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MUSIC IN THE MOMENT? REVISITING THE EFFECT OF LARGE SCALE STRUCTURES[1,2]

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Summary.—The psychological relevance of large-scale musical structures has been a matter of debate in the music community. This issue was investigated with a method that allows assessing listeners' detection of musical incoherencies in normal and scrambled versions of popular and contemporary music pieces. Musical excerpts were segmented into 28 or 29 chunks. In the scrambled version, the temporal order of these chunks was altered with the constraint that the transitions between two chunks never created local acoustical and musical disruptions. Participants were required (1) to detect on-line incoherent linking of chunks, (2) to rate aesthetic quality of pieces, and (3) to evaluate their overall coherence. The findings indicate a moderate sensitivity to large-scale musical structures for popular and contemporary music in both musically trained and untrained listeners. These data are discussed in light of current models of music cognition.

For listeners, music is apparently more than a simple succession of nice tones. These sounds are integrated into small units, which are then integrated into larger ones, leading to a large unified hierarchical organization. This view of Western musical structure has been predominant in numerous accounts in music theory (Czerny, 1949/1979; Koch, 1865/1983; Riemann, 1882/1909; d'Indy, 1912; Conyus, 1933; Schenker, 1935; Meyer; 1956; Cooper & Meyer, 1960; Schoenberg, 1967; Lerdahl & Jackendoff, 1983), as well as in music psychology (Dowling & Harwood, 1986; Bigand, 1993; Deutsch, 1999). Does a strong reorganization of the temporal structure of a piece (called "musical form" by music theorists) affect both the expressivity and the feeling of coherence, as Hodeir (1951, p. 15) claimed: "A musical phrase, no matter how beautiful it is, reaches its expressive summit only when it is in perfect harmony with preceding and following phrases. What would be a musical piece whose parts, far from working as a whole, could be suppressed, replaced, transplanted?" Alternative views have, nevertheless, been proposed. Recently Levinson (1997) argued in favour of a concatenationist approach of perceived temporal structure that is radically opposite Hodeir's.

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According to a strict concatenationist approach, music is perceived moment-by-moment, all structures being local and transient.

Empirical research in perception of large-scale structure provided support for a concatenationist approach (see below), and some authors have even suggested that hierarchical accounts of musical structures describe more closely the structure intended by composers than the structures perceived by listeners (Cook, 1987). The question remains whether listeners perceive large-scale structures moment-by-moment as suggested by Levinson, and if not, what kinds of overall structures they do perceive. The purpose of the present study was to reconsider listeners' perception of large-scale musical structures by manipulating the temporal structure of 20th century pieces of music. Before going into this experiment, it is useful to consider briefly how musical form and musical time arise theoretically from a musical and psychological point of view.

Music Theory Perspective

Music theorists usually view musical form as an essential aspect of music composition. Musical form is supposed to guarantee the unity and the coherence of the work. In his book Fundamentals of Musical Composition, Schoenberg (1967, p. 1) claimed: "Without organization music would be an amorphous mass, as unintelligible as an essay without punctuation, or as disconnected as a conversation which leaps purposelessly from one subject to another." Since the mid-eighteenth century, music theorists have developed two opposing models of musical form that are often called *architectonism* and *organicism*. On the one hand, *architectonism* (Czerny, 1849/1979; Koch, 1865/1983; Riemann, 1882/1909; d'Indy, 1912; Conyus, 1933; Cooper & Meyer, 1960) considered musical form a combination of patterns, motives, sentences, and periods organized according to principles such as repetition, contrast, and symmetry. On the other hand, *organicism* (de Momigny, 1806; Marx, 1841-1847; Schering, 1911; Schenker, 1935; Salzer, 1962) considered musical form as a living organism in which the structure is unfolded from a "seed." In Theory of Organic Coherence Schenker (1935) regarded musical form as deployment of a fundamental structure (*Ursatz*) by means of techniques of prolongation. The main difference between these two models lies in the attention given to the foreground level (musical surface) or to the background level in the process of music analysis. Thus, *architectonism* focused on metric hierarchies and thematic aspects, while *organicism* focused on tonal hierarchies and leading voice (the melodic movement of each instrumental part).

Compared to these extreme two models, contemporary music theory presents a more balanced approach. Lerdahl and Jackendoff's Generative Theory of Tonal Music (1983) is mostly based on nonthematic aspects. Even so, thematic structure may have an indirect influence at least in the grouping structure of the model. This generative theory proposes a theoretical framework describing the listeners' perceptual processing which allows them to grasp the hierarchical structure from the musical surface: "pitch-events are heard in a strict hierarchy, . . . structurally less important events are not heard simply as insertions, but in a specified relationship to surrounding more important events" (p. 106).

However, these theoretical assumptions were contradicted in a provocative claim by the philosopher Levinson (1997), who built on a position of Gurney (1880) referred to as *concatenationism* by Levinson. In its most extreme form, concatenationism asserts that musical understanding, enjoyment, and value arise entirely from the impressiveness of a composition's individual parts and from the succession of adjacent parts. According to Levinson (1997, p. 35): "A piece typically 'makes no sense' to a listener when he is unable to find it coherent on a small scale, when he is unable to perceive local connections . . . when he cannot become absorbed in the music's developing present." Levinson (1997, p. 2) also argued that "the music of any extent consists of a series of successive events, which cannot be apprehended simultaneously in a single perceptual act. The parts of an architectural facade can be taken in more or less in only one sweep; the parts of a symphony cannot." Thus, large-scale relationships between parts widely separated in time should have a very weak influence on the listener's experience.

Perspective of Music Cognition

From a psychological point of view the main difficulty raised by large-scale musical structures consists in apprehending a structure that evolves through time. Listeners perceive incoming events through a short temporal window that is sliding along the event stream (Fraisse, 1957; Michon, 1978; Clarke, 1987; Bigand, 1993). The size of a temporal window (referred to as *perceptual present* in Fraisse, and as *quasi-hearing* in Levinson) is influenced by several factors, but its maximal duration is considered to vary between 5 sec. (Fraisse, 1957) over 8 sec. (Michon, 1978) to 10 sec. (Clarke, 1987) and even 30 sec. (Levinson, 1997). Inside each temporal window, all attentional resources are supposed to be allocated to the contained events, with only a few (if any) supplementary resources for processing events outside this window. As a result it may be that music is perceived from one temporal window to the next, with no consideration of what has been perceived in the preceding window (Michon, 1978). If transitions are smooth enough, one may perceive music from moment to moment without being disturbed by the absence of coherence between these moments. In fact, this is nicely illustrated by some musical pieces, referred to as "potpourri": excerpts of very famous musical pieces are linked together with the single constraint that transitions between excerpts are musically smooth. As a consequence, for listeners, there is no consideration for the overall structure created. The fact that most listeners enjoy this musical "potpourri" raises the question of the importance of large-scale structure in music perception: Are all musical pieces perceived moment-by-moment?

Several empirical studies support this view. Two aspects whose importance has been particularly stressed in musicology have been studied, tonal unity and the global organization of a musical piece. The importance of tonal closure has been underlined in most treatises on Western music (Meyer, 1956). To assess listeners' sensitivity to tonal closure, Cook (1987) manipulated musical excerpts of different duration (from 30 sec. to 6 min.) so that the tonality at the end of the excerpt was or was not different from the main tonality. Beginning music students judged the excerpts on subjective scales for their coherence, completion, pleasure, and expressiveness. The results showed an influence of tonal closure only for the excerpts as short as 30 sec. and only for scales of coherence and completion. Converging data have been reported by West-Marvin and Brinkman (1999) with explicit judgments about whether an excerpt (shorter than 2 min.) ended in the same tonality in which it started. Musically trained participants succeeded in detecting the change with 64% correct responses. In a second experiment, musical excerpts were segmented into quarters and scrambled to violate tonal closure. In this situation, subject's performance was at chance (55%) and subjects seemed "completely unaware that the large-scale musical structure of these works had been violated by the rearrangement."

Other studies have investigated the perception of form by systematically manipulating the global organization of the musical pieces (Konecni, 1984; Gottlieb & Konecni, 1985; Karno & Konecni, 1992; Tillmann & Bigand, 1996). In these studies, participants were usually required to rate the musical pieces on subjective scales, e.g., on interest, on preference, on expressivity, pleasingness, and desire to own a recording. Manipulations of the order of movements inside Beethoven's sonatas (Konecni, 1984) and of the order of the Goldberg Variations by Bach (Gottlieb & Konecni, 1985) did not result in clear changes of listeners' subjective rated judgments on interest, preferences, and expressivity. Karno and Konecni (1992) manipulated Mozart's Symphony in G Minor (K550) with shorter chunks. The subjective judgments on different scales of musically untrained participants and music students did not result in significant differences between original and modified versions. According to Karno and Konecni (1992), these results clearly question the perceptual effect of musical structures for the listener. The story may, however, be somewhat more complex since participants' ratings systematically tended to favor the original versions.

Other research provides evidence of the weak importance of large-scale

structures for listeners. In Tillmann and Bigand, (1996), short musical pieces were segmented in chunks of 6 sec. on the average. These chunks were sequenced together in the original order of the composer or in the inverted or retrograde order. The chunk-retrograde modification destroyed the global directionality of the piece but preserved the local structures inside the chunks. Nonmusician participants judged either the original or the chunk-retrograde versions on 29 subjective scales. The judgments of expressivity and coherence were not influenced by the destruction of global organization. Moreover, after the experiment, the authors explained to participants the manipulations and asked them to indicate their experimental condition. Participants of the chunk-retrograde condition were unable to say that they had listened to the manipulated pieces and responded correctly only at 43%. The interesting point was that participants of the original condition responded almost perfectly to this question. Put differently, participants of the chunk-retrograde version were unaware they listened to incoherent music, but participants of the normal condition were sure that they listened to coherent music. This finding also suggests that a sensitivity to global form might have been observed had the experimental design allowed participants to listen to both versions.

Several other experiments investigating participants' sensitivity to the temporal order of musical sections of short minuet were run with tasks such as "solving a musical jigsaw puzzle" (Tillmann, Bigand, & Madurell, 1998), detecting musical targets (Tillmann & Bigand, 1998), evaluating musical tension of chords in normal and scrambled sequences (Bigand & Parncutt, 1999), or expecting target chords in normal and scrambled sequences (Tillmann & Bigand, 2001), all pointing to the weak sensitivity to large-scale structure by both musically trained participants and nonmusicians. This overall data pattern further suggests a weak influence (if any) of the extent of musical training on perception of musical form.

Paradoxically, the few studies that provided evidence for the psychological reality of perceived large-scale structure used contemporary music pieces (Clarke & Krumhansl, 1990; Lalitte, Bigand, Poulin-Charronatt, McAdams, Delbé, & D'Adamo, 2004). For example, Clarke and Krumhansl (1990) compared perception of musical form in Stockhausen's Klavierstück IX and Mozart's Fantasy in C minor K. 475. In the first experiment, subjects were asked to indicate the main sections of the pieces. In the second experiment, subjects were asked to localize excerpts of the pieces according to the boundaries established during the first experiment. Concerning the contemporary piece, two main boundaries (common to a majority of listeners) matched the division of the Klavierstück IX into three main sections. The average values of localization judgments were correlated significantly with their positions in the piece. A recent study (Lalitte, *et al.*, 2004) investigated the perceptual structure of the five themes of The Angel of Death by Roger Reynolds. Participants segmented the piece by musical ideas while listening to the piece. Segmentation responses were strongly matched with the formal structure of the themes imagined by the composer.

In light of these rather puzzling data, the present study was designed to examine the perception of large-scale structure with a different methodological approach. Use of serious classical music for this purpose was questioned. On the one hand, it may be that Western classical music can be thought of as a prototype of musical form. On the other hand, it may also be that contemporary listeners actually are sensitive to musical forms, but no longer to those which were composed several centuries ago. The fact that the only evidence in favour of perceived large-scale structure comes from research using contemporary music is consistent with this view. Accordingly, the present study used music from the 20th century as stimuli, with popular music (Rock, Jazz, and World music) illustrating large-scale structures governed by tonal musical syntax, and contemporary music illustrating Western nontonal syntax. Using popular music instead of classical music had additional advantages. It renders the experiment more attractive for participants, an important condition to have participants fully engaged in the task. Second, it allowed us to create a strong contrast between two styles of music, popular music being usually qualified as easy-listening music, while contemporary music is often qualified as a complex style of Western music. The comparison will allow us to specify whether "ease of listening" relates to the large-scale structures or reflects only a higher familiarity with local syntactic organisations. Moreover, observing some similarity between the processing of both styles would suggest that the cognitive system is sensitive to some quality of musical time independently of style. A final benefit of using popular music was to compare musically trained participants and nonmusicians with a musical style with which they are equally familiar (because popular music is the most broadcasted style).

The present study further differs from previous studies in the way the whole structures were investigated. The original pieces exhibited a clear temporal directionality (Kramer, 1988), i.e., the pieces unfold toward successive states and developments, which lead to a "goal" (metaphorically). Accordingly, one would expect that removing this temporality would be perceptible for both musical styles. To break this temporality, the pieces were segmented into short chunks (average 6 sec. long), which were locally coherent, e.g., a chunk corresponded to a musical phrase. The chunks in the scrambled version were linked so that the transitions between two chunks did not create acoustical disruptions and, insofar as possible, did not create obvious syntactical violations. The large-scale musical structure of the pieces were reorganised in a concatenationist way: the chunks were sequenced with a local coherence but without global coherence. Destroying the large-scale structure may be assumed to reduce the ratings of coherence and the aesthetic value of the piece.

Method

Participants

Twenty musically trained participants (referred to as musicians) and 20 musically untrained students (referred to as musically untrained participants) participated in this experiment. Candidates for the final diploma in music education at Dijon Music Conservatory were regarded as musicians. They had had an average of 10 years of intensive study in musical instrument and ear training. Most had studied music theory and were familiar with contemporary music. Musically untrained participants were students in an introductory psychology course at the Université de Bourgogne. They had no formal training in music. The mean age of participants was 24 yr.

Material

The first 3 minutes of six pieces (3 contemporary, 3 popular) were chosen[3] as representative of different styles of contemporary music (Ligeti, Xenakis, and Leroux) and of popular music (Rock-Blues, Jazz, and World Music). They also illustrated different instrumental ensembles from duo to large ensembles. All the pieces exhibited a clear temporal directionality (Kramer, 1988), i.e., the pieces followed a musical progression. Many musical dimensions can bear directionality such as harmony (chord progression), instrumentation (instruments appearing successively), tempo (progressive acceleration), dynamics (long crescendo), etc. A short description of the temporal structure of each piece is given below.

Deux guitares (F. Santa Orchestra, performer).—This piece, for strings, cymbalum, and clarinet, is divided in clear, large sections marked by cadences, *rallentandi*, and short silences. The tested excerpt contains an introduction followed by seven sections (A1/B1/C/D/A2/B2). The temporal directionality arises from an increase of tempo and instrumental engagement, which increases over the 3 min.

Down Down Down (J. Satriani, composer and performer).—This is a typical Rock-Blues for lead and rhythmic guitars, bass, and drums. The excerpt is based on three cycles of chords of eight measures. The temporal directionality is created by the development of the guitar solo that progressively and constantly leads towards stronger dynamics for all instruments by varying parameters such as register (from low to high) and timbral qualities (from soft to aggressive).

[3]The stimuli for this experiment can be found on http://leadserv.u-bourgogne.fr/lalitte/examplesMIM.html.

In a Sentimental Mood (D. Ellington, composer, D. Lockwood & Niels-Henning Orsted Pedersen, performers).—This standard is played by a solo violin accompanied by a double bass. The excerpt is based on two repetitions of a sequence of chords. The directionality is largely produced by the subtle evolution in the violin part. The soloist starts by presenting the theme with highly expressive tender *ponticello* sounds played with a noisy bow without respecting a clear metrical structure. The quality of vibrato, timbre, register, the occurrence of *glissandi*, then evolves during the improvisation towards more usual playing.

Tracées (1987, I. Xenakis, composer).—This is a piece for orchestra in which sequences of sophisticated orchestral sonorities continually transform from one into another. According to the composer, it evokes the cosmic initial Big Bang, with very high dynamics and loudness. The excerpt contains seven sections of specific sonorities, which create consecutive contrasts. The directionality of the temporal structure is borne by the evolution of the orchestral sonorities.

Fleuve (2nd movement, 1987, rev. 1993, P. Leroux, composer).—This is a piece for an ensemble of 14 musicians. The excerpt explores different combinations of "point" and "line" figures (short and long notes). Temporal directionality results from continuous changes in texture and register. The piece begins with repeated notes of short duration, alternating with long sustained notes. The density of the instrumental textures then increases, with sustained notes being mixed inside large *glissandi*, trills, and vibratos.

Trio for violin, cor, and piano (1982, 2nd movement, G. Ligeti, composer).—The excerpt evokes an imagining folklore mixing of Balkanik and Latin features, notably by use of an asymmetric metric. The excerpt contains one exposition section followed by three development sections. The temporal directionality is based on the development of thematic features accompanied by a piano *ostinato*.

ProTools Free software (Digidesign) was used for editing the scrambled pieces. To define the scrambled condition, the pieces were segmented into short chunks, mostly corresponding to a functional unit. The chunks were an average of 6 sec. long (from 2.1 sec. to 15.5 sec.). There were 28 or 29 chunks per piece (28 for *Down Down Down*, *In a Sentimental Mood*, *Trio*, and *Tracées*; 29 for *Deux guitares* and *Fleuve*). These chunks were then linked in a scrambled order with the goals of (a) avoiding linking a chunk to its initially neighboring section and (b) creating transitions without obvious acoustical disruption. Also an attempt to avoid as much local incongruity as possible was made: great care was taken so that the linkages never created changes in metric, pulse, and never introduced obvious harmonic dissonances. The first and the last chunks always remained in their original position. The experiment was run with PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). The stimuli were presented over Sennheiser HD 200 headphones and a Luxman A357 power amplifier.

Procedure

The six original and six scrambled versions of the pieces were presented in a pseudo-random order, with two constraints: (1) the two versions of a piece, i.e., original and scrambled, were always separated by two other pieces and (2) two pieces of the same style were never presented consecutively. Participants listened to six original and six scrambled versions presented with a pseudo-random order for each of them. They were told that the pieces were initially segmented into chunks and that two sound engineers had then been asked to edit (to relink) the chunks in a musically coherent way. One engineer was said to be very expert in music, but the other not. Three tasks were used: (1) error detection—during the hearing of each piece, participants were required to indicate when they perceived an incoherent linkage by pressing a key on the computer keyboard that registered the exact response time. Ideally, about 27 or 28 responses should be registered in the scrambled versions. (2) Liking—at the end of the piece, participants evaluated on a subjective 20-point scale how much they liked the piece, using anchors of 0: Poor, disliked and 20: Liked very much. (3) Engineer experience—they then indicated which of the two sound engineers, experienced or inexperienced, created the piece.

Familiarity.—In addition, participants also indicated how familiar they were with the musical style on a 6-point scale with anchors of 1: Unfamiliar and 6: Very familiar, and whether they felt familiar with each specific piece on a 6-point scale with the same anchors. The experiment lasted about 50 min.

Results

Familiarity

Musically trained participants rated themselves as more familiar with contemporary music than did musically untrained participants ($M = 3.4$ vs 1.6, SDs = 1.4 and 1.4 on a 6-point scale), and both groups reported similar mean familiarity ratings for the popular music (3.4, SDs = 1.6 and 1.4). These ratings did not change as a function of the version (original vs scrambled).

Errors Detected During Listening (On-line Measure)

Given that 28 or 29 chunks have been reordered in each piece, the number of detected errors could vary from 0 to 28. As can be seen in Table 1, participants detected a few errors in the scrambled versions: 17% of erroneous chunks were detected in popular music and about 13% in contemporary music. For the original versions, responses reflected false alarms (detecting erroneous chunks in original versions). Notably, this number was rela-

TABLE 1
Means and Standard Errors (SE) of Detection of Erroneous Linkage For Each Style by Version and Musical Expertise

Group	Popular Music				Contemporary Music			
	Original Pieces		Scrambled Pieces		Original Pieces		Scrambled Pieces	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	2.17	2.21	4.40	3.74	3.63	3.41	4.85	3.29
Musicians	1.83	2.26	5.27	4.23	1.40	1.90	2.60	2.79

tively high for contemporary music for musically untrained participants. A 2 (Musical Style) × 2 (Version) × 2 (Musical Expertise) analysis of variance was performed on the number of detected errors and indicated a significant effect of Version ($F_{1,38} = 51.75$, $p < .0001$, $MSE = 3.16$), with more numerous errors detected in scrambled versions. This effect of Version was more pronounced in popular music, as attested by a two-way interaction between

TABLE 2
Means and Standard Errors (SE) For Detection of Erroneous Linkage For Each Piece by Version and Musical Expertise

Group	Popular Music											
	Original Pieces						Scrambled Pieces					
	Down Down Down		*In a Sentimental Mood*		*Deux guitares*		*Down Down Down*		*In a Sentimental Mood*		*Deux guitares*	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	1.95	1.96	2.45	2.42	2.10	2.25	3.10	2.67	5.60	5.00	4.50	3.56
Musicians	1.40	1.96	1.85	2.13	2.25	2.69	5.55	5.00	4.90	3.95	5.35	3.73
	Contemporary Music*											
	Original Pieces						Scrambled Pieces					
	Trio		*Fleuves*		*Tracées*		*Trio*		*Fleuves*		*Tracées*	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	4.10	4.01	3.50	3.22	3.30	2.99	5.50	3.65	4.45	3.14	4.60	3.08
Musicians	1.35	1.98	1.10	1.65	1.75	2.07	2.15	2.76	2.25	2.67	3.40	2.95

*Contemporary pieces: *Trio* by Ligeti, *Fleuves* by Leroux, and *Tracées* by Xenakis.

Musical Style and Version ($F_{1,38} = 12.95$, $p < .0001$, $MSE = 2.04$) even if the difference between versions remained significant for each style. The effect of musical expertise found expression in a two-way interaction between Musical Style and Musical Expertise ($F_{1,38} = 31.25$, $p < .0001$, $MSE = 2.01$). Musically untrained participants tended to detect more errors for contemporary pieces than musically trained participants, for both scrambled ($F_{1,38} = 8.46$, $p < .01$, $MSE = 5.98$) and original versions ($F_{1,38} = 9.535$, $p < .01$, $MSE = 5.23$). The two-way interaction between Version and Musical Expertise was not significant, suggesting that both groups performed similarly on the original and scrambled versions. Tables 1 and 2 display the number of errors detected for each style and for each piece as a function of version and musical expertise.

Liking

A 2 (Musical Style: popular/contemporary) × 2 (Version: original/scrambled) × 2 (Musical Expertise: musicians/nonmusicians) analysis of variance was performed on liking ratings (see Table 3), with the first two factors as within-subject variables, and the third as a between-subjects variable. Scrambled pieces received lower liking ratings than original pieces ($F_{1,38} = 14.42$, $p < .005$, $MSE = 1.63$), but this effect was entirely due to popular music as reflected in a two-way interaction between Version and Musical Style ($F_{1,38} = 4.02$, $p = .052$, $MSE = 2.78$). A planned comparison indicated that the effect of Version was significant for popular music ($F_{1,38} = 15.37$, $p < .001$, $MSE = 2.18$) but not for contemporary music ($F_{1,38} < 1.00$). In addition, contemporary music received lower liking ratings ($F_{1,38} = 55.23$, $p < .0001$, $MSE = 16.16$). There was no further significant effect. In Tables 3 and 4 are liking ratings for each style and for each piece as a function of version and musical expertise.

TABLE 3
Means and Standard Errors (SE) of Liking Ratings For Each Style by Version and Musical Expertise

Group	Popular Music				Contemporary Music			
	Original Pieces		Scrambled Pieces		Original Pieces		Scrambled Pieces	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	14.20	2.69	13.26	3.60	6.96	4.56	6.74	4.31
Musicians	13.20	3.45	11.55	4.29	10.04	5.30	9.68	4.87

Engineer Experience

The second analysis assessed participants' ability to identify the incoherent version, measured as "Engineer Experience." A 2 (Musical Style: popular/contemporary) × 2 (Version: original/scrambled) × 2 (Musical Expertise: musicians/nonmusicians) analysis of variance gave a significant effect of version ($F_{1,38} = 39.01$, $p < .0001$, $MSE = .095$) with more numerous responses of "inexperienced engineer" for the scrambled than the original versions. The interaction between Musical Style and Musical Expertise was also significant ($F_{1,38} = 30.97$, $p < .0001$, $MSE = .07$). A planned comparison indicated that for musically untrained participants the original and scrambled versions of the contemporary pieces were judged as created by the "inexperienced engineer" ($F_{1,38} = 0.43$, $p < .0001$, $MSE = .086$, and $F_{1,38} = 10.71$, $p < .005$, $MSE = .066$, re-

TABLE 4
MEANS AND STANDARD ERRORS (*SE*) OF LIKING RATINGS FOR EACH PIECE BY VERSION AND MUSICAL EXPERTISE

Group	Popular Music											
	Original Pieces						Scrambled Pieces					
	Down Down Down		*In a Sentimental Mood*		*Deux guitares*		*Down Down Down*		*In a Sentimental Mood*		*Deux guitares*	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	15.85	2.11	12.10	3.24	14.65	2.72	15.00	4.01	11.40	3.90	13.38	2.90
Musicians	11.80	4.35	12.45	4.10	15.35	1.90	9.70	4.26	11.55	4.67	13.40	3.94
	Contemporary Music*											
	Original Pieces						Scrambled Pieces					
	Trio		*Fleuves*		*Tracées*		*Trio*		*Fleuves*		*Tracées*	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Nonmusicians	7.15	5.12	7.15	4.18	6.58	4.50	6.80	4.25	6.58	4.25	6.85	4.17
Musicians	10.50	5.26	10.30	5.42	9.33	5.22	10.45	4.72	10.40	4.91	8.18	4.98

*Contemporary pieces: *Trio* by Ligeti, *Fleuves* by Leroux, and *Tracées* by Xenakis.

spectively). For musically trained participants, the original and scrambled versions of the popular pieces were judged as created by the "inexperienced engineer" ($F_{1,38} = 4.28$, $p < .05$, $MSE = .052$ and $F_{1,38} = 7.60$, $p < .01$, $MSE = .094$, respectively). This suggests that participants were not only responding to the lower incoherence created by the scrambling but to their liking of the musical style. It should be noted that there was no significant interaction between Version and Musical Style, i.e., scrambled versions of musical pieces increased the feeling of incoherence, whatever the musical style liked by the participants. Tables 5 and 6 show the percentage of responses "inexperi-

TABLE 5
PERCENT OF RESPONSES "INEXPERIENCED ENGINEER" FOR EACH STYLE BY VERSION AND MUSICAL EXPERTISE

Group	Popular Music				Contemporary Music			
	Original Pieces		Scrambled Pieces		Original Pieces		Scrambled Pieces	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*
Nonmusicians	17.00	0.35	47.00	.50	52.00	.51	75.00	.44
Musicians	32.00	.46	73.00	.45	22.00	.41	48.00	.51

enced engineer" for each style and for each piece as a function of version and musical expertise.

Correlations Between Tasks

Additional analyses were performed to evaluate whether participants'

TABLE 6
PERCENT OF RESPONSES "INEXPERIENCED ENGINEER" FOR EACH PIECE BY VERSION AND MUSICAL EXPERTISE

Group	Popular Music											
	Original Pieces						Scrambled Pieces					
	Down Down Down		*In a Sentimental Mood*		*Deux guitares*		*Down Down Down*		*In a Sentimental Mood*		*Deux guitares*	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*
Nonmusicians	15.00	.37	30.00	.47	5.00	.22	30.00	.47	60.00	.50	50.00	.51
Musicians	20.00	.41	45.00	.51	30.00	.47	60.00	.47	75.00	.44	75.00	.44
	Contemporary Music*											
	Original Pieces						Scrambled Pieces					
	Trio		*Fleuves*		*Tracées*		*Trio*		*Fleuves*		*Tracées*	
	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*	%	*SE*
Nonmusicians	55.00	.51	40.00	.50	60.00	.50	80.00	.41	70.00	.47	75.00	.44
Musicians	10.00	.31	25.00	.44	30.00	.47	40.00	.50	45.00	.51	60.00	.50

*Contemporary pieces: *Trio* by Ligeti, *Fleuves* by Leroux, and *Tracées* by Xenakis.

performance in one of the three tasks (liking, judgment of engineer's experience, and error detection) were correlated. Low to moderate correlations, ranging from .25 ($p > .10$) to .50 ($p < .01$), were observed among these three tasks, suggesting that each task may capture a different aspect of participants' sensitivity to the manipulation. In addition, no significant correlation was observed between participants' detection of errors for one style with that for another style. In other words, participants may have detected errors correctly in contemporary music but badly in popular music, or vice versa.

Analysis of Musical Features

An additional analysis attempted to specify the musical features responsible for a feeling of musical incoherence. The erroneous linkages that were the most often detected correspond to several types of discontinuities. A few of these discontinuities occurred at a surface level (sudden changes in loudness, timbre, or tempo). Other discontinuities involved a more abstract level, for example, the beginning of a new musical idea that clashes with the previous one, the interruption of a musical harmonic progression, the unexpected resolution of a musical tension, or a musical development that obviously occurs too early compared to what was just heard before. Erroneous linkages detected in the scrambled version of contemporary pieces corresponded more than for popular music to surface discontinuities.

Discussion

The present experiment was designed to investigate listeners' detection of changes in large-scale structures of musical pieces. Scrambled versions were created by reordering the chunks inside each of the six pieces, in such a way that the transition between adjacent chunks neither involved obvious acoustical disruptions nor obvious musical discontinuities. The incoherence of the scrambled pieces was not the result of obvious local errors but mostly resulted from the feeling that the musical process was going nowhere. This manipulation may be compared with those performed in the psycholinguistic domain by scrambling sentences in texts (Gernsbacher, 1990). The principal aim of the experiment was to evaluate listeners' sensitivity to large-scale structure in two contrasted styles of 20th century Western music (tonal/atonal, easy-listening/complex) as current research in music theory and music cognition leads to contrasting predictions. According to several music theorists (Riemann, 1882/1909; d'Indy, 1912; Conyus, 1933; Schenker, 1935; Hodeir, 1951; Meyer, 1956; Cooper & Meyer, 1960; Schoenberg, 1967; Lerdahl & Jackendoff, 1983), scrambling a musical piece should induce a strong feeling of incoherence for listeners. According to others (Gurney, 1880; Levinson, 1997), and based on several empirical studies in music psychology (Konecni, 1984; Gottlieb & Konecni, 1985; Cook, 1987; Karno & Konecni, 1992; Tillmann & Bigand, 1996, 1998, 2001; Tillmann, *et al.*, 1998; West-Marvin & Brinkman, 1999), scrambling should not strongly affect listeners' impressions. In addition, the performance of musically trained listeners was compared with that of musically untrained listeners. Based on differences reported in the psycholinguistic domain between "good" and "poor" comprehenders (Gernsbacher, 1990), one would expect higher sensitivity of musically trained listeners to the scrambled versions.

The present findings moderate these claims. First, the data provided evidence that a temporal reordering of small sections of a musical piece decreases its aesthetic value (at least for popular music) and increases the feeling of incoherence. If the link between two chunks of the scrambled version was creating obvious acoustical discontinuities, the present finding would simply suggest that listeners respond to very local incongruities involving low perceptual processing. On the contrary, analysis of the detection of errors showed that only a relatively small number of errors was detected in the scrambled versions. The findings rather suggest that listeners are sensitive to some abstract features of the temporal organization of Western music, such as the integration of local musical chunks into larger building blocks according to specific rules (depending on the musical style, syntactic rules in tonal pieces and specific rules or surface discontinuities in atonal pieces; cf. Lerdahl & Jackendoff, 1983; Lerdahl, 2001). Perceived incoherence may arise in listeners when chunks are linked in a way that violates these rules. However, the present experiment was not designed to investigate the nature of these rules. One may wonder whether music integration follows general integrative rules which may be found for discourse, movies, or dance, as suggested by Gernsbacher (1990). The qualitative analysis of the data suggests that the interruption of a harmonic progression or the linkage of the beginning and the ending of a musical development can create a feeling of incoherence. Researchers may discover the nature of the process involved in incoherence of experience with such scrambled pieces.

A striking finding of the present study was the effect of scrambling for both musical styles. The fact that participants judged scrambled versions of contemporary music pieces as less coherent than original versions is highly surprising. Indeed, contemporary music is often of greater structural complexity than Western tonal music (in particular, popular music), and it has been claimed that this musical style is too complex to be cognitively relevant. Some music theorists or psychologists (Francès, 1958; Ansermet, 1987; Cook, 1987; Lerdahl, 2001) have even argued that the high complexity of this musical style explains its weak success for the general audiences. The fact that untrained listeners (even though they consider this music as strongly incoherent and even unpleasant) manage to capture some refined aspects of the temporal organization of contemporary pieces highlights the sophisticated nature of the integrative process that occurs during listening to music.

The present conclusions may be seen as conflicting data reported by previous empirical research dealing with the cognitive reality of large-scale structures in music (Konecni, 1984; Gottlieb & Konecni, 1985; Cook, 1987; Karno & Konecni, 1992; Tillmann & Bigand, 1996, 1998, 2001; Tillmann, *et al.*, 1998; West-Marvin & Brinkman, 1999). Some authors argued that large-scale structures are useful for music composition but not for music perception (Cook, 1987). An alternative view was suggested by Tillmann and Bigand (1996). Since playing chunks of 6-sec. duration on average in the retrograde order did not yield strong effects on various semantic scales, the authors argued that numerous expressive cues are contained on a local level in each chunk. The expressive cues in each chunk would be sufficient to induce a rich aesthetic experience for listeners even when these chunks are linked together in a meaningless way. In other words, the presence of a coherent large-scale organization would not significantly add to the aesthetic experience. The present finding suggests a moderation of this claim: listeners managed to detect lack of coherence in large-scale structure, and they usually enjoyed scrambled pieces less.

However, the present study does not definitively contradict the previously reported data sets. Indeed, it may be argued that the scrambling performed here was particularly strong: the 3-min. pieces were segmented into 28 or 29 chunks. With this type of manipulation, or even stronger ones

(Levitin & Menon, 2005), it might not be surprising to see some effect of scrambling in listeners' response. On this basis, one should probably have expected a stronger effect of scrambling on a listener's response in the detection-error task. The most surprising finding was to observe that participants managed to detect only a few incoherent linkages, even for popular music. This suggests that sensitivity to large-scale structures remains very weak, which is strongly consistent with the data reported in other studies. However, it is worthwhile to notice an important methodological difference with the previous studies: in this study, participants listened to both original and scrambled versions. Listening to both versions would have to help participants to detect incoherent linkage in the scrambled versions (at least in the case where they listened to the original version first). Further analyses have been run to test this possibility. The only evidence supporting this view was found for musicians in the engineer test. The number of inexperienced engineers' errors detected tended to be lower for scrambled pieces when the pieces were heard after the original pieces in the experimental session. This percentage went from 83% to 63% for popular music and from 60% to 47% for contemporary music, but this difference does not reach statistical significance. Researchers will have to specify what factors may increase or decrease listeners' detection of incoherent linking.

Finally, a further important point for these findings was that the sensitivity to large-scale structures does not strongly depend on the extent of musical training. Musical training influenced which musical style was preferred by listeners, but on the whole both groups exhibited a similar sensitivity to the scrambling on both aesthetic and grammatical-like judgments. This finding is consistent with results of several other studies showing that musically trained and untrained listeners behave similarly on numerous perceptual tasks (see Bigand & Poulin-Charronnat for a review, in press), including those that require the processing of large-scale structures (Tillmann & Bigand, 1998).

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