Music: A Link Between Cognition and Emotion

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Abstract

Cognition and emotion are closely linked in music. The interplay between expectations and the sounded events is hypothesized to play a central role in creating musical tension and relaxation. The research summarized here is part of an ongoing program investigating how this dynamic aspect of musical emotion relates to the cognition of musical structure. Musical emotions change over time in intensity and quality, and these emotional changes covary with changes in psychophysiological measures. Perceptual studies support music-theoretic descriptions of musical structures that underlie listeners' expectations. Cross-cultural comparisons suggest that certain psychological principles of expectation are quite general, but that musical cultures emphasize these differentially. A schema of temporal organization that relates episodes of tension and relaxation to musical form and expressive aspects of musical performance is described. Finally, some results suggest that the expression of emotion in music shares properties with the expression of emotion in speech and dance.

Keywords

music cognition; music emotion

The emotional effect of music raises a number of basic psychological questions. People report that their primary motivation for listening to music is its emotional effect. And people listen to music a great deal, often hours a day. How is it that patterns of sound in time can have such a profound effect? What is it in the music that causes the emotion? Are musical emotions like other emotions? Antecedents of emotion in real life are generally conditions that have real, or perceived, consequences for an individual's well-being. Emotions may prepare the individual to act on the prevailing conditions to attain or maintain a state of well-being. In contrast, music does not obviously change an individual's material state, nor does it necessarily elicit any action. Despite these differences, psychological evidence indicates musical emotions are at least to some degree like other emotions.

EXPLAINING MUSICAL EMOTIONS

One commonly held view is that music acquires its emotional meaning by association with consequential events. Particular pieces of music are often connected to significant personal memories. If this were all, then emotional responses to music would vary greatly from individual to individual depending on their unique past experiences. But listeners agree remarkably well with one another in labeling musical emotions. Something in the music must produce this agreement. Words of songs may carry emotion. However, we respond to songs in languages we do not understand, we may not attend closely to the words, and, most decisively, much of the world's music is instrumental, without words. Another possibility is that music imitates the sounds of objects or events with emotional connotations. Yet such iconic use of sounds is rather limited when the great variety of music is surveyed.

Thus, musical sounds may inherently have emotional meaning. Support for this comes from the classic study by Hevner (1936), who had listeners choose emotion adjectives for instrumental selections. The adjectives fell on a circle similar to that proposed for nonmusical emotions, with underlying dimensions of positive-negative and degree of activity. For example, although both happy and serene are positive emotions, happy has a high level of activity, whereas serene has a low level of activity. Musical characteristics determining the adjective choices included major versus minor mode, firm versus flowing rhythm, and complex and dissonant versus simple and consonant harmonies. Studies such as this one have demonstrated associations between global aspects of musical structure and the overall mood of the music. Is it possible to describe more precisely the musical structures that produce musical emotions, which may change in intensity and quality over time? The research directed at this goal, reviewed here, uses the concept of musical tension to link the cognition of musical structures with musical emotions.

TENSION, EXPECTATION, AND MUSICAL EMOTION

The theoretical starting point for this research is the seminal work of the musicologist Leonard Meyer (1956, 1967), who wrote: "Music is a dynamic process. Understanding and enjoyment depend upon the

perception of and response to attributes such as tension and repose, instability and stability, and ambiguity and clarity" (Meyer, 1967, p. 43). Meyer proposed that expectations play the central psychological role in musical emotions. Some points in the music engender strong expectations for continuation, creating a sense of tension and instability. Other points in the music fulfill expectations, and units are perceived as closed off and completed. Musical meaning and emotion depend on how the actual events in the music play against this background of expectations.

Music theory provides technical descriptions of how styles organize musical sounds and offers insights about musical structures that might underlie listeners' expectations. Cognitive science has recently influenced music theory. A major development is Lerdahl and Jackendoff's (1983) generative theory of tonal music and its recent extension in Lerdahl's (2001) tonal-pitch-space theory. It proposes cognitive representations of meter, grouping, event hierarchies, and harmonic tension. Another cognitively oriented theory is Narmour's (1990) implication-realization model of melodic expectations, which proposes principles rooted in psychological processes. Later I describe some empirical studies testing these theories. First, however, I summarize the results of a study that examined more directly the dynamics of musical emotions.

DYNAMIC RATINGS OF BASIC EMOTIONS AND TENSION

A recent trend in studies of music is to collect listeners' responses continuously while the music is played, recognizing that retrospective judgments are not sensitive to unfolding processes. In one study (Krumhansl, 1997), I used instrumental excerpts chosen to represent the emotions of sadness (e.g., Albinoni's *Adagio*), fear (e.g., Mussorgsky's *Night on Bare Mountain*), and happiness (e.g., Vivaldi's *La Primavera* from *The Four Seasons*). Previous research had shown music is reliably described at the level of basic emotions. The sad excerpts had slow tempos, minor harmonies, and fairly constant ranges of pitch and dynamics. The fear excerpts had rapid tempos, dissonant harmonies, and large variations of dynamics and pitch. The happy excerpts had relatively rapid tempos, dancelike rhythms, major harmonies, and relatively constant ranges of pitch and dynamics. The excerpts were approximately 3 min in duration and were not previously known by most of the participants.

Listeners in one condition were instructed to adjust the position of a computer indicator to reflect how the amount of sadness they experienced changed over time while listening to each of the excerpts. Listeners in two other conditions similarly judged the amount of fear and happiness that they experienced. Ratings for the intended emotion were significantly higher than ratings for the unintended emotions, but still varied considerably over the duration of the excerpts. For comparison with music-theoretic accounts, a fourth group judged the amount of tension. Tension correlated most strongly with the fear ratings, but also with the happy and sad ratings, especially when these were predominant. Thus, tension appears to be a multivalent quality, influenced to some degree by all three of the basic emotions represented by these excerpts.

PSYCHOPHYSIOLOGICAL MEASURES

Another group of listeners heard the same excerpts while their physiological responses were recorded. These covered a fairly wide spectrum of physiological measures of emotional responses, and included measures of cardiac function, blood flow, electrical conductance of the skin, and respiratory function. The measures taken during the music differed significantly from baseline levels. Most measures either remained at a fairly constant level or increased during the music. All the musical excerpts produced the same direction of change compared with baseline levels, suggesting that music has an overall effect on emotion physiology. In addition, the measures showed different amounts of change depending on the emotional quality of the excerpt. The primary focus was on the relationship between the physiological measures and the dynamic ratings of emotions, following Meyer's proposal that emotions are time-locked to events in the music.

Sad ratings were most strongly associated with changes in heart rate, blood pressure, and skin conductance and temperature. The fear ratings were associated with changes in the rate and amplitude of blood flow. The happy ratings were associated with changes in respiration measures. The correlations were fairly low, however. A limiting factor may have been characteristic response times and lags of physiological systems. The general difficulty of identifying emotion-specific changes in these psychophysiological measures should also be noted. Nonetheless, this exploratory study found physiological changes that depended on the amount and type of musical emotion. Do the physiological changes found for musical emotions correspond to those for nonmusical emotions found in other studies? The degree of correspondence depended on the emotion-eliciting manipulation. Greatest agreement was found when the experimental

manipulation was extended over time, as were the musical excerpts.

MUSICAL TENSION AND TONAL STRUCTURE

These selections were chosen to have strongly contrasting musical characteristics. Physiological measures were also obtained while listeners heard a single piece lasting approximately 8 min. It was the first movement of Mozart's Piano Sonata in E-flat major, K. 282. Another group of listeners (Krumhansl, 1996) had made various perceptual judgments on the piece: how it is segmented, when new musical ideas are introduced, and the degree of tension. The tension ratings correlated with heart rate and blood pressure despite the relative homogeneity of the piece (Krumhansl, 2000).

Analyzing the Piano Sonata also uncovered a number of features that covaried with tension (Krumhansl, 1996). Some of the surface features related to tension were the pitch height of the melody, the density of notes, dissonance, and dynamics. Other more cognitive features were key changes, the appearance of chromatic (nonscale) tones, interruption of a harmonic process, and denial of stylistic expectations. However, Lerdahl's (2001) tonal-pitch-space model provided the most precise musical analysis.

This model proposes that tension is a combination of surface dissonance and the position of each event in a tree structure. The top of Figure 1 shows the major branchings of the tree for the first eight measures of this sonata. The tree is inverted, such that the root is at the top. Events that are more directly linked to the root have less tension than those that are less directly linked to the root. The section subdivides into two, with the second subsection subordinate to the first. As predicted, the tension values were generally higher for the second subsection than the first. A closer look shows that tension judgments dropped at events most directly linked to the root of the tree. For example, tension drops at the beginning of measure 4, when events that link quite directly to the root are sounded. A quantitative reformulation of the tree fit the tension ratings well. This result encourages the development of music-theoretic descriptions relating tonal structure to its emotional effect.

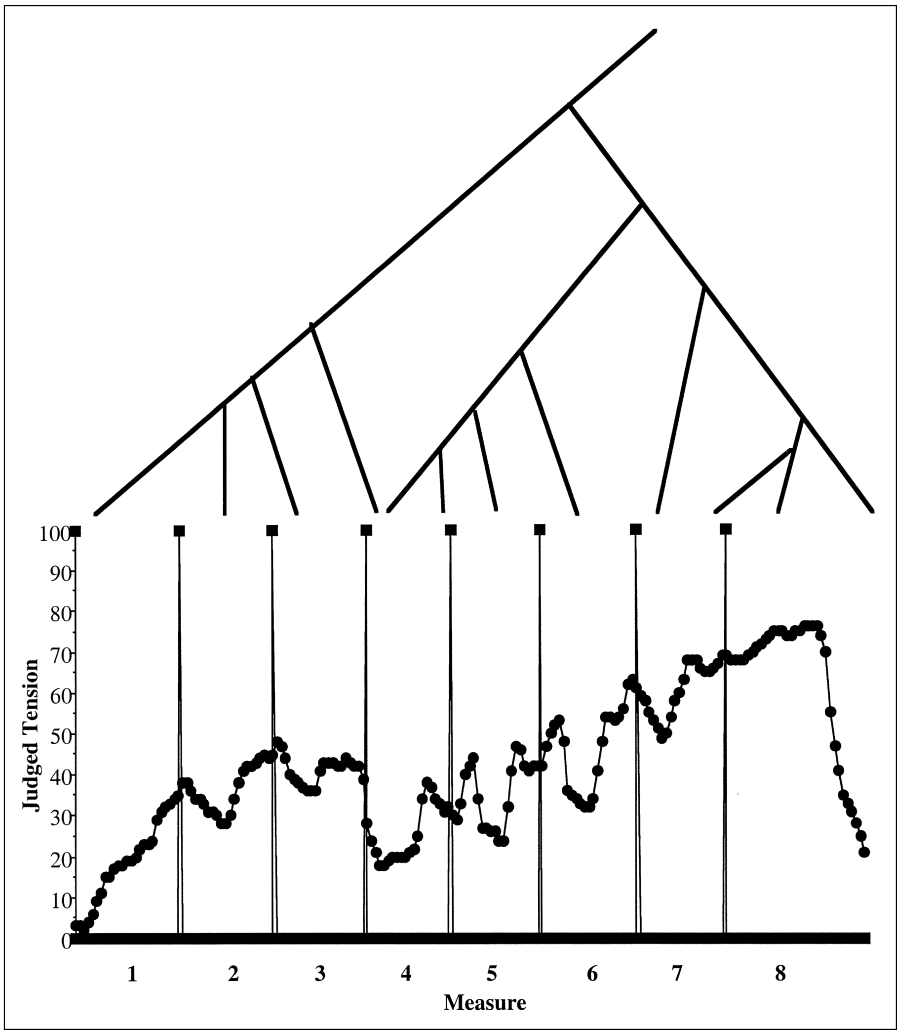

Fig 1. The main branches of Lerdahl's (2001) tree model for the first eight measures of Mozart's Piano Sonata in E-flat major, K. 282 (top panel) and the tension ratings made by listeners (Krumhansl, 1996; bottom panel). From "Music and Affect: Empirical and Theoretical Contributions From Experimental Psychology," by C.L. Krumhansl, 2000. In D. Greer (Ed.), *Musicology and Sister Disciplines: Past, Present, and Future*, p. 91. Copyright 2000 by Oxford University Press. Reprinted with permission of Oxford University Press.

MUSICAL TENSION, MUSICAL FORM, AND PERFORMANCE

The study of the Mozart Piano Sonata also suggested that variations in tension are related to musical form (the overall structure of the piece) and performance expres-

sion. The tempo and dynamics of the performance of this work by a renowned pianist, together with the perceptual judgments, followed a pattern, shown in Figure 2, that recurred throughout the piece. The beginnings of segments were associated with new musical ideas, a neutral tempo, and low tension levels. The tension levels tended to increase within segments, with accompanying increases in dynamics and note density. The tension curves usually had an asymmetric peak toward the end (see Fig. 1 as an example). The section ends were marked by slow tempos, lower dynamics and note density, and rapidly decreasing levels of tension.

This pattern of temporal organization in music may be analogous to patterns of intonational units in discourse. In discourse, topics are introduced and developed, and then closed off with slowing of speech rate, drops in pitch and dynamics, and pauses. A tradition of music analysis identifies *topics* in classical music, each with distinctive rhythmic, melodic, dynamic, and affective qualities. Agawu (1991) identified the topics in movements from Mozart's String Quintet in C major, K. 515, and Beethoven's String Quartet in A minor, op. 132. Listeners (Krumhansl, 1998) made real-time judgments of memorability, degree of openness (whether there is a sense that the music must continue or whether the section has ended), and amount of emotion. All three judgments could be accounted for by the music analysis. The topics in the Mozart piece functioned primarily to establish the musical form; that is, they coincided with the sections of the piece. In contrast, the topics in the Beethoven piece were more strongly associated with contrasts in the amount of emotion. Thus, different composers may use topics to variously highlight structural and emotional aspects of the music.

EMOTION IN MUSIC AND DANCE

Another study (Krumhansl & Schenck, 1997) investigated the similarity of emotional expression in music and dance. It used the Minuetto from Mozart's Divertimento no. 15 choreographed by George Balanchine. One group of participants only heard the music. A second group only saw the dance. A third group both heard the music and saw the dance. All groups made real-time judgments of when sections ended, when new ideas occurred, and the amount of tension and emotion expressed. The judgments in all three stimulus conditions conformed to the general pattern of Figure 2. This result suggests that this temporal organization operates in both music and dance, and that the two artistic forms are closely coordinated.

In addition, the participants judged the emotional quality of the stimulus. As can be seen in Figure 3, these judgments were remarkably similar across the conditions. This was true even though the stimuli were completely different in the music-only and the dance-only conditions. Analysis of the music and dance suggested a number of features that may convey the shared emotional qualities. These include the tempo of the music and dance, melodic and choreographic gestures, and the high degree of symmetry and regularity in both music and dance. Additional factors may be the pacing of segment endings and new ideas, and the experienced contours of tension and emotion. The finding that music and dance can express such similar emotional qualities suggests nonaccidental relationships between music and bodily movement.

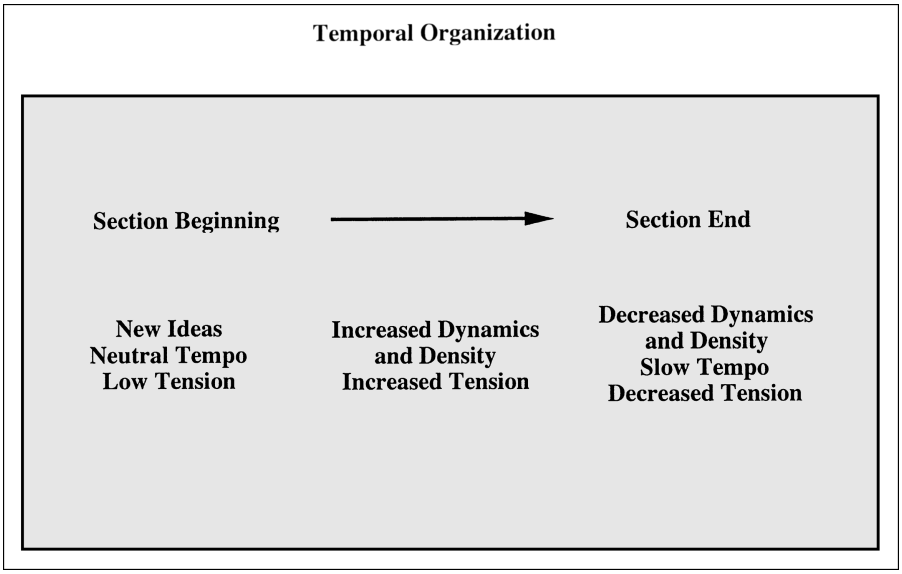

Fig. 2. The temporal organization found for Mozart's Piano Sonata in E-flat major, K. 282, showing the relationship between tension judgments, tempo, dynamics, and note density.

MELODIC EXPECTATION

The theoretical starting point for this research was that musical emotions depend on the interplay between expectations and the events sounded in the music. Nar-

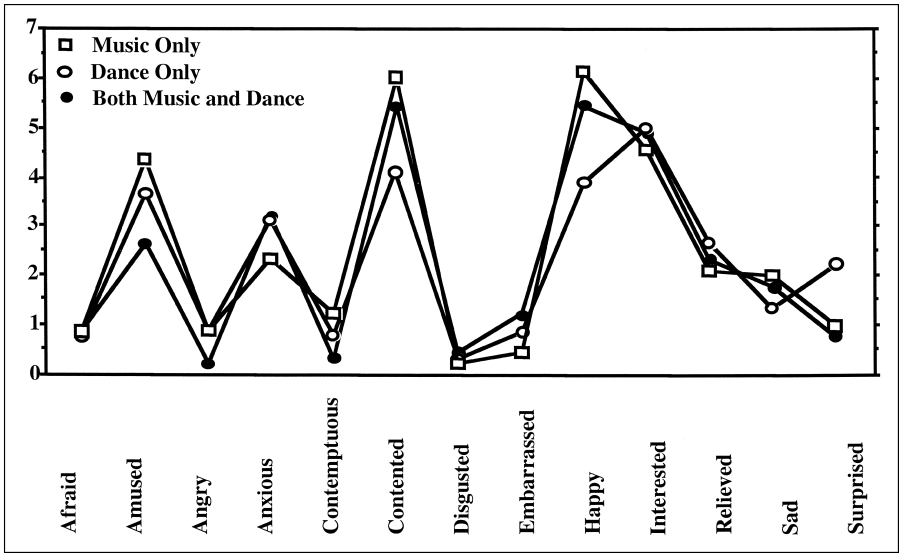

Fig. 3. The emotion-quality judgments made for the three conditions: music only, dance only, and both music and dance. From "Can Dance Reflect the Structural and Expressive Qualities of Music? A Perceptual Experiment on Balanchine's Choreography of Mozart's *Divertimento* No. 15," by C.L. Krumhansl and D.L. Schenck, 1997, *Musicae Scientiae*, *1*, p. 75. Copyright 1997 by the European Society for the Cognitive Sciences of Music. Reprinted with permission.

mour's (1990) implication-realization model proposes that melodic expectations are governed by general principles of perceptual organization, presumed to be universal. To test the model, I used excerpts from British folk songs, atonal songs, and Chinese folk songs (Krumhansl, 1995). Listeners judged different tones (presented as possible continuations of the songs) as to how well they fit with their expectations. In the cases of the Western musical excerpts, judgments of musicians and nonmusicians were compared. In the case of the Chinese excerpts, judgments of native Chinese and American listeners were compared. The results supported the principles of the model, and, consistent with its claims concerning universality, the differences between the groups were relatively small.

Two cross-cultural studies (Krumhansl, Louhivuori, Toiviainen, Järvinen, & Eerola, 1999; Krumhansl et al., 2000) tested the model further. The first used excerpts from Finnish spiritual folk hymns. The second used excerpts from vocal music, called *yoiks*, of the Sami in northern Scandinavia. Both studies compared listeners who were active in the musical culture in question with Western musicians unfamiliar with the music. The results generally supported the implication-realization model. However, the relative importance of the principles varied across styles, and even listeners unfamiliar with the music showed sensitivity to this variation. In sum, these results support the idea that music draws on common psychological principles of expectation, but that musical cultures shape these in unique ways.

CONCLUDING COMMENTS

Musical emotion is currently an active area of psychological research. The series of studies summarized here represents one line of investigation directed at understanding how the dynamic aspect of musical emotion relates to the cognition of musical structure. A number of other approaches provide complementary results. Developmental studies indicate infants are surprisingly sensitive to various musical properties. Brain-imaging techniques reveal areas of activation associated with music listening. Studies of patients with brain damage find they may react to the emotional content of music even though their song recognition is poor. Research on musical performance suggests that musicians vary such attributes as tempo, dynamics, and attack to express different emotions. Finally, surveys of the contexts in which people make and listen to music demonstrate that it serves highly significant, but remarkably diverse functions.

These various approaches promise new insights into the psychological effects of music. The methods of cognitive neuroscience can reveal the extent to which neural substrates for music overlap those for emotion, memory, and language. Comparisons across stages of development, cultural origin, and level of musical training provide tools to examine how music cognition and emotion are shaped by experience. Finally, closer examination of musical emotions can reveal whether humans have an aesthetic response that is distinct from the currently more well-understood basic emotions.

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Note

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