal function: $A^{\flat}$ and $G^{\#}$, for example). They were also asked to rate how secure they felt each of their judgements to be, on a scale of 1–10, where 1 was "very unsure" and 10 was "certain." The underlying methodological assumption was that the results would give a reasonable indication of how professional western musicians in general – including Sergeant's subjects – perceive the (often unintended) interaction between tone-rows and the perception of tonality.

$B^\flat$ minor	*$A^\flat$ Major*	*F minor*	*$E^\flat$ major*	*C minor*	*$B^\flat$ major*	*G major*	*F major*	*D minor*	No sense of key	Categories	Means	Sums	Mean confidence ratings
–	–	–	–	–	–	1	–	1	–	8	2	17	6.9
–	–	–	–	–	–	–	–	–	4	5	2	15	6.9
–	1	–	–	–	–	–	–	1	–	7	3	19	7.9
1	7	–	–	1	–	–	–	–	–	6	2	16	7.1
–	–	–	6	–	4	2	–	4	–	5	3	17	6.9
1	–	–	1	–	**12**	–	–	1	–	3	4	15	7.6
–	–	–	–	–	–	**10**	–	–	1	7	4	16	7.0
–	1	–	1	**6**	–	–	–	–	1	7	3	21	6.2
–	–	–	–	–	–	–	–	–	1	8	2	17	7.2
–	2	–	–	–	–	–	–	–	2	6	2	16	6.1
–	–	–	–	–	–	–	–	–	1	4	4	15	7.4
–	–	–	–	–	–	2	–	–	1	6	2	15	6.8
1	–	–	–	–	1	–	–	–	3	5	2	17	6.1
									Means	**6**	**3**	**17**	**6.9**
								Sums	**14**			**216**	

Results

The participants appeared to have taken considerable care with the task for which they volunteered: their answers were often supplemented with comments and, in one case, complete harmonizations. The results are summarized in Table 4.

As the data show, subjects occasionally gave alternative responses as to the key in which they considered some of the segments to end; commonly two, sometimes three options or more were provided. Segment 8 had most alternatives (six), while Segments 2, 6, 11 and 12 had only one response per listener. The reaction "no recognisable key" was given by six subjects on one to four occasions, amounting to a total of 14 out of the 216 responses, which equates to a little under 6.5%. Segment 2 engendered a sense of atonality most often (four times). Different listeners frequently expressed distinct ideas as to the key in which they thought a segment ended. The smallest number of keys was four (pertaining to Segment 11), and the largest, in the case of Segments 1 and 9, was eight ($M = 6$, SD = 1.5). Frequently, choices spanned the "circle of fifths," with contrasting tonalities chosen as "solutions": C major and $G^\#$ minor in the case of Segment 2, for example, and C minor and $G^\#$ minor for Segment 8. The highest number of ratings the same was 12, made in relation to Segment 6, which was felt by the majority of listeners to end in $B^\flat$ major; the next highest was 10, which pertained to A major for Segment 3 and G minor for Segment 7. By far the most frequent scenario, however, was for unique judgements to be made (36), with a dual rating occurring 17 times. The confidence scores varied widely from subject to subject, ranging between means of three and 10. The segments attracting the lowest average score were 10 and 13 ($M = 6.1$), while the highest pertained to Segment 3 ($M = 7.9$). No correlation was found between confidence ratings and the distribution of tonality judgements.

Analysis and discussion

What are we to take from these results? First, it appears that fragments of tone-rows can appear to emanate "tonal signals" to which musicians are sensitive, and which they are generally reasonably confident in interpreting. Evidently, though, some segments are more tonally ambiguous than others, depending on the clarity with which a tonality defining patterns of intervals are presented. Where there is ambiguity, multiple interpretations are likely to be engendered, sometimes within the same listener. It seems to be rare, however, for *no* key to be discernible.

Where does this leave the aim of being able to distinguish potential tonal from possible anti-tonal listening in Sergeant's probe-tone results? The only segments that are likely to be provide usable data are those that are heard as ending in a particular key with reasonable consistency. A criterion of > 50% of ratings pertaining to one key yields five of the 13 excerpts: Segment 7 (87% G major/minor),[8] Segment 6 (80% B♭ major), Segment 3 (74% A major/minor), Segment 8 (57% C major/minor), and Segment 1 (53% B major/minor).

Determining the concluding keys of the five segments is an important stage in being able to allocate probe-tone responses to tonal or anti-tonal categories. However, it is not merely a question of assigning notes to the relevant diatonic pitch set, because (a) all 12 pitch-classes can fulfil distinct tonal functions in a given key (hence none could necessarily be excluded on the grounds of being intrinsically "anti-tonal"), and (b) tonality is defined through the different transition patterns with which relative pitches tend to succeed one another (from a listener's point of view, based on heuristics derived from the frequency of previous utilization; Huron, 2006). To put the matter simply: pitches may be defined as "tonal" if they provide a satisfactory resolution to the segment in question, within a defined key. Conversely, they may be regarded as "anti-tonal" to the extent that they are not heard as provide a fitting end to the sequence in the tonality concerned.

Judgements of melodic resolution within the common practice western tonal system are invariably made in the context of *harmony*, sounded or implied (cf. Schenker, 1935/1979). The degree to which a given harmony provides a sense of closure depends in part on its perceived *stability* within a given key. Krumhansl (1990, p. 171), combining the results of two probe-tone experiments, found that, in a major modality, listeners regarded the most stable chord to be the tonic (chord I, for example, C in C major), followed by the subdominant (chord IV, or F in C major) and then the dominant (chord V, or G in C major).[9] Resolution implies change; that is, movement within a part and from one chord to another. Hence, in order to undertake the tonal/anti-tonal analysis in relation to Segments 1, 3, 6, 7, and 8, it is necessary to identify, in each case, stylistically plausible cadential progressions that lead to one of these stable chords (according to Krumhansl's hierarchy). Harmonic "solutions" pertaining to each segment that respected these constraints were developed in consultation with two music theorists who were otherwise independent of the research. Given the need to end on chord I, IV, or V (or their minor equivalents) and the fact that resolution demands change (so the final note of each segment could not be repeated), the possibilities were in reality limited, and discussion centred around the one or two instances where progressions were theoretically possible but unlikely to occur within western "common practice" style. In particular it was decided to omit chord I (B major) as a potential ending in Segment 1, as this would have implied a "false relation" (a semitonal clash) with the last note of the row; and the transition to a subdominant chord (IV or iv) was not deemed to be stylistically plausible. This yielded harmonized segments (with an additional chord of resolution, corresponding to potential probe tones) as shown in Figure 16.

These analyses enable us to categorize which notes can be regarded as "tonal" and which "anti-tonal" when heard as probe tones. To reiterate: in respect of listeners who approach Sergeant's rating task with a tonality seeking mindset, we would expect those pitch-classes

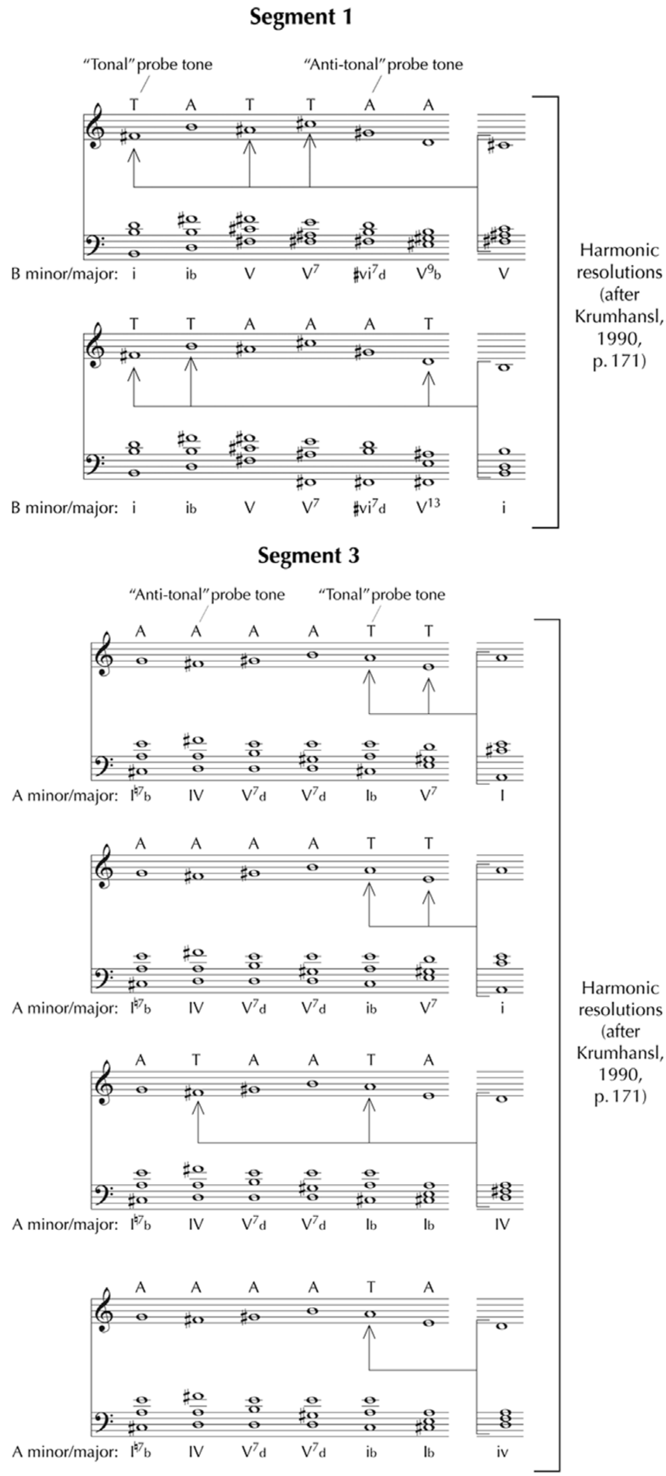


Figure 16(a). Derivation of "tonal" and "anti-tonal" categories for probe-tones in Segments 1 and 3

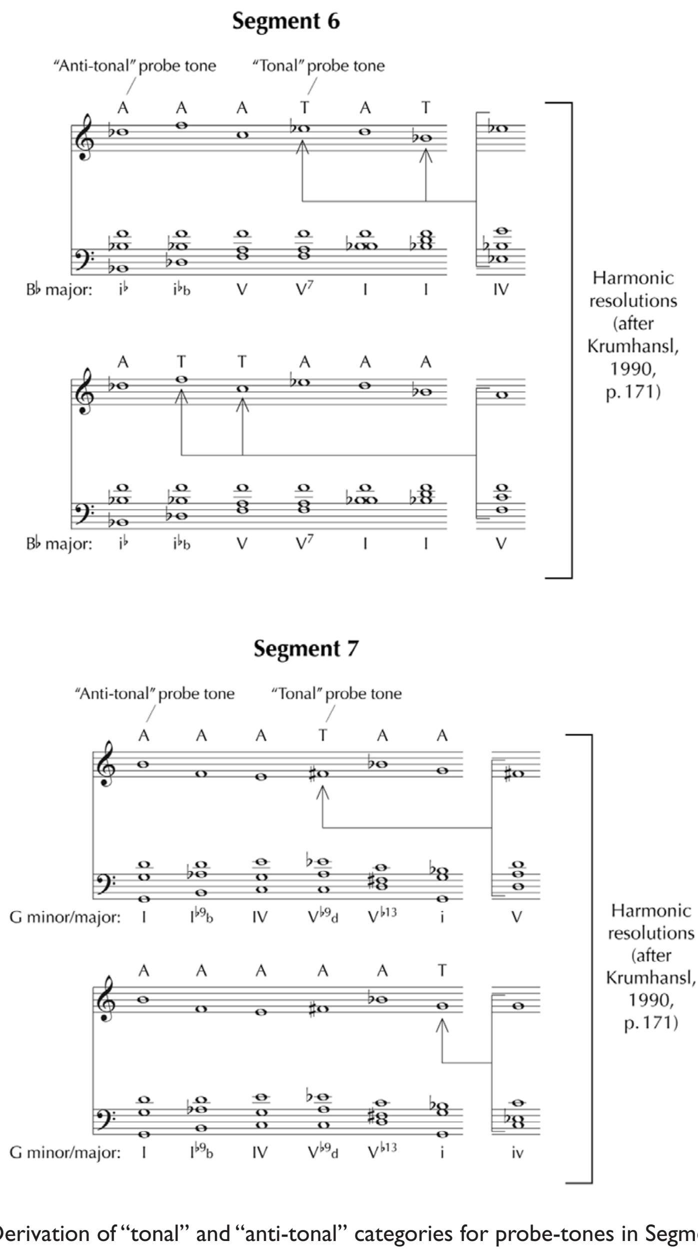


Figure 16(b). Derivation of "tonal" and "anti-tonal" categories for probe-tones in Segments 6 and 7

regarded as tonal to have scores higher than predicted by the zygonic model, and those classed as anti-tonal to be lower, whereas those listening anti-tonally would be expected to suppress the ratings associated with tonal pitch-classes and elevate those pertaining to those that are categorized as anti-tonal.

Hence there are four possibilities, which relate to the two different listening styles as follows (see Table 5).

The higher and lower magnitudes pertaining to T and A are defined as the ratio between the *difference* between the probe-tone responses ("R") and scaled predictions of the zygonic model ("P") (see Figure 11), and their *sum*:

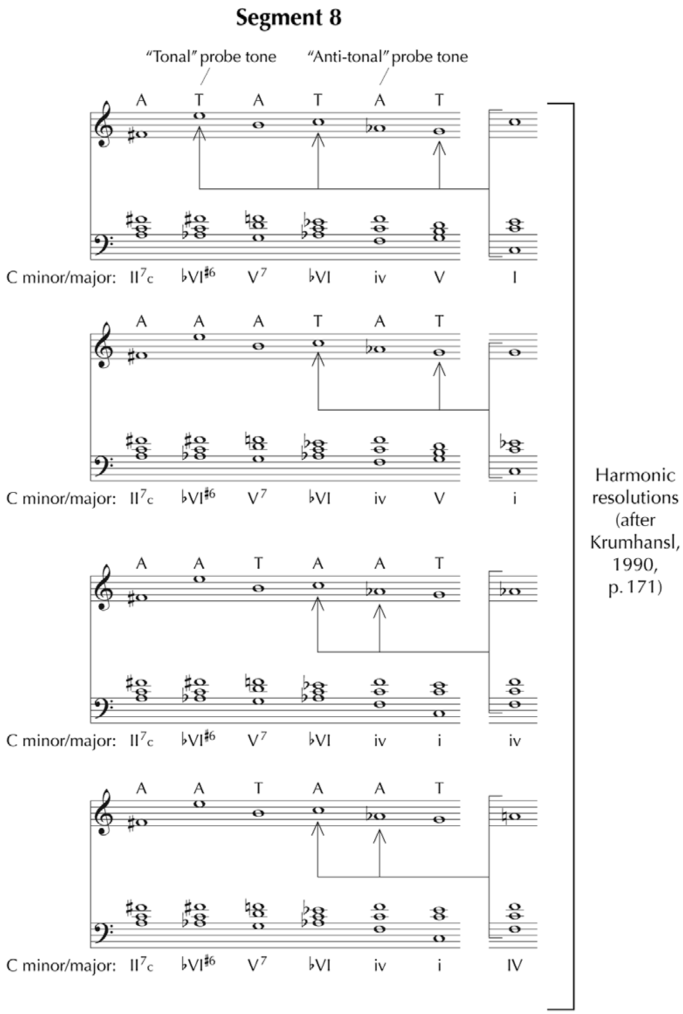


Figure 16(c). Derivation of “tonal” and “anti-tonal” categories for probe-tones in Segment 8

12. $$T \text{ or } A = (R - P) : (R + P)$$

To the extent that the mean of T (“$\overline{T}$”) across all respondents is greater than 0, and the mean of A (“$\overline{A}$”) is less than 0, so we can say that they have a tendency to listen tonally. And where is $\overline{T}$ less than 0, and $\overline{A}$ is greater than 0, we can assume that listeners are adopting an anti-tonal approach. That is:

13. $$\text{if } \overline{T} > 0 \text{ and } \overline{A} < 0 \Rightarrow \text{tonal listening}$$

and

14. $$\text{if } \overline{T} < 0 \text{ and } \overline{A} > 0 \Rightarrow \text{anti-tonal listening.}$$

The range of results from Segments 1, 3, 6, 7, and 8, given the suggested chords of resolution set out in Figure 16, are as follows (see Table 6).

Table 5. How the differences in responses and modelled ratings relate to "tonal" and "anti-tonal"

Pitch-class categorized as "tonal" or "anti-tonal"	Probe-tone rating higher or lower than modelled	Expected of "tonal" listening strategy?	Expected of "anti-tonal" listening strategy?
Tonal ("T")	Higher	Yes	No
Tonal ("T")	Lower	No	Yes
Anti-tonal ("A")	Higher	No	Yes
Anti-tonal ("A")	Lower	Yes	No

Table 6 (a). Quantitative evaluation of potential tonal and anti-tonal listening

Chords of resolution (in B minor/major)

Segment 1			V		i	
Pitch-class	Response	Predicted	Ratio R – P : R + P		Ratio R – P : R + P	
			Anti-tonal	Tonal	Anti-tonal	Tonal
	3.86	3.74		+0.016		+0.016
	3.57	4.01	–0.058			–0.058
	3.36	4.1 1		–0.010	–0.010	
	4.93	3.46		+0.175	+0.175	
	3.07	4.00	–0.132		–0.132	
	2.86	2.34	+0.100			+0.100
		Means	**–0.090**	**+0.091**	**–0.057**	**–0.058**

Chords of resolution (in A minor/major)

Segment 3			I		i		IV		iv	
P-c	R	P	Ratio R – P : R + P		Ratio R – P : R + P		Ratio R – P : R + P		Ratio R – P : R + P	
			A	T	A	T	A	T	A	T
	4.06	3.75	+0.040		+0.040		+0.040		+0.040	
	3.91	4.25	–0.042		–0.042			–0.042	–0.042	
	4.01	4.42	–0.049		–0.049		–0.049		–0.049	
	3.33	3.50	–0.025		–0.025		–0.025		–0.025	
	3.83	3.00		+0.122		+0.122		+0.122		+0.122
	3.28	3.50		–0.032		–0.032	–0.032		–0.032	
		Means	**–0.076**	**+0.090**	**–0.076**	**+0.090**	**–0.066**	**+0.080**	**–0.108**	**+0.122**

Consolidating these data (the means from each of the segments) produces the following result (see Figure 17).

The mean tonal rating $\bar{T} = 0.051$, while the mean anti-tonal rating $\bar{A}$ is -0.032. Testing the directional tendencies of these two sets of values with a Mann-Whitney U test shows the

Table 6 (b). Quantitative evaluation of potential tonal and anti-tonal listening

Chords of resolution (in B♭ major)

Segment 6			IV		V	
P-c	R	P	Ratio R – P : R + P		Ratio R – P : R + P	
			A	T	A	T
	4.00	3.97	+0.004		+0.004	
	3.92	3.50	+0.057			+0.057
	3.83	3.79	+0.005			+0.005
	4.83	3.87		+0.110	+0.110	
	3.08	3.95	–0.124		–0.124	
	3.58	3.15		+0.064	+0.064	
		Means	**–0.058**	**+0.174**	**+0.054**	**+0.062**

Chords of resolution (in G minor/major)

Segment 7			V		v	
P-c	R	P	Ratio R – P : R + P		Ratio R – P : R + P	
			A	T	A	T
	4.00	3.19	+0.113		+0.113	
	2.92	3.58	–0.102		–0.102	
	3.75	3.37	+0.053		+0.053	
	3.67	3.63		+0.005	+0.005	
	2.83	3.33	–0.081		–0.081	
	3.50	3.58	–0.011			–0.011
		Means	**–0.028**	**+0.005**	**+0.012**	**–0.011**

Chords of resolution (in C minor/major)

Segment 8			I		i		IV		iv	
P-c	R	P	Ratio R – P : R + P		Ratio R – P : R + P		Ratio R – P : R + P		Ratio R – P : R + P	
			A	T	A	T	A	T	A	T
	3.75	3.50	+0.034		+0.034		+0.034		+0.034	
	4.08	3.04		+0.146	+0.146		+0.146		+0.146	
	3.83	3.99	–0.020		–0.020		–0.020		–0.020	
	4.17	3.89		+0.035		+0.035		+0.035		+0.035
	3.17	3.82	–0.093		–0.093			–0.093	–0.093	
	2.92	3.68		–0.115		–0.115	–0.115		–0.115	
		Means	**–0.079**	**+0.066**	**+0.067**	**–0.080**	**+0.045**	**–0.058**	**–0.048**	**+0.035**

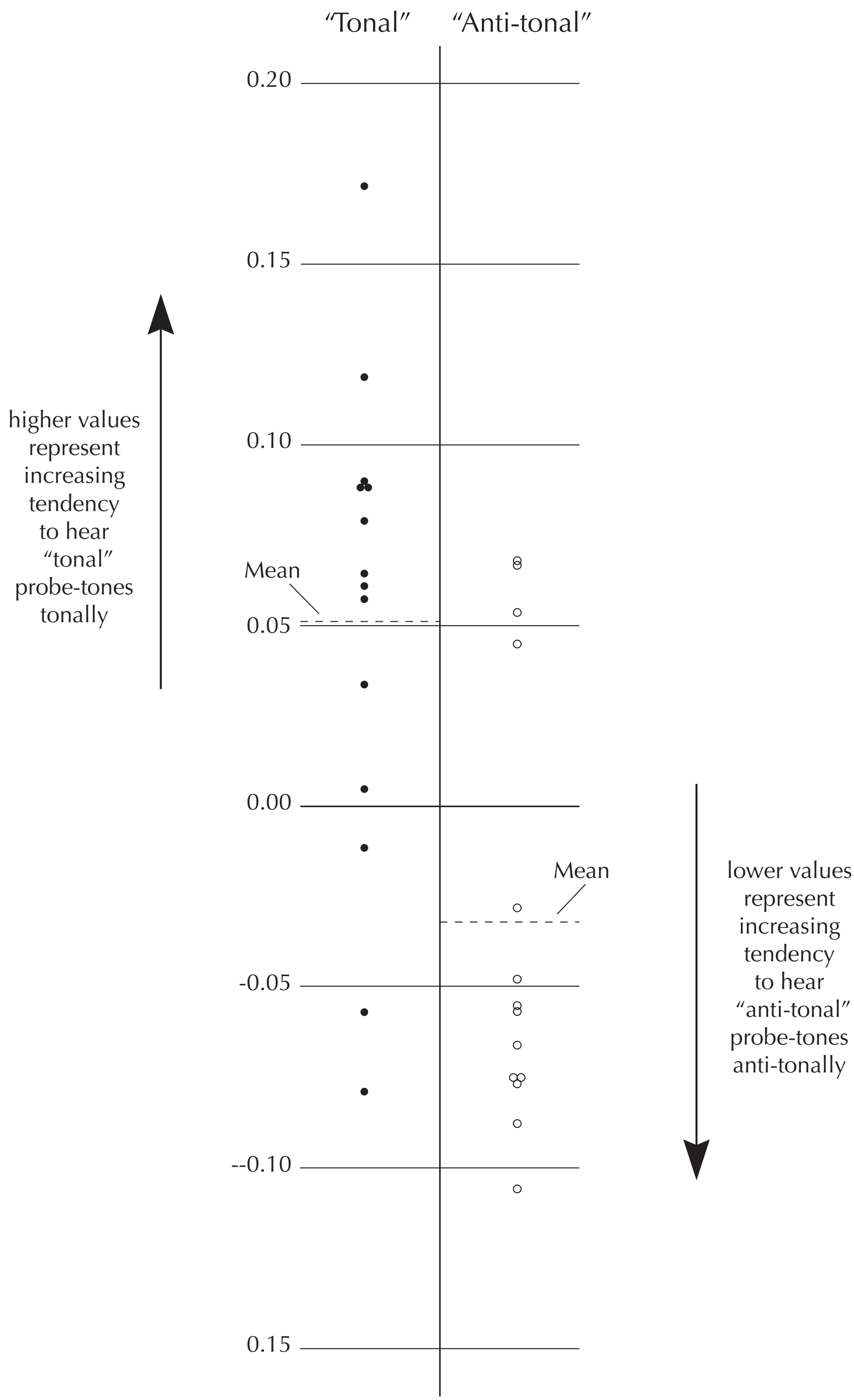


Figure 17. Derivations from predicted responses to "tonal" and "anti-tonal" probe tones

difference to be statistically significant: $U(26) = 38$, $p = .017$. That is to say, the data presented here suggest that Sergeant's listeners as a whole tended to *suppress* anti-tonal pitches in their probe-tone results by around 3%, and *elevate* tonal pitches by around 5%. In other words, they tended to listen to at least five of the 12-tone series *tonally*. Of course, it could fairly be argued that the sample of rows is too small and the analytical assumptions too great for this to be anything other than an indicative result, which future, more substantial, research in this area may support or confute. Nonetheless, the principles underlying the analysis appear to be theoretically coherent and are capable of consistent application, yielding data that make intuitive musical sense. Hence the approach adopted, while novel and even speculative in nature, in our view merits further investigation.

Conclusion

Two studies were undertaken to explore the manner in which musically sophisticated western listeners process 12-tone rows. Two forms of "antistructure" were identified: (a) that pertaining to a lack of repetition, and (b) that involving the avoidance of the relative pitch schemata characteristic of tonality. The results suggest that listeners can intuitively recognize (a) while, at least in some cases, resisting the atonal style of perception indicated by (b). This finding is subtly different from that of Krumhansl et al. (1987), whose subjects fell into two groups: either detecting and responding to *both* forms of antistructure or *neither.* The wide variation in the way that listeners reported hearing the potential "tonal flecks" in the segments presented to them in Study 2 indicates that, where tonal information is very limited, many "solutions" are possible.

These findings suggest that, while experienced listeners attending to serial music may indeed be able to detect certain aspects of its artificial compositional grammar (the eschewal of pitch repetition), other types of structure that were not necessarily designed by the composer (the syntax of tonality) may be imposed by listeners. Moreover, the way such listening grammars are construed, given the little structural information available, may be highly idiosyncratic. So the manner in which listeners experience serial music may vary considerably between individuals.

Acknowledgments

The authors extend their thanks to the participants in both studies and to the insightful suggestions of the three anonymous reviewers.

Notes

1. Zygonic relationships such as those depicted in Figure 1 offer, at best, a highly simplified version of certain cognitive events that are hypothesized to take place during meaningful participation in musical activity. Moreover, the single concept of a zygon bequeaths a vast perceptual legacy, with many 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 qualities of sounds, or proactively, in ideating an attribute as an orderly consequence of one that has been heard (the notion that lies at the heart of expectation as it is held to function in the current article). Zygons may operate between anticipated or remembered sounds, or even those that are wholly imagined, only ever existing in the mind. Hence there is no suggestion that the one concept is cognitively equivalent in all these manifestations, but that it is *logically* so.

2. At the first blush, it may appear that this article is about musical expectancy specifically in serial rather than wider atonal contexts. However, we believe that, to the extent that a piece of atonal music adopts serial principles (e.g., the eschewal of pitch repetition), then the findings reported here may well have wider relevance. In general terms, the problem for research in atonal music is that the term "atonal" lacks a clear definition. Whilst the principles of tonality have been elaborated by successive (western) music theorists since the seventeenth century, the notion of atonality has no such historic provenance, and no universally agreed procedures or "rules" for atonal composition have been articulated. The term is itself a negative form, meaning only "not conforming to the structures of western tonality." This presents a difficulty for researchers, as, in the absence of universal principles, an atonal composition can only be analysed on the basis of those structural properties manifested by that particular piece. A possible exception is the serial music of the Second Viennese School – produced by Schoenberg, Berg, Webern, and their associates. With the music of these composers, although each composition has its own individual structure deriving from the ordering of the 12 tones of its basic series or "Grundgestalt," the music, whilst incontrovertibly being atonal (Budrys & Ambrazevičius, 2008), stemmed from commonly adopted principles and procedures that were unambiguously elaborated by theorists. Thus 12-tone serial pieces, as a corpus, are possibly the only form of atonal music that readily lends itself to psychological research.
3. These are taken to be variables in the sense of being logical sets of perceived attributes. They can also be manipulated mathematically and algebraically, as will become apparent.
4. By way of explanation, the first of these formulæ reads: "the mean of 'not R,' which equals the sum of individual values of 'not R,' tends to a general value of 'not R.'"
5. Five subjects had absolute pitch, although the responses of these listeners did not differ significantly from those of the other musicians.
6. That is, a standard score showing how many standard deviations an observation is above or below the mean.
7. Observe that the ratings for listeners who disregard potential tonal implications in the series – who approach the task with an "atonal" mindset – should accord with the model.
8. Major and minor keys with the same tonic can be regarded as equivalent for the purposes of this essentially cadential analysis, as, in accordance with western "common practice," minor passages often end in the major through the use of the device known as the "tierce de picardie."
9. For the purposes of this exercize, chords I, IV and V are treated as potential resolutions in minor keys as well as major.

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