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Motivic Structure and the Perception of Similarity

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This paper presents a theoretical and empirical investigation into the ways in which different listeners perceive similarity relationships in different kinds of music. We first extend the current understanding of similarity relations in music by drawing together theory and evidence from general cognitive psychology, cognitive psychology of music, and music theory. In the empirical study, trained musicians and nonmusicians rated the similarity of pairs of extracts from piano pieces by Beethoven (Sonata op. 10, no. 1, first movement) and Schoenberg (Klavierstück op. 33a) and provided adjective ratings for each extract. Similarity judgments were found to be context-specific and roughly equivalent for both types of listener, and were primarily based on more "surface" features such as dynamics, articulation, texture, and contour rather than on "deeper" features such as motivic or harmonic relationships. The implications for music-theoretic views of similarity are discussed.

How do listeners understand a piece of music? More specifically, how do they remember its main features and recognize how these are subtly altered throughout the course of the music? General cognitive psychology provides theory and evidence for how similarity and categorization processes may operate in other domains. Music theory supplies theories of how composers construct (and analysts deconstruct) the relationships between parts of pieces of music. Studies of music perception have begun to provide evidence for some ways in which listeners make sense of these relationships, although this is somewhat patchy and inconsistent. We extend the current understanding of similarity relations in music here by draw-

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ing together and comparing the relative contributions of these three fields, first in a theoretical review and second through an empirical study.

GENERAL COGNITIVE PSYCHOLOGICAL APPROACHES

Similarity and categorization processes have been viewed from many different angles within the field of general cognitive psychology. Two main types of similarity have been distinguished: first, that based on perceptual equivalence, and second, a more conceptual level of category formation (Eysenck & Keane, 2000).

Within the perceptual approach, classification is primarily viewed as based on similarity, where similarity is understood as perceived equivalence (Medin & Schaffer, 1978; Rosch, 1975). Of the various theories proposed of this type, prototype theory has received the most empirical validation. The prototype is viewed either as a particular privileged exemplar of a given category or as an abstracted central tendency (Komatsu, 1992; Rosch, 1978), and similarity is a function of the distance between a given item and the prototype, measured in terms of common and distinctive features. Rosch (1975) also proposes a hierarchy of categorization, with a basic level representing the simplest and most accessible (prototypical) levels (e.g., chair) with subordinate and superordinate levels (e.g., armchair and furniture, respectively). As Tversky (1977) points out, similarity is dependent on a large number of interacting variables that vary in their degree of importance such that similarity judgments are not necessarily symmetrical; the asymmetry of similarity relations is determined by the relative salience of referent and subject, with salience defined as goodness of form.

Some categories, however, do not seem to be based on perceptual equivalence. In contrast to similarity-based classification, a second approach has highlighted the importance of explicitly defined concepts, or theory-based classification (e.g., Murphy & Medin, 1985; Rips, 1989). According to this view, similarity is insufficiently clear and constrained to act as an explanation of categorization, and it suggests that we categorize not on the basis of clusters of similarity but on the basis of selecting the concept that best explains the instance to be categorized. This view emphasizes the role of background knowledge and gives a higher priority to the role of context in similarity relations. It can also include a consideration of connectionist or network models, where categories are structured as relational networks made up of abstract attributes to which particular values are assigned for any particular instance of a category member. According to this account, categories are organized around "conceptual models" that guide decisions about category membership (Barsalou, 1992).

So, although robust evidence exists for categorization based on perceptual similarity, contemporary accounts argue that this view should be broad-

ened to encompass information that goes beyond the perceptual appearance of objects (Hampton, 1997). Such conceptual similarity often requires experience with the particular domain (Keil, 1989), and for this reason, it has been described as a form of perceptual learning in which we acquire categorizations that are less immediately obvious (it is for this reason that conceptual similarity is sometimes referred to as "deep" similarity; cf. Hampton, 1997). However, it has been argued that in certain domains congruence between perceptual and conceptual structures can facilitate the perception of deeper similarity relationships (the notion of psychological essentialism proposed by Medin & Ortony, 1989). Context is increasingly recognized as a critical feature of similarity, one that may also determine the features that are used in making similarity judgments (Ramscar & Hahn, 1998; Rips, 1989). Thus, according to this view, category representation relies on correlated attributes plus underlying principles that determine the attributes that are attended to. The implication of this approach is that perceived similarity changes in context-dependent ways with knowledge and experience.

In summary, despite a distinction in the literature between perceptually based and conceptually or theory-driven categorization, general cognitive psychological approaches to similarity and categorization are converging on the idea that both perceptual and conceptual features are important and that these may represent different types of perceptual learning. While experience and training are important for the development of conceptual ("deep") similarity, features of the environment may reinforce this by virtue of congruence between perceptual and conceptual similarities.

MUSIC THEORETICAL APPROACHES

In the context of music theory relating to Western concert music, similarity has been considered central to an understanding of musical form and coherence. One of the ways in which this has been theorized is in terms of motivic relationships in music of the classical period. A motif is commonly understood as a core of pitch and rhythmic information that may be subjected to variation by a range of musical transformations and that forms an important part of formal development in classical music (e.g., sonata form; Rosen, 1976). A number of theories of motivic processes and their relative importance within transformations follow the prototype approach (Meyer, 1973; Réti, 1951; and, most explicitly, Zbikowski, 1999). Some features of motifs have been categorized as "surface" (changes of texture, orchestration, register, pace, and so on) and others as "deep" (derivation and fragmentation of the original pitch and rhythm information; see Meyer, 1973; Réti, 1951), although the relative importance of these features differs according to the particular accounts (e.g., intervallic properties are central

for Schenker [1979] and Réti, whereas Epstein [1987] suggests that the basic shape—a term usually used to describe an underlying intervallic pattern—is not inherently pitch based).

Schoenberg (1975) has written extensively on the importance of similarity to the comprehension of music. For Schoenberg, the motif is an interval and rhythmic pattern combined to produce an easily memorable shape, and comprehension of this shape forms the basis for the perception of musical coherence. Therefore the motif should have a clear statement at the beginning of a work, but need retain only some features in common so long as it has the potential for connection to other motif forms (what Schoenberg termed "developing variation"). Thus, in contrast to theorists such as Réti, rhythm and contour are central components of Schoenberg's conception of the motif (see Carpenter & Neff, 1995). Schoenberg also discussed the syntactic character of motivic processes. One such function is "liquidation," the process whereby closure is achieved through repetition and in which the features constituting the motif's identity are discarded. Through these means, certain kinds of motivic processes become associated with particular rhetorical functions and with order (van den Toorn, 1996; Zbikowski, 1999). Indeed, despite Schoenberg's insistence on the importance of presenting a memorable motif at the beginning of a piece (the idea/basic shape/Grundgestalt), van den Toorn argues that motifs take their shape and become memorable as a result of repetition and the connections formed between motifs as they repeat.

Although some shared motivic processes have been identified in tonal and atonal styles (cf. van den Toorn, 1996), issues of similarity become more problematic when one considers the early 20th-century dodecaphonic style of the Second Viennese School. The structural coherence of dodecaphonic music is based on the tone row, an ordered collection of the 12 possible pitch classes, which is manipulated at the level of pitch structure (e.g., inversion or retrogression) and subjected to surface variation (rhythm, pitch level, contour, direction, note clusters, and so on). Theorists treat this row as the basic shape or abstract prototype; for example, Rufer (1954) suggests that the row reduced to its melodic intervals serves as the basic shape of the whole work, in an analogous manner to the derivation of motivic material from key in tonal music (see also Alegant, 1996). Thus, dodecaphonic music theory tends to focus on the abstract prototype view as appropriate for this style (despite its apparent perceptual opacity). Coherence is guaranteed by the row and not by "surface" similarity, and so a similar theoretical view is adopted for both classical sonata form and dodecaphonic music.

Zbikowski (1999) gives an account of the role and effects of motif forms in terms of categorization. His central points are, first, that the cognitive salience of the motif mirrors that of the basic level (cf. Deliège & Mélen,

1997, and Schoenberg, 1975), and second, that the coherence and transformation of motif form can be modeled by categories that show typicality effects. Drawing on Barsalou's theory of frames (1992), Zbikowski argues that frames capture the category structure for the motif forms of pieces of music: the basic structure is a relational network made up of abstract attributes (e.g., orchestration, dynamic, melodic profile) that are assigned concrete values for particular motif forms (e.g., solo or tutti for orchestration). However, in practice certain attributes have a greater influence on category structure than others, hence the need to take into account "conceptual models"—the way in which categories are organized around concepts in particular relationships—which vary according to the circumstances of categorization. Relating this theory of conceptual models to music theory, the various attempts by theorists to define the attributes of motivic transformation can be understood as the compositional and listening practices (the conceptual models) specific to that genre and period.

EMPIRICAL EVIDENCE FROM COGNITIVE MUSIC PSYCHOLOGY

Given the theoretical predictions of both general cognitive psychology and music theory and analysis, it seems reasonable to assume that similarity relationships play an important role in musical comprehension and that empirical evidence is converging on the role of motivic structure in music perception. Irène Deliège has provided an account of the role of similarity processes within music perception that starts with the segmentation of the musical surface, based on principles of similarity and difference, and the abstraction of "cues" (salient local features that are rapidly picked up). Deliège suggests that perception of similarities between motifs is based on shared cues and results in a stored trace (an "imprint"). A series of experiments with adults and children provides evidence for this theory (summarized in Deliège & Mélen, 1997; see also Deliège, 2001; Koniari, Predazzer, & Mélen, 2001; and Mélen & Wachsmann, 2001).

Further evidence on the nature of these cues and their relationship to motivic structure is provided by a range of different studies. These studies indicate important differences in the way listeners respond that are highly context-specific.

The first factor is *experience*: children often prioritize melody-unspecific attributes of music such as loudness whereas adults focus on melody-specific attributes such as contour (Schwarzer, 1997). Age-related increases in sensitivity to rhythmic information have been found when judging the difference between a theme and variations (Demorest & Serlin, 1997). Less experienced adult listeners also often perform more poorly in correctly identifying themes than do adults with more musical experience (Francès, 1958/1988).

A further feature is *familiarity* with the music: surface features such as contour, loudness, and texture dominate responses in short-term contexts (Bartlett & Dowling, 1980), such as after a single hearing (Pollard-Gott, 1983), but are less influential once listeners are familiar with the music (Dowling & Bartlett, 1981; Pollard-Gott, 1983). This feature is closely related to findings comparing melodic recognition in shorter and longer term memory conditions (see also Edworthy, 1985).

A third feature relates to the *complexity* of the materials. With extracts selected from real pieces of music, findings tend to be rather contradictory: listeners are often misled by surface features like contour and rhythm as well as being able to recognize deeper motivic processes (Rosner & Meyer, 1986), yet with specially constructed stimuli, more robust evidence has been found for recognition of melodic prototypes (Welker, 1982).

Evidence for these three influences on similarity judgments is far from clear, however, with some studies showing young children and inexperienced adults easily able to extract melodic similarities and to deal with the more analytic features of melodies even under short-term conditions (Chapin, 1982; Dowling, 1978; Schwarzer, 1997). This introduces a fourth factor, relating to *task complexity*: in less cognitively demanding situations, thematic relationships are more easily extractable (cf. Peretz & Morais, 1983).

NEW DIRECTIONS FOR MUSICAL SIMILARITY

The empirical evidence suggests that four factors play a role in the perception of similarity relations in music—listeners' experience, familiarity of the material, complexity of the material, and task complexity—all of which point to the importance of *context*. More surface features may dominate when listeners are inexperienced, the material is unfamiliar and complex, and the task demands are high; conversely, deeper thematic connections may be easier to perceive when listeners are experienced, the material is familiar and simple, and the task demands are relatively low.

None of the previous studies have compared listeners' responses to different musical styles by using the same listeners and the same paradigm. On the basis of the music-theoretical approaches to similarity in tonal classical music and dodecaphonic music, it would be expected that differences would also be caused by these two different styles. For instance, a tonal classical piece will have certain boundaries around the acceptable tonalities used within it—an example of style-specific similarity. A piece that has featured solo piano throughout will typically not suddenly introduce the sound of a vacuum cleaner in its final bars. Less extremely, each piece of music also sets up its own similarity criteria. As our review of music-theoretic predictions indicates, it is thus difficult to set out precisely how similarity relations operate at more generic levels because these are likely to be

highly context-specific. However, in the given examples, these differences are also in part related to "familiarity." So, for example, for listeners enculturated into Western tonal music (Sloboda, 1985), the surface features of a Western classical piece (even if unfamiliar) would be expected to be less influential than those of a dodecaphonic piece, even though the underlying compositional principles of similarity have been theorized as equivalent.

Furthermore, previous research has not considered how similarity based on thematic and motivic relations is set up and developed at different points within particular pieces of music. Following the emphasis on context, it is expected that relations between different parts of a piece will differ. Adopting the distinction between surface and deeper levels of relationships, music theory indicates that in any given piece, there may be (functional) places where all the potential levels of similarity relations would reinforce each other. For example, at the start of a piece one compositional strategy might be to establish the pattern of what will follow by highlighting critical features. This notion is consistent with theories of key derivation (Brown, Butler, & Jones, 1994) and of meter induction (Povel & Essens, 1985), which indicate that the clearest and most unambiguous statements occur at the beginning of a piece of music to orient the listener and provide a guiding framework. Similar notions have been proposed in compositional theory (Schoenberg, 1975), and this relates to the concept of psychological essentialism (Medin & Ortony, 1989) discussed earlier. (It appears that listeners also use a variant of this prioritization of beginnings when making similarity judgments: Deliège [1992, 2001] shows how the imprint formation process is strongly dependent on the beginnings of extracts presented and changes that occur later in time are less salient.)

The more surface features of similarity, however, may not necessarily emphasize the underlying thematic similarity, since in addition to the unifying underlying thematic connections, surface differentiation is included to create interest and variety. Some parts of the music will be strongly related at a range of different levels: for example, the exposition and recapitulation in sonata form (which are often identical with the exception of occurring at different time points). Other parts of the music may share more surface similarities but with underlying differences. These would be the similarity relations that "deceive" the casual listener. Still other parts of the music may share deeper similarities but not more surface similarities (again, deceiving the casual listener that they are different when after repeated listening, for example, the similarities may reveal themselves). It is also important to note that, in the majority of musical styles, there will be parts of compositions that are dissimilar on many levels.

This leads to a number of hypotheses in this investigation of motivic similarity. First, if listeners do perceive similarity while listening to music,

upon which criteria are these similarity relationships based? Second, and more specifically, is similarity based on the predictions of music theory, namely on the deep thematic relationships, or on the similarities at the musical surface? Third, are these similarity relationships style specific, or do the same similarity criteria operate across musical styles? And finally, do these similarity relationships apply for listeners with different amounts of experience? These questions are addressed in the following empirical study.

Empirical Study

METHODS

Participants

Participants were 40 university student volunteers from the University of Sheffield, who were paid for participating. Of these, 20 participants had extensive musical training (currently enrolled for an undergraduate music degree and having studied a musical instrument for at least 8 years), and 20 had no musical training (apart from general class music in mainstream school education).

Materials

Two different piano pieces were chosen: Beethoven's piano sonata op. 10, no. 1, first movement, and Schoenberg's Klavierstück op. 33a. The Beethoven piece was selected following Réti's (1951) analysis of this piece as constructed in its entirety on the same basic shape with a range of different surface relationships. The Schoenberg piece was selected as a dodecaphonic piece built on the intervallic content of a pair of combinatorially related 12-note sets that provide the basis for both themes in serial sonata form (Cook, 1987; Perle, 1968). Both pieces thus use the principle of developing variation, have more than one thematic group, and are written for the same instrument. In addition, the similarity between pieces in terms of structural and thematic features and their difference in terms of tonality means that it would be possible to separate out the effects of tonality and theme on listeners' similarity judgments: if listeners do not respond to tonal structure but can respond to motivic relations or surface attributes, then the patterns of response would be similar across both pieces. Finally, based on self-reports, none of the participants were familiar with either piece.

Nine extracts were selected from each piece, with some sharing many features on many levels, others sharing more surface elements but not deeper elements, still others sharing deeper elements but not surface elements, and others with very low levels of similarity at any level (musical scores of the extracts are given in Appendices A and C and descriptions of the extracts in Appendices B and D). The extracts were recorded from commercially available compact disc recordings (see Appendices B and D) onto an Apple Macintosh computer and re-recorded onto CD for presentation to listeners.

Procedure

Participants heard each piece first in its entirety. They then heard 36 extract pairs, consisting of each extract paired with every other extract in the list. The extracts were presented in quasi-random order, such that for each piece the first member of the first pair

heard was the opening motif (occurring first in the piece in real time), and the internal order of subsequent pairs followed this same order. This was to set up the piece-specific criteria for similarity judgments. As such, the order of presentation was the same for all participants. Participants rated each pair for their similarity on a scale of 1 to 11, where 1 represented minimal similarity and 11 maximal similarity. Finally, they heard each extract individually and provided a series of adjective ratings on a set of bipolar scales derived from Pollard-Gott (1983), who had found that these adjectives covered the kinds of attributes spontaneously mentioned by subjects in her study, and designed to cover a range of attributes (Table 1).

RESULTS

Listeners' ratings were treated separately for each piece, and each analysis followed the same structure. First, two factorial analyses of variance were conducted for each piece: the first included the between-subjects variable of musical training (2 levels, trained musicians and nonmusicians) and the within-subjects repeated measure of similarity ratings (36 levels), and the second included musical training and adjective ratings (12 levels). The results are summarized in Table 2.

Trained musicians and nonmusicians gave equivalent similarity ratings for the Beethoven extracts, but the difference between the similarity ratings for the Schoenberg extracts of the two groups approached significance. There was a significant interaction between adjective ratings and musical training, and this was most marked for the Beethoven. Given these small differences, the two groups were treated separately in the following analyses. However, before collapsing the ratings for each group, it was important to determine that the listeners in each group showed reasonable agreement in their similarity judgments. Cronbach's alpha was calculated to determine intersubject reliability for each group. The reliabilities obtained indicated a high degree of commonality (Beethoven, .8463; Schoenberg, .8424), allowing judgments to be averaged across listeners.

TABLE 1
Adjective Pairs Used for Extract Descriptions

Loud	Soft
Getting Louder	Getting Softer
High	Low
Up	Down
Fast	Slow
Speeding Up	Slowing Down
Even	Uneven
Smooth	Staccato
Simple	Elaborated
Thick	Thin
Major	Minor
Open	Closed

TABLE 2
Analyses of Variance: Similarity Judgments and Adjective Ratings by Group

	Beethoven	Schoenberg
Similarity judgments	$F(35,1190) = 13.962$ $p < .0001$	$F(35,1190) = 23.196$ $p < .0001$
Similarity judgments × Musical training	$F(35,1190) = 1.159$ $p = .2431$	$F(35,1190) = 1.408$ $p = .0588$
Adjective ratings	$F(11,3729) = 10.191$ $p < .0001$	$F(11,3751) = 9.423$ $p < .0001$
Adjective ratings × Musical training	$F(11,3729) = 3.556$ $p < .0001$	$F(11,3751) = 1.96$ $p = .025$

Beethoven Piano Sonata Op. 10, No. 1, Movement 1

To gain an impression of how each group organized the global attributes of the musical extracts, a simple multidimensional scaling analysis was carried out on the similarity matrices for both groups individually.[1] A two-dimensional solution was chosen in both cases, given the small number of data values and a reasonable fit to each group's data (trained musicians $R^2 = .83$, Kruskal stress = .192, nonmusicians $R^2 = .893$, stress = .126). Simple correlations were carried out between the emergent dimensions and listeners' adjective ratings, to explore whether listeners' descriptions of the extracts related to their similarity judgments (Table 3).[2] The dimensions were also interpreted in the light of potential thematic relationships that are not incorporated in the list of adjective ratings (see Appendix B for brief descriptions).

For the trained musicians, the first dimension is clearly explained by dynamics, articulation and texture. Extracts with loud dynamics, staccato rhythmic figures, and full chords (notably the opening of the piece, Extract A) were located at one end of this dimension, contrasted with extracts with soft dynamics, lyrical melody lines, and flowing accompaniments (including the second theme, Extract E). This also corresponds to listeners' de-

1. Multidimensional scaling is a tool for uncovering the global relational information that listeners use, is based on a similarity matrix that is derived from listeners' pairwise comparisons, and produces a range of multidimensional arrangements of the individual data points. For the following global analyses, we used the Alscal procedure in SPSS software.

2. In the following analysis of adjective ratings, positive correlations indicate a positive relationship to similarity dimensions from the *first* adjective of the pair whereas negative correlations indicate a positive relationship to similarity dimensions from the *second* adjective of the pair. It is not possible to predict in advance which ends of the scales might be most influential, and thus recoding could not be performed.

TABLE 3
Beethoven Adjective Ratings: Correlations with Individual Multidimensional Scaling Dimensions

	Trained Musicians		Nonmusicians	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Loud/Soft	–.791**	.249	.618	–.282
Getting Louder/Getting Softer	–.467	–.693*	.405	–.250
High/Low	–.061	.936***	.596	–.024
Up/Down	.134	.664*	.499	–.229
Fast/Slow	–.309	–.059	.807**	–.583
Speeding Up/Slowing Down	–.239	–.108	.328	–.117
Even/Uneven	.748*	–.281	–.520	.082
Smooth/Staccato	.811**	–.261	–.542	.078
Simple/Elaborated	.372	.251	–.595	.591
Thick/Thin	–.766*	–.181	.554	–.306
Major/Minor	.614	.109	.112	–.194
Open/Closed	.583	.324	–.119	.490

*$p < .05$. **$p < .01$. ***$p < .0001$.

scriptions of the extracts (Table 3), as extracts described as Staccato, Loud, Thick, and Uneven were contrasted with those described as Smooth, Soft, Thin, and Even. The second dimension relates to pitch height and contour, with the two extracts with stridently descending melodic lines and lower pitches grouped at one end, contrasted with those emphasizing high pitches and ascending melodic lines. This is partly supported by listeners' descriptions: extracts described as Low, Down, and Getting Louder are contrasted with those described as High, Up, and Getting Softer. However, the descriptions of dynamics does not relate clearly to this dimension, as two extracts that have gradual crescendi to fortissimo are located at either end of this dimension, suggesting that listeners may not have described these extracts wholly accurately (see Discussion).

For the nonmusicians, the first dimension is also explained by dynamics and articulation, with a very similar arrangement to the trained musicians, although for this group the dynamics at the *ends* of the extracts seem more influential than either initial or overall dynamic levels. This does not relate to these listeners' descriptions (Table 3), which indicate that extracts described as Fast are contrasted with those described as Slow (the Fast extracts relating to the softer and more lyrical end of the dimension). The second dimension is related to texture and pace, with extracts with a faster rate of harmonic change and more complex textures contrasted with slower and more simple extracts. Although none of the correlations between nonmusicians' descriptions and this dimension were significant, extracts described as Simple and Slow are contrasted with those described as Elaborated and Fast (where $p < .1$).

It appears that motivic relations do not emerge as clear determinants of the dimensions. The clearest indication of motivic relatedness occurs in the first dimension for both groups. However, more surface level features are intricately associated with these thematic relations, such that themes are grouped with other extracts that share dynamics, texture, and smoothness. Thus, for example, the second theme (Extract E) is grouped with a new theme from the development section that shares its Alberti accompaniment and flowing melodic lines (Extract G) and with a bridging extract (D) that shares only its melodic feature of a rising sixth in the melody line. The restatement of the second theme in a minor key (Extract H) is located farther along this dimension, although closer to the second theme (E) than to the opposite pole of the opening theme (A).

In order to examine the relative weight that the two groups put on the different dimensions, an INDSCAL analysis was performed, entering the similarity matrices for the trained musicians and nonmusicians as separate "individuals." The INDSCAL solution in two dimensions fitted both groups equally well (trained musicians R^2=.802, Kruskal stress = .184, nonmusicians R^2 = .847, stress = .151). The dimensions are shown in Figure 1.

The first dimension clearly relates to the first dimensions of both groups and is based upon dynamics, articulation, and texture. Overall this dimension accounted for 70.1% of the variance in listeners' similarity ratings.

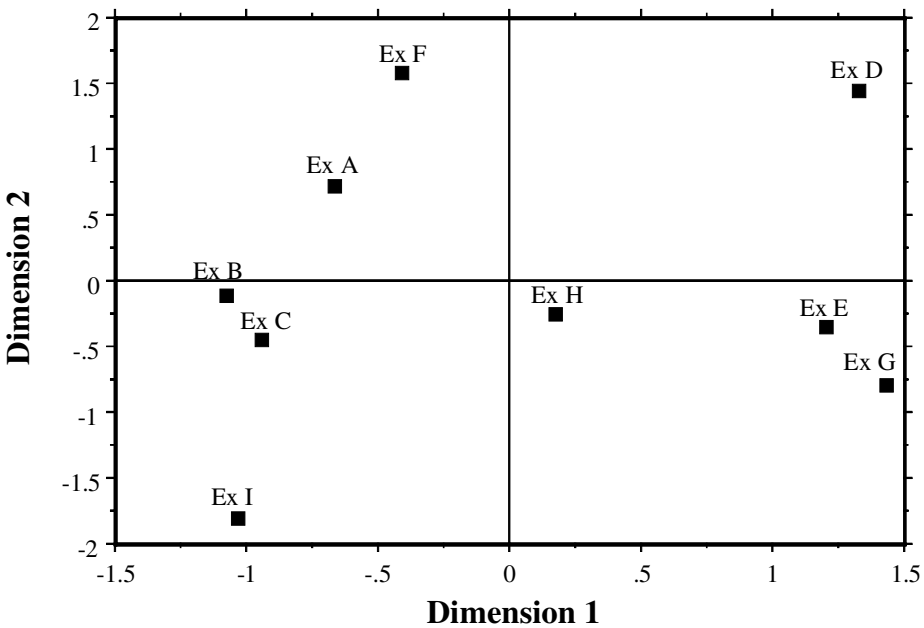

Fig. 1. Beethoven: INDSCAL multidimensional scaling analysis.

For trained musicians, the weight placed on this dimension was .8551, whereas for nonmusicians, the weight was .819. This also corresponded to listeners' adjective ratings from both groups (Table 4), with extracts described as Smooth, Even, Soft, and Thin being used by both groups to contrast with extracts that were Staccato, Uneven, Loud, and Thick.

The second dimension relates to contour and tessitura, with descending extracts (Extract I being a marked example) being contrasted with extracts that rise in contour and have higher tessituras (e.g., extract F, the opening of the development). Overall, this dimension accounted for 12.3% of the variance in listeners' similarity ratings. For trained musicians, the weight of this dimension was .2652, whereas for nonmusicians, the weight was .4192. This again corresponded to listeners' adjective ratings (Table 4), with the extracts described by trained musicians as Up and Simple contrasted with those rated Down and Complex. The nonmusicians' descriptions do not relate to this dimension, although the descriptions of Fast compared with Slow almost reached significance ($p = .0572$).

In summary, these analyses show that there are differences between the two groups of listeners in terms of both the similarity judgments and adjective ratings of the Beethoven extracts. The most significant dimension of the similarity judgements appears to be dynamics and articulation, and this is supported by listeners' descriptions of the extracts. A subsidiary dimension of similarity judgments relates to contour and tessitura, which reflects the trained musicians' descriptions. Motivic relationships do not play a role independently of these more surface features of the extracts, although

TABLE 4
Beethoven Adjective Ratings: Correlations with Global INDSCAL Dimensions

	Trained Musicians		Nonmusicians	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Loud/Soft	–.736*	–.208	–.746*	–.242
Getting Louder/Softer	–.560	–.639	–.369	–.549
High/Low	.047	.612	–.723*	–.042
Up/Down	.208	.665*	–.611	–.357
Fast/Slow	–.274	–.643	–.474	–.651
Speeding Up/Slowing Down	–.197	–.594	–.089	–.421
Even/Uneven	.736*	.057	.913**	.114
Smooth/Staccato	.787**	.308	.951***	.148
Simple/Elaborated	.362	.822**	.616	.562
Thick/Thin	–.757*	–.543	–.683*	–.307
Major/Minor	.573	.264	.326	–.182
Open/Closed	.629	.603	.613	.583

*$p < .05$. **$p < .01$. ***$p < .0001$.

as would be expected from a monothematic piece, they are inextricably bound up with these at certain key points (such as the distinction between the first and second themes).

Schoenberg Klavierstück, Op. 33a

As with the Beethoven extracts, a simple multidimensional scaling analysis was carried out on the similarity matrices for both groups individually. The two-dimensional solution was chosen in both cases, given the small number of data values and a very clear fit to each group's data (trained musicians R^2 = .9798, Kruskal stress = .067, nonmusicians R^2 = .9879, stress =.055). Simple correlations were carried out between the emergent dimensions and listeners' adjective ratings, and the dimensions were also interpreted in the light of potential thematic relationships (see Appendix B for details).

For the trained musicians, the first dimension appears to be organized according to relative tempo and dynamics. Extracts that are loud (and/or that involve an extreme crescendo) and fast are grouped together and contrasted with extracts that are quiet and at a moderate speed (Extracts A, D, E, and H), and extracts that are in between have attribute values midway between these extremes (e.g., Extract C crescendos and decrescendos like Extract A but is louder overall; extract B shares contour, texture, and dynamics with Extract A but is faster, and so on). This corresponds very closely to listeners' descriptions (Table 5), with extracts described as Loud, Getting Louder, High, Up, Fast, Speeding Up, Staccato, and Elaborated all

TABLE 5
Schoenberg Adjective Ratings: Correlations with Individual Multidimensional Scaling Dimensions

	Trained Musicians		Nonmusicians	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Loud/Soft	.989***	.495	.971***	.121
Getting Louder/Softer	.827**	.241	.917***	–.034
High/Low	.804**	.161	.939***	.126
Up/Down	.832**	.252	.901**	.084
Fast/Slow	.972***	.341	.965***	.163
Speeding Up/Slowing Down	.885**	.364	.913**	.108
Even/Uneven	–.517	–.335	–.570	–.505
Smooth/Staccato	–.870**	–.435	–.872**	–.235
Simple/Elaborated	–.903**	–.261	–.795**	–.226
Thick/Thin	.547	.804**	.799**	.021
Major/Minor	.100	–.497	.900**	.183
Open/Closed	.052	–.174	.641	.349

*$p < .05$. **$p < .01$. ***$p < .0001$.

being contrasted with extracts described as Soft, Getting Softer, Low, Down, Slow, Slowing Down, Smooth, and Simple. The second dimension corresponds to texture: extracts with chordal movement (A, C, F, and I) are grouped together and are maximally distant in the similarity space from extracts that involve melodic movement (B, E, and H). This is supported to some extent by the adjective ratings, which show extracts rated as Thick are contrasted with extracts rated as Thin.

Again, the first dimension for the nonmusicians corresponds to relative tempo and dynamics, although with some differences in the location of Extracts A, B, and C (Extracts A and G were judged more similar by the nonmusicians than by the trained musicians). This may be because nonmusicians are responding more to the ending of fragments: for example, the slow ending of Extract G makes it more similar to Extract A, and the slow ending of Extract B makes it less similar to Extract C. This is again supported by the adjective ratings (see Table 5), which include Thick and Major contrasted with Thin and Minor in addition to the same group of adjectives as the trained musicians for this dimension. No clear interpretation emerges for Dimension 2. Placement of Extract C with the more melodic extracts suggests that texture is not the main criterion here. One possibility is that this dimension corresponds to the rhythmic character of the extracts: metrically regular extracts (e.g., Extract A) are maximally distant from metrically irregular/unmetrical extracts. This dimension is not explicable in terms of this group's adjective ratings (nor in terms of the trained musicians' ratings).

The correlation of tempo with dynamics that emerges from the similarity ratings reflects the way in which these attributes are confounded in the extracts presented to participants (e.g., extracts are loud and fast, or quiet and slow, but never fast and quiet). One point to emerge from the similarity ratings is that other attributes (in this case, contour, articulation, and register) are partly, but not completely confounded in the extracts used (e.g., there is a tendency for slow and quiet extracts to have a flat contour, with the exception of Extract A, where the contour is arch shaped). Thus, their absence as a controlling factor in the similarity space points to the lesser importance of these attributes in listeners' similarity judgments.

The influence of motivic relations does not emerge as a clear determinant of the dimensions. In accordance with serial music theory relating to this piece, all thematic material corresponds to a statement of a pair of combinatorially related sets, but the two main subjects use different segmentations of the serial material: the second subject stresses the hexachords resulting from the combinatorial pair, treating them as antecedent and consequent, but as a consequence has no distinctive harmonic identity; the first subject segments the material in terms of tetrachords, resulting in much more distinctive harmonic formations (the development segments into

trichords; Cook, 1987, p. 326). Dimension 1 reflects some thematic grouping: coda and development material is grouped at one extreme of the dimension, with second subject material at the other extreme—this is most apparent for the musicians. However, both groups of listeners position the first statement of the first subject (Extract A) with the second subject extracts: it appears that listeners are more influenced by the surface characteristics it shares with the second subject (slow and soft) than the harmonic and contour features it shares with the other second subject statements. Neither is the attempt to the emulate the tensional arch shape of classical sonata form through transpositional level reflected in the similarity ratings: Extract F constitutes a "modulation" away from the home statement of the row and is correspondingly placed at maximum distant from Extract A on Dimension 1; however, it is not maximally distant from Extract C (with which it shares more surface features) even though according to this account it should be. In summary, Dimension 1 corresponds to serial structure only where serial structure is confounded with surface characteristics such as texture.

In order to examine the relative weight that the two groups put on the different dimensions, an INDSCAL analysis was again performed. The INDSCAL solution in two dimensions fitted both groups equally and very well (trained musicians $R^2 = .944$, Kruskal stress = .121, nonmusicians $R^2 = .972$, stress = .077). The dimensions are shown in Figure 2.

The first dimension clearly relates to the first dimensions of both individual groups and is based on tempo and dynamics. Overall, this dimension accounted for 88.33% of the variance in listeners' similarity ratings. For trained musicians, the weight placed on this dimension was .9631, whereas for nonmusicians, the weight was .916. This also corresponded to listeners' adjective ratings from both groups (Table 6), with extracts described as Loud, Getting Louder, High, Up, Fast, Speeding Up, Staccato, and Elaborated being used by both groups to contrast with extracts described as Soft, Getting Softer, Low, Down, Slow, Slowing Down, Smooth, and Simple (and Major versus Minor also being used by the nonmusicians).

The second dimension seems to be described by texture, although this is less clear: there is still a distinction between chordal and melodic extracts, with chordal Extracts A, C, F, and I grouped together. Overall, this dimension accounted for 7.49% of the variance in listeners' similarity ratings. For trained musicians, the weight of this dimension was .1285, whereas for nonmusicians the weight was .365. This was only partly supported by the adjective ratings, with extracts described by the trained musicians as Thick being contrasted with those described as Thin ($p = .0581$).

In summary, these analyses suggest that the two groups of listeners differ in terms of similarity judgments and adjective ratings of the Schoenberg

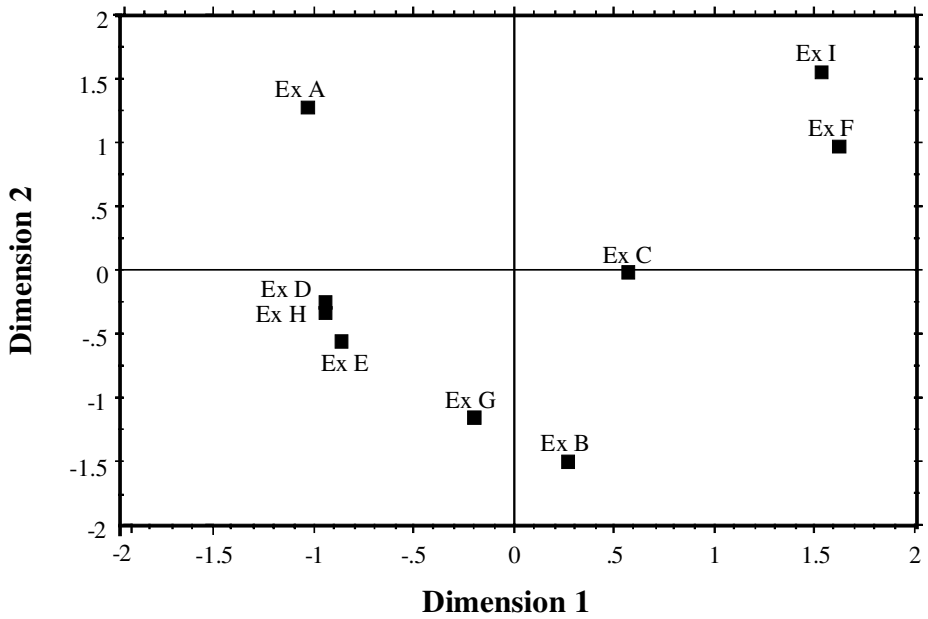

Fig. 2. Schoenberg: INDSCAL multidimensional scaling analysis.

extracts. The most significant dimension for both groups appears to be tempo and dynamics, supported by subjects' adjective descriptions of the extracts. A subsidiary dimension appears to be related to texture, although

TABLE 6
Schoenberg Adjective Ratings: Correlations with Global INDSCAL Dimensions

	Trained Musicians		Nonmusicians	
	Dimension 1	Dimension 2	Dimension 1	Dimension 2
Loud/Soft	–.997***	–.413	–.967***	–.431
Getting Louder/Softer	–.837**	–.490	–.872**	–.516
High/Low	–.797**	–.350	–.947***	–.406
Up/Down	–.811**	–.520	–.877**	–.410
Fast/Slow	–.977***	–.289	–.975***	–.388
Speeding Up/Slowing Down	–.896**	–.501	–.895**	–.418
Even/Uneven	.530	.061	.682*	–.149
Smooth/Staccato	.926***	.319	.849**	.338
Simple/Elaborated	.873**	.336	.832**	.208
Thick/Thin	–.564	–.649	–.756*	–.440
Major/Minor	–.051	.175	–.952***	–.309
Open/Closed	.012	–.286	–.717*	.018

*$p < .05$. **$p < .01$. ***$p < .0001$.

this is supported only partly by listeners' adjective ratings. Motivic relationships based on serial structure do not appear to influence listeners' similarity ratings, although serial structure and surface characteristics are confounded in a number of examples. This agrees with Nicholas Cook's observation that the piece reverses tonal practice: "harmonic structures play a surface role in [Schoenberg's] sonata, while phrase structure and texture are the main means of formal articulation" (Cook, 1987, p. 333).

DISCUSSION

The results of this study provide important evidence for the kinds of similarity relationships that are perceived by listeners under relatively short-term conditions. For the Beethoven piece, the primary dimension relates to dynamics, articulation and texture whereas the subsidiary dimension relates to contour and tessitura. For the Schoenberg piece, the primary dimension relates to tempo and dynamics and the subsidiary dimension relates to texture. This indicates that the two pieces set their own similarity criteria within which listeners made appropriate judgments, but also suggests that two surface features of both pieces may have been more salient to the listeners, notably dynamics and texture. However, even these were used in different ways and combinations across the two pieces, providing further evidence for the context-specific nature of listeners' judgments of similarity relations in music.

As expected, there were differences between the judgments made by listeners with musical training and those without, although these are comparatively slight. As noted earlier, one such difference may be explained by the emphasis placed by musically untrained listeners on the features associated with the endings of extracts (final dynamics for Beethoven and final tempo for Schoenberg). Listeners often commented that it was difficult to categorize the extracts globally in the adjective rating task, because extracts often exhibited features at both ends of the bipolar scale (e.g., loud and soft). They were encouraged to use their global impressions, and it appears that untrained listeners based their similarity judgments on the final parts of the extracts. This may reflect a shorter term processing of the extracts, leading to "recency" effects, in contrast with the longer term processing by the trained musicians, which leads to an ability to treat the properties of the extracts in a global manner. This conflicts with the typical findings from previous research in music psychology (discussed earlier) that less experienced listeners are less able to respond "analytically" to musical sequences, and also with findings from Deliège (2001) suggesting that the beginnings of extracts are most salient for listeners. Further research is needed to clarify this issue.

Although there are similarities between the two groups, listeners did vary considerably in their descriptions of the extracts (as shown by the adjective

ratings). The nonmusicians were less able to provide consistent descriptions of the extracts according to surface features. For example, those extracts in the Beethoven piece that involved simple melodic lines with an Alberti bass accompaniment were differentiated by nonmusicians as Fast in comparison with the strident staccato extracts, which were described as Slow. However, the similarity ratings show that these listeners were able to perceive these features accurately and use them as the basis for making similarity judgments (as shown by the differentiation of these extracts along the second dimension). This suggests that the adjective rating task may not tap the same kind of knowledge as the similarity judgments, and that the gap between the two tasks is particularly wide for listeners without formal musical training.

In this short-term context, there is no evidence to suggest that listeners are using thematic or motivic similarities, even listeners with musical training. As discussed earlier, these motivic relationships often coincide with surface variations, with the consequence that important structural features (e.g., the difference between the two thematic groups in sonata form) are emphasized. However, the choice of extracts was designed to enable a comparison of the relative importance of deeper and more surface features, and on this basis, listeners prioritized the more surface features (as illustrated by the similarity ratings for the Beethoven piece). It is not possible to predict from the current study how this might change with repeated hearings and, therefore, with increased familiarity for the particular pieces, although Pollard-Gott (1983) has shown that increased familiarity leads to greater use of motivic similarities. It is apparent that familiarity with the musical *style* did not lead to greater thematic detection, as no more evidence of thematic relations was found in the Beethoven piece than in the Schoenberg piece (as might have been expected). It would be interesting to explore the effects of increased familiarity with the two pieces over time and investigate any differences in the development of similarity relations between the two musical styles.

Implications

In this article, we have outlined some new directions for empirical research in the perception of similarity relations in different musical styles. When considering how listeners respond to musical styles, it is important to incorporate views from music theory as to how these styles are constructed. General cognitive psychological approaches to similarity also provide a fuller understanding of how these processes may operate in music listening.

"Deep" levels of structure (e.g., motivic/thematic relationships) are often given primary emphasis by the music theoretical literature pertaining

to similarity relations, yet our evidence from the similarity ratings of extracts suggests that listeners use surface attributes when responding to these pieces of music. Should this suggest that the music theoretic literature has little to offer music psychology? The lack of evidence to support judgments based on thematic and motivic similarity is probably due to the short-term nature of the study, and we would suggest that in time, or with explicit instruction, listeners may come to recognize and use these kinds of relationships to guide their similarity judgments. However, it is possible that "deep" structure, of the sort described by music theory, may never be used in music listening in what Cook terms a "musical" mode of listening (i.e. "listening to music for the purposes of direct aesthetic gratification," Cook, 1990, p. 152). In particular, existing evidence militates against any perceptibility of the tone row (Bruner, 1984; Krumhansl, Sandell, & Sergeant, 1987; Stammers, 1994). It is more plausible that these "deeper" levels of musical structure may reveal themselves only under more "musicological" listening (listening to music to establish "facts or formulation of theories"; Cook, 1990, p. 152) or under conditions of extreme familiarity such as those envisaged by Schoenberg, to whom we give our final words via his student, Rufer (1954):

> The whole collection of themes in a work, though apparently independent of one another, can be traced back to a single basic idea . . . *whether or not one can recognise and demonstrate these relations in every case* [italics added]. This corresponds to the thesis that a work of art is a unity, the unity existing even where it cannot be exactly demonstrated (p. 29).[3]

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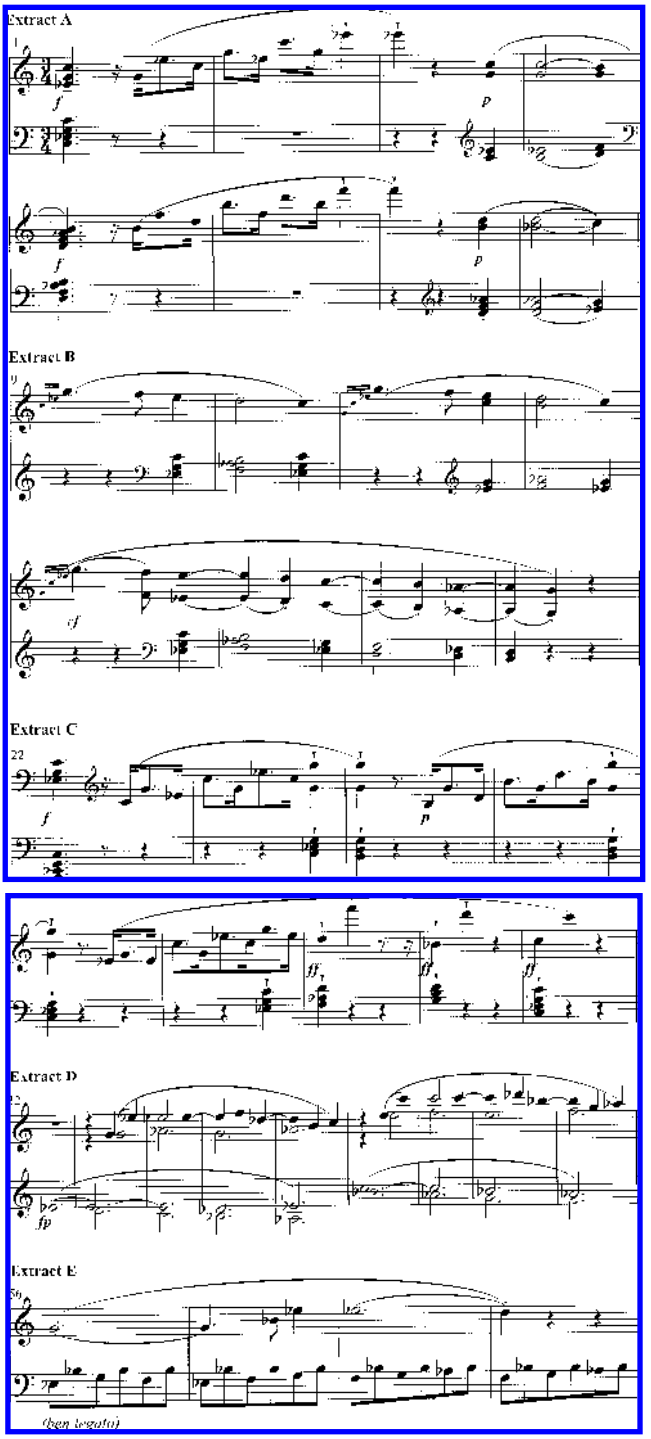
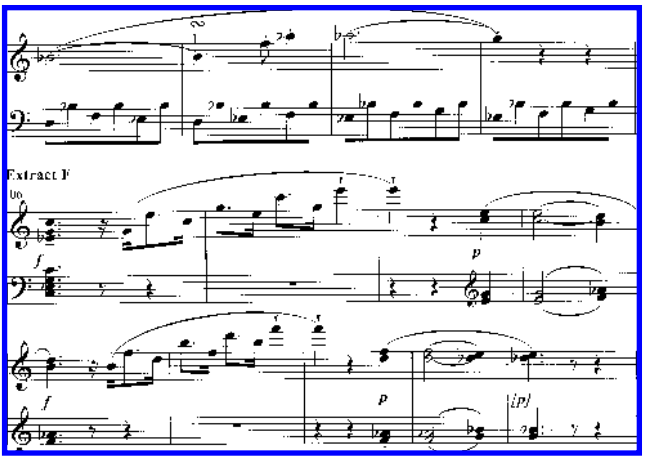
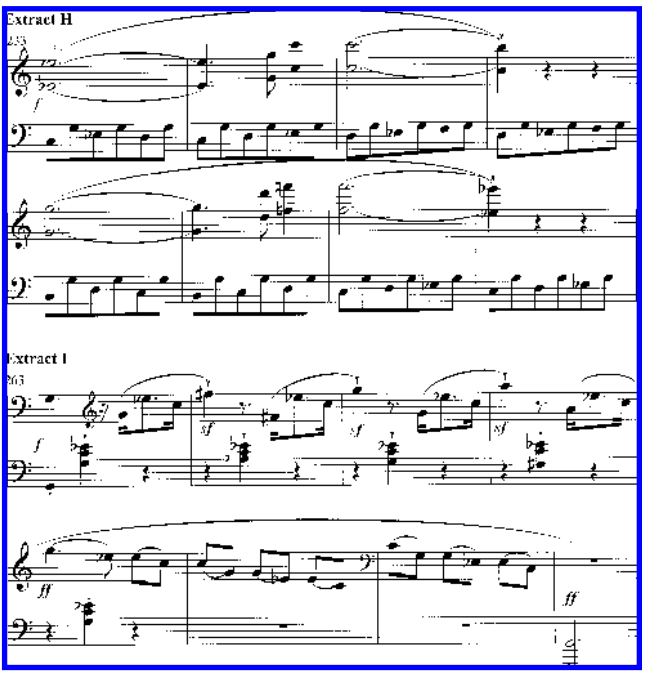
Appendix A
Beethoven Piano Sonata Op. 10, No. 1, First Movement
Extracts Used




Extract F
106
f
p
f
p
[p]


Extract H
253
f
Extract I
263
f
sf
sf
sf
ff
ff

Appendix B
Description of Extracts: Beethoven Piano Sonata Op. 10 No. 1, First Movement

EXTRACT A (MM. 1–8)

Opening of piece. Presents the first subject material, which consists of a strident *forte* chord followed by a rising arpeggiated figure, built around a rising sixth interval, in dotted rhythm and completed by a short *piano* closing figure. This is presented first in the tonic and then repeated on a dominant harmony. The overall dynamics consist of contrasting loud and soft passages, and the contour is mainly rising.

EXTRACT B (MM. 9–16)

Immediately following Extract A, this section begins *piano* with a linear descending appoggiatura-style melodic line accompanied by chords. The first two bars are repeated with variations in ornamentation and accompanying chords. The second half repeats and extends the linear descending melody in octaves, ending on the dominant with gradually increasing dynamics to *forte*. The overall contour is falling.

EXTRACT C (MM. 22–30)

The opening of this extract borrows thematic material from Extract A, the first subject, and develops the rising arpeggiated figure into an upbeat to downbeat rhythmic motif, emphasized by octave doubling and strident chordal accompaniment. This two-bar phrase is restated on the dominant, and the final five bars consist of an extended version of this pattern with a gradual crescendo to *fortissimo* cadencing (with the rhythmic emphasis now on first and second beats of the bar).

EXTRACT D (MM. 32–40)

This extract consists of transitional material built around the rising sixth motif of the first thematic material. Harmonically this begins on the relative major E♭, and the second half provides a modulation to F minor. Bar-length sustained notes in the bass are paired with a syncopated appoggiatura-style treble melody that falls from the rising sixth. Four bars of the opening five are repeated to form the second part of this phrase.

EXTRACT E (MM. 56–63)

This extract consists of the second subject material, also based around the opening motif of a rising sixth and including the appoggiatura element from Extract A. In relative major key (E♭), a rising and falling treble melody is paired with an Alberti-type eighth-note movement accompaniment, neatly divided into two 4-bar phrases. The extract outlines a harmonic movement from tonic to dominant and back to tonic following a typical antecedent and consequent pattern. Dynamics are *piano* throughout.

EXTRACT F (MM. 106–114)

At the opening of the development section, this presents the first subject material in its tonic major key. Dynamics again alternate between loud and soft. Each four-bar phrase ends on a diminished chord, and the extract ends with a repetition of the diminished chord rather than a movement directly to new material (as occurred in m. 9), thus creating a slight phrase asymmetry.

EXTRACT G (MM. 118–125)

From the development, this extract is based on the second subject material presented in F minor. It also consists of an antecedent-consequent movement from tonic to dominant and returning to tonic. More tension is created here by the use of chromatic semitone movement and the octave doubling of the melodic line. The extract also includes a crescendo at the start of the second half and thus although beginning *piano*, the overall dynamic levels are louder than Extract E.

EXTRACT H (MM. 233–240)

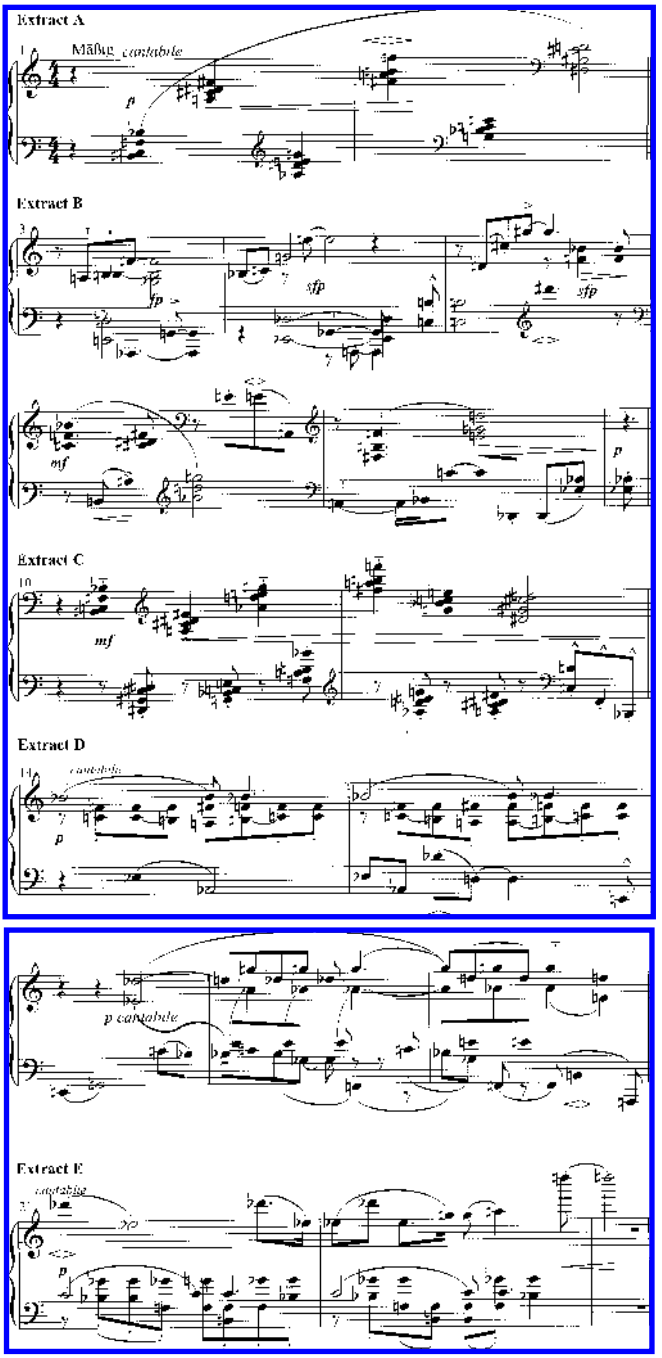
This extract begins the restatement of the second subject material in the recapitulation. It is presented in the tonic (minor), includes octave doubling of the melodic line, and its dynamic is a constant *forte*.

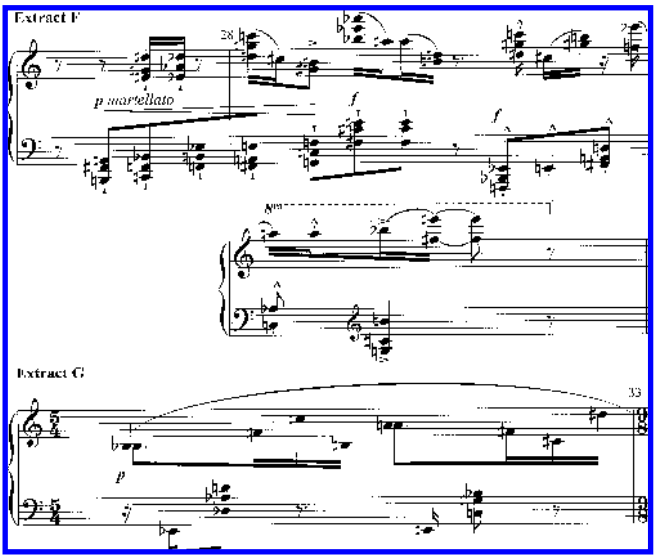
EXTRACT I (MM. 263–270)

From the coda section of this movement, this extract is based on a fragmentation of the initial dotted and arpeggiated figure from the first subject, this time broken into one-bar units that involve *forte* cadencing on the dominant. The second half of this extract consists of a descending arpeggio, *fortissimo*, which reaches a low bass dominant octave.

The recording used here was Elektra Nonesuch, Beethoven—The Complete Sonatas, performed by Richard Goode (CD 7559 79328-2).

Appendix C
Schoenberg Klavierstück Op. 33a
Extracts Used




Extract F
28
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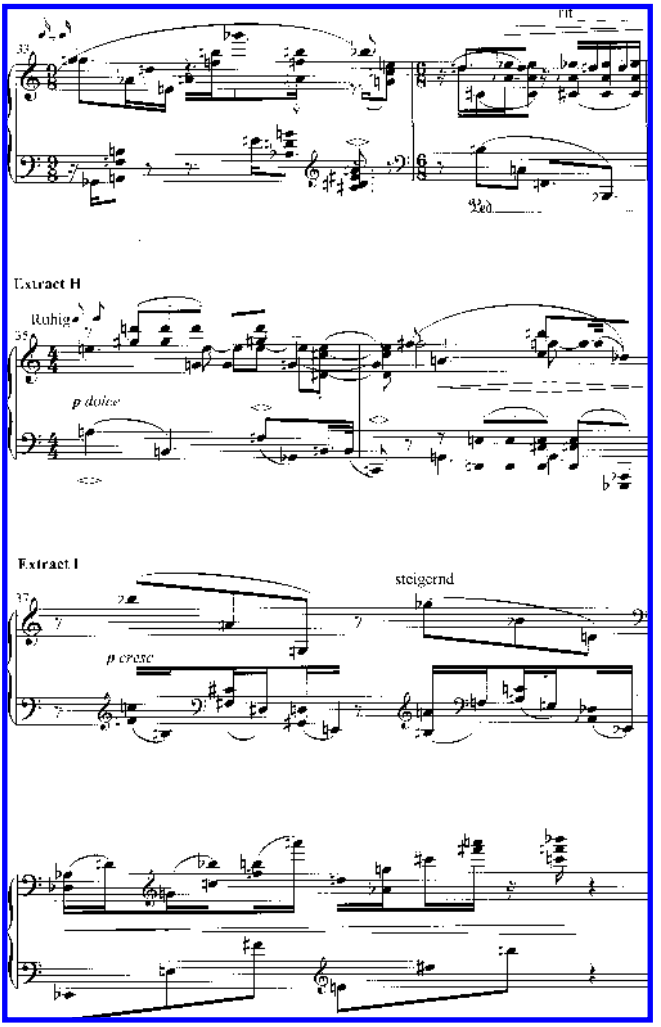
f
f
8va
Extract G
33
p


33
Fit
Extract H
Ruhig
35
p dolce
Extract I
37
steigernd
p cresc

Appendix D
Description of Extracts: Schoenberg Klavierstück Op. 33a

(This description includes the variants of the row forms used in this piece. P = prime; I = inversion; R = retrograde; RI = retrograde inversion. The letters refer to the starting point of the pitch of the row in relation to P-0. For more information see Perle, 1968.)

EXTRACT A (MM. 1–2)

Opening of piece. Presents a linear statement of the primary harmonic material (row forms P_0 and RI_5). This material is hexachordally combinatorial (i.e., one hexachord forms a 12-note aggregate with a transformation of itself: P-0 & I-5 and R-0 & RI-5). The collection is divided into tetrachords in the form of a chordal texture. It forms a single phrase but the arch contour provides symmetry. There is regular quarter-note movement and a crescendo through the phrase with a slight diminuendo (in this performance).

EXTRACT B (MM. 3–8/1)

This is an episode based on the opening theme. Bars 6–7 are based on P-0 & I-5 / R-0 & RI-5 used one after another. The harmonic content of fourths is maximized (mm. 5–6). The arch contour provides symmetry but stretches the arch of Extract A over 5 rather than 2 bars. The texture is arpeggiated. There is a rhythmic motif of four eighth notes then minim and a crescendo, plus *forte-piano* on the third beat of bars 3, 4, and 5.

EXTRACT C (MM. 10–11)

Return of first subject. This extract uses the home harmonic material of P-0 & I-5. A single phrase, but the arch contour provides symmetry. As with extract A, the texture is chordal but there are twice the number of chords as before in regular quarter-note movement. The crescendo and diminuendo follow the arch shaped contour of the pitch structure.

EXTRACT D (MM. 14–18)

Second subject. Uses same harmonic material, P-0 & I-5, but hexachords are treated as antecedent and consequent. Because the hexachords contain every interval in a balanced distribution, the theme has no striking harmony identity. (Association of second subject passages depends on texture and register instead.) The extract falls into two equal two-bar phrases with an eighth-note accompaniment figure to the right-hand melody, regular eighth-note movement, soft dynamics, and a flat contour (with a step up to a higher register for the second phrase).

EXTRACT E (MM. 21–23/1)

Return of second subject. The hexachords are treated as antecedent and consequent. A chordal accompaniment figure accompanies the right-hand melody. A regular eighth-note pattern, with soft dynamics, and the same flat contour as Extract D (with a slight inverted arch shape).

EXTRACT F (MM. 27/3–29/2)

Development. Pairs of combinatorially related hexachords are presented. First, there is a "modulation" to the second fifth above P-7/RI-0, then the first fifth above (traditionally this would happen at the second subject in tonal sonata form). There is a thick chordal

texture (of superimposed fourths) and broken arpeggios. Loud dynamics and a number of short rising units.

EXTRACT G (MM. 32/3–34)

Recapitulation of first subject. Pitch material is presented at another fifth descent, restoring the original "key" (P-0 & I-5 and R-0 & RI-5). The symmetry of Extract A is retained but the phrase is registrally expanded in a broken arpeggiation. A snap figure appears in the left hand, dynamics are soft with a crescendo, and it follows the typical arch shape, although flattened at the end (m. 34), which constitutes a very different idea than that of Extract A or C.

EXTRACT H (MM. 35–36)

Recapitulation of second subject. Hexachords are treated as antecedent and consequent. Like Extract D, there is chordal accompaniment against a right-hand melody, regular eighth-note movement, soft dynamics, and a slight descent from a high register.

EXTRACT I (MM. 37–38/3)

Coda. The harmonic material consists of P-0 and I-5/R-0 and RI-5 used one after the other. An inverted arch shape spans two bars. The texture is arpeggiated and thick due to sixteenth-note movement, with soft dynamics and a crescendo.

The recording used here was Deutsche Grammophon/Polydor International, *Schoenberg—The Piano Music*, performed by Maurizio Pollini (CD 423 249-2 GC).