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Emotion in Music: Affective Responses to Motion in Tonal Space

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ABSTRACT

Tonal modulation is the reorientation of a scale on a different tonal center in the same musical composition. Modulation is one of the main structural and expressive aspects of music in the European musical tradition. Although it is known a priori that different degrees of modulation produce characteristic emotional effects, these effects have not yet been thoroughly explored. We conducted two experiments to investigate affective responses to tonal modulation by using semantic differential scales related to valence, synesthesia, potency, and tension. Experiment 1 examined affective responses to modulation to all 12 major and minor keys of the Western tonal schema using 48 brief harmonic progressions. The results indicated that affective response depends on the degree of modulation and on the use of the major and minor modes. Experiment 2 examined responses to modulations to the subdominant, the dominant, and the descending major third using a set of 24 controlled harmonic progressions and a balanced set of 24 excerpts from piano compositions belonging to the First Viennese School and the Romantics; all stimuli were in the major mode to maintain the ecological validity of the modulation to the dominant. In addition, Experiment 2 investigated the affective influence of melodic direction in soprano and bass melodic lines. The results agreed with the theoretical model of pitch proximity based on the circle of fifths and demonstrated the influence of melodic direction and musical style on emotional response to reorientation in tonal space. Examining the affective influence of motion along different tonal distances can help deepen our understanding of aesthetic emotion.

I. INTRODUCTION

Tonal modulation is the reorientation of a scale on a different tonal center within the same composition. Modulation is one of the main structural and expressive aspects of music in the European musical tradition. Freedom of tonal modulation was achieved with the introduction of the tempered (i.e., systematically mistuned) diatonic scale. Our sense of the tonal scale is also a sense of tonality, which can be described as the intuitive understanding of the language of tonal harmony (Schenker, 1954; Holleran, Jones & Butler, 1995). The pitch set of a scale establishes tonal material that is characteristic for a given composition. A tonic triad (a triad built on the first step of a diatonic scale) is a concise presentation of a particular tonality.

Tonal space is generally explained by means of the circle of fifths, which succinctly illustrates tonal "distance." It is important to remember that the spatial proximity of keys on a keyboard has nothing to do with tonal proximity, which is defined by the perceived degree of attraction between tones and is rooted in the "hidden" dimension of overtones. The more steps there are between two letters on the circle of fifths, the more differences there will be between the two pitch sets that define the tonalities represented by these letters. With each step around the circle, one of the tones in a scale is replaced by another tone; the replacement is dictated by "construction formulas" for the diatonic scales in the major and minor modes. At the bottom of the circle of fifths, the accumulation of the sharps and flats allows the so-called enharmonic exchange. While enharmonic exchange relies on acoustical replication, thinking in terms of sharps as compared with flats creates an idiosyncratic difference for the pianist; thus, D-flat major is known as the "love" tonality, but the enharmonically equal C-sharp major is not. Other musicians—including string players, vocalists, and wind instruments players—sense enharmonic exchange differently because sharps are generally played and sung slightly higher than their enharmonically equivalent flats.

The circle of fifths represents the most extreme version of the tempered scale, called equal temperament. The many different versions of temperament (Schulter, 1998) reflect the history of the adjustments made to a diatonic scale to accommodate the demands of motion in tonal space—specifically, the demands of freedom of modulation. Equal temperament provides the invariance of the melodic intervals of a scale and thus supports the universality of all the 12 steps of a scale (seven diatonic and five chromatic) in regard to modulation. The achievement of freedom of modulation through tempering had its price, however: Equalizing the frequency relationships among all adjacent semitones on a piano keyboard resulted in the sonic "dirtying" of the important Pythagorean intervals of a fifth and a fourth, as well as of the major and minor thirds and sixths. Yet these sonic impurities were splendidly compensated for by a host of new expressive and structural possibilities. The new, tempered tonal space allowed the creation of the language of tonal harmony, which was essential for the emergence of complex musical structures such as the Baroque fugue and classical sonata allegro form.

The reorientation of a tonal system of reference from one center to another is conceptually similar to changing a point of view in the three-dimensional space of Cartesian coordinates. During tonal reorientation, a scale is restored on a different tonal center (this is similar to the restoration of Cartesian coordinates for our perception when we move in 3-D space and our perception of the proportions of visible objects is reestablished from a new vantage point). The tonal transition from one tonal center to another—from one tonality to another—produces a change in pitch set, from that of the opening scale to that of the new scale. The degree of change, as indicated by the number of newly introduced pitches, defines the tonal "distance" traversed (see Figure 1). Each of the 12 available steps of a diatonic scale can be the center for two tonalities, one in a major mode and another in a minor mode. The affective influence of the major and minor modes has been thoroughly investigated (Hevner, 1935; Kastner &

Crowder, 1990; Panksepp & Bekkedal, 1997; Gagnon & Peretz, 2003; Webster & Weir, 2005; Halpern, Martin, & Reed, 2008).

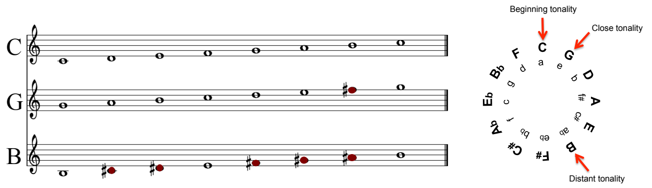

Figure 1. An increase in tonal distance between two tonalities brings new pitches (in red) into the opening pitch set: For C major as an opening tonality, G major represents a close modulation (adding only one new pitch) and B major represents a more distant modulation (adding five new pitches)

It is well known a priori from musical practice that modulations of different distances (degrees) have characteristic effects on the listener. It is also known that some modulations (for example, the Neapolitan) are popular in sudden reorientation, whereas other modulations, such as to the dominant and subdominant, are routine in certain musical forms such as the Baroque fugue and the classical sonata (Rosen, 1988). To our knowledge, however, there has been no systematic exploration of emotional responses to reorientation in tonal space. For our study, we conducted two experiments, using both artificial stimuli and real music.

II. METHODS AND RESULTS

A. Experiment 1

1) Stimuli and apparatus. The Experiment 1 explored affective responses to all degrees of modulation and in all modal conditions with 48 harmonic progressions. The principal experimenter wrote 12 chorale-like progressions, one for each of the 12 chromatic steps of the scale. The first three to five chords established the opening tonality, and the following chords made a smooth transition to a target tonality; different degrees of modulation demanded different numbers of transitional chords. The 12 progressions were then modified to obtain four versions of each progression: from major to major mode (M-M), from major to minor mode (M-m), from minor to major mode (m-M), and from minor to minor mode (m-m). Of the resulting 48 progressions, two remained in the same tonality (the zero-step major-major and minor-minor "modulations") and were included for completeness of design. The progressions were eight chords long; slightly different in rhythm and voice leading; and similar in tempo, style, sound intensity, timbre, and range. They were each 11 seconds in duration (MM = 72) and included a slight *ritenuto* at the end to make the modulation sound natural. Each progression was followed by a delay of 10 seconds. All stimuli were digitally recorded by the principal experimenter playing a Yamaha grand piano and were presented to participants via loudspeakers with high-quality stereophonic equipment.

2) Participants and procedure. The participants were 69 psychology students from the University of Texas at Dallas (54 females and 15 males aged 19–53, with a mean age of 24.8), which took part in the experiment to fulfill a course requirement. Among them, 31 females and 6 males had four or more years of musical training and were classified as "experienced"; their musical experience included playing musical instruments and singing in a choir. The participants were asked to indicate the intensity of their affective responses to the concluding part of each progression on six bipolar adjective scales (Osgood, Suci, & Tannenbaum, 1957): the valence-related scales happy/sad and pleasant/unpleasant, the quasisynesthetic scales warm/cold and bright/dark, and the potency-related scales strong/weak and firm/wavering. The order of adjective scales in a table was scrambled for each stimulus. The participants were tested in group sessions, with three to nine persons per group. During data analysis, the six-point adjective scale was centered on a midpoint (3.5) to make the graphs easier to read.

B. Results for Experiment 1

The data obtained were subjected to principal component analysis (PCA), analysis of variance (ANOVA), and Tukey pairwise comparisons.

On a loading plot for the PCA analysis, the first component is defined by the valence-related and synesthesia-related scales and explains 85% of variance (see Figure 2). Triads in the major mode fall mostly on the side of positive connotations (happy, pleasant, bright, and warm), whereas triads in the minor mode fall mostly on the negative side (sad, unpleasant, dark, and cold). The important dominant (7) and subdominant (5) steps are well differentiated. The proximity of steps 5, 8, and 1 on the positive side indicates that these steps are recognized as belonging together (to a subdominant region). The prominent "sadness" and "darkness" of the dominant step on the negative side reflects, most likely, the ecological weakness of modulations to a minor key on the dominant step (a triad on the dominant must be in a major mode, according to the rules of classical functional harmony, Schoenberg, 1954). This ecological weakness was the consequence of our experimental design that covered all possible degrees of modulation and in all possible modal conditions. The positive responses to distant modulations in a major mode to steps 1, 4, 8, and 11 can be identified as "pleasant surprise" modulations; the attribution of positive feeling to these distant reorientations illustrates Lerdahl's concept of "folding in tonal space" (Lerdahl, 2001). The "pleasant surprise" modulations can be divided into two groups: the "leading" kind and the "pseudostability" kind. We suggest that it was the effect of approaching semitones in the leading-type modulation and the conversion of a tonic into the mode-defining third in the "pseudostability" modulation that generated the "pleasant surprise" responses (see Figure 3). The opening and concluding tonic triads in a modulation to step 1 include, reciprocally, the approaching semitones; the same is true for a modulation to the leading tone (step 11). The "pseudostability" modulation to steps 4 and 8 utilizes the power of the mode-defining third in a tonic triad: Modulation to step 4 converts the mode-defining third of the opening tonic triad into the tonic of the concluding triad, whereas modulation to step 8 converts the tonic of the opening triad into the mode-defining third of the concluding triad.

An omnibus ANOVA with 2 levels of experience X 12 steps X 6 adjective scales X 4 mode conditions showed a main effect of step, $F(11, 286) = 4.16$, $p < .001$, $R^2 = 0.96\%$; a main effect of mode, $F(3, 78) = 53.92$, $p < .001$, $R^2 = 3.03\%$; and a main effect of scale, $F(5, 130) = 10.66$, $p < .001$, $R^2 =$

1.34%. There was no main effect of experience. The ANOVA revealed an interaction of step X mode, $F(33, 858) = 2.04$, $p < .001$, $R^2 = 1.16\%$; an interaction of step X scale, $F(55, 1{,}430) = 4.16$, $p < .001$, $R^2 = 2.21\%$; an interaction of mode X scale, $F(15, 390) = 9.75$, $p < .001$, $R^2 = 1.54\%$; an interaction step X mode X scale, $F(165, 4{,}290) = 1.81$, $p < .001$, $R^2 = 2.69\%$; and an interaction of mode X scale X experience, $F(15, 390) = 2.15$ $p < .001$, $R^2 = 3.40\%$. Given the complexity of the interactions found, the analysis was broken into separate ANOVAs focusing on particular areas of interest in the data (for a complete set of ANOVAs and Tukey pairwise comparisons, please contact the principal investigator). Among the findings was a cumulative effect of the same modal condition at the beginning of a modulating passage, $F(1, 3{,}308) = 60.62$, R-sq = 1.83%, $p < .001$, and the ending of a modulating passage, $F(1, 3{,}308) = 495.04$, R-sq = 14.96%, $p < .001$ for the *happy/sad* scale. Though the participants responded primarily to the major and minor endings of the modulations, the uniformly major progressions were rated the "happiest," and the uniformly minor progressions were rated the "saddest," $F(3, 272) = 77.24$, $p < .000$, $R^2 = 46\%$. (For the main effects for other scales, please contact the principal investigator.) Another interesting result was the high ratings in perceived potency (firm and strong) for those modulations to the dominant (step 7) that began in the minor mode.

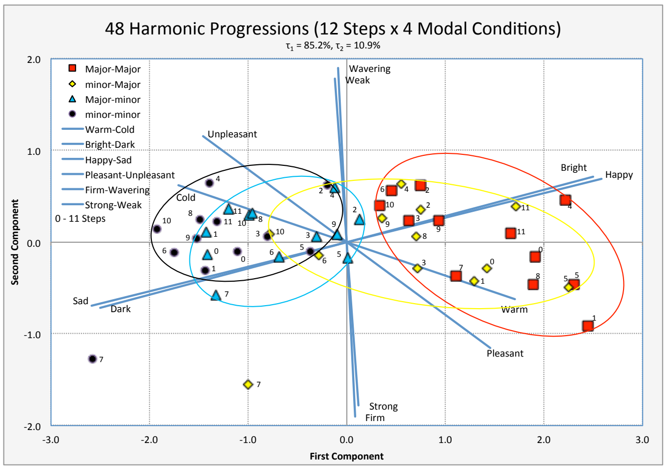

Figure 2. PCA for 48 harmonic progressions. The adjective scales *happy/sad*, *bright/dark*, *warm/cold*, and *pleasant/unpleasant* grouped themselves into the valence dimension, whereas the adjective scales *strong/weak* and *firm/wavering* formed the potency dimension. The strongest variable commonality is related to modes. Triads in the major-major condition (red dots) fall on the side with the positive connotations (happy, pleasant, bright, and warm), whereas all triads in the minor-minor condition (black dots) fall on the negative side (sad, unpleasant, dark, and cold). Steps are numbered from 0 (tonic) to 11 (the leading tone).

1) Categorization of steps targeted by modulation as Expected, Unexpected, and Ambiguous. The presented study was concerned with the influence of the degree of proximity between different tonalities on the affective response to music. A triad built on the root of a given diatonic scale represents a conceptual core of tonality. This is why an analysis of the data focused on the relationships between the tonic triads of the opening and concluding tonalities. By taking into account the four available modal conditions (M-M, M-m, m-M, m-m) and the degree of modulation, we classified the relationships between the opening and concluding tonic triads in our examples into three categories: Expected, Unexpected, and Ambiguous (see Table 1). The classification employed the following criteria:

The Expected final triad is built on the diatonic steps of an opening tonality (minus the diatonic seventh step, since neither a major nor a minor triad can be built on this step using diatonic tones). The exceptions in this category are the same-name major-minor (M-m) and minor-major modulations (m-M), which takes into consideration the power of the tonic (for example, the m-M same-step modulation frequently occurs in Baroque music and produces the "Picardy third").

The Unexpected final triad has at least one chromatic tone.

The Ambiguous final triad contains either (i) the root of the opening tonality as the third in a final triad (as in a modulation from C major or c minor to A-flat major), (ii) the third diatonic step of the opening tonality as the target of modulation (as in a modulation from C major to E major), or (iii) approaching semitones to the tonic triad of the opening tonality (as in a tonal "shift" from C major to B major). The swapping of the mode-defining third and tonic (i and ii) produces a mild, if deceptive, sense of staying in the same tonality. The approaching semitones (iii) create a feeling of quasi-resolution, as in a modulation from C major to D-flat-major (a difference of five flats) and from C major to B major (a difference of five sharps). There are two exceptions for the Ambiguous group. The first is a minor triad on a dominant tone, as a triad on the dominant is expected to be in a major mode according to the rules of classical tonal harmony. The second exception is a minor triad on a supertonic in the minor-minor condition; this exception is dictated by the alteration of the sixth diatonic step (VI) in a melodic minor.

Figure 3. The "pleasant surprise" modulations into major keys can be grouped into two kinds: the "leading" kind (to step 1 and step 11) that utilizes the attraction of approaching semitones and the "pseudostability" kind (to step 4 and step 8) that utilizes the "stabilizing" influence provided by the swapping of the mode-defining third and tonic.

2) Analysis of variance for Expected, Unexpected, and Ambiguous categories. An analysis of variance with three categories X six adjective scales X four mode conditions showed a main effect of category, $F(2, 19{,}845) = 65.91$, $R^2 = 0.33\%$, $p < .001$; a main effect of scale, $F(5, 19{,}845) = 66.20$, $R^2 = 0.33\%$, $p < 0.00$; a main effect of mode, $F(3, 19{,}845) = 355.32$, $R^2 = 1.79\%$, $p < .001$; an interaction of scale X category, $F(10, 19{,}845) = 1.88$, $p = .042$, $R^2 = 0.01\%$; and an interaction of mode X category, $F(6, 19{,}845) = 15.06$, $p < .001$, $R^2 = 0.76\%$. The overall response was stronger for the Expected group on "pleasantness," "firmness," and "strength." In contrast, the Unexpected modulations were sensed as "darker," "sadder," and less "pleasant." The character of the responses to the Ambiguous and Unexpected modulations illustrates the difference between a pleasant surprise and a not-so-pleasant surprise.

Table 1. Classification of twelve target steps as Expected, Unexpected, or Ambiguous

Mode	Expected	Unexpected	Ambiguous
M-M	0,5,7	2,3,6,9,10	1,4,8,11
M-m	0,2,4,5,9	6,8,10	1,3,7,11
m-M	0,3,7,8	1,2,6,9,10	4,5,11
m-m	0,5,7	6,9,10	1,3,2,4,8,11
Total	15	16	17

C. Experiment 2

Experiment 2 examined responses to modulation to three steps only: the distant step 8 and the close dominant and subdominant steps (for the rationale for this choice of steps, see Figure 4). All stimuli started and concluded in a major mode. The experimenter wrote eight harmonic progressions for each degree of modulation. This set of 24 "artificial" progressions was matched with a balanced set of 24 real music excerpts taken from pieces by the composers of the First Viennese School and the European Romantics. Unlike the deliberately impoverished harmonic progressions, the real music excerpts varied in tempo, duration, register, texture, and musical style. To control for the affective influence of melodic direction (Hevner, 1936; Sloboda, 1991; Toiviainen & Krumhansl, 2003) the set of artificial stimuli was balanced on the melodic direction in the bass and soprano lines. The affective responses have been measured with semantic differential scales related to valence, synaesthesia, potency, and tension.

1) Participants and procedure. The participants were 65 psychology students at the University of Texas at Dallas—49 females and 16 males, aged 19–47 (with a mean age of 25.2)—who took part in the experiment to fulfill a course requirement. Thirty-one participants—25 females and 6 males—with musical experience of playing a musical instrument or singing in a choir for more than three years were classified as "experienced."

2) Stimuli and apparatus. Affective responses to modulation were measured by using two sets of stimuli: the "artificial" harmonic progressions (HPs) and real music excerpts. The 24 brief, chorale-like progressions included eight modulations each to the subdominant (step 5), dominant (step 7), and ascending minor sixth (step 8). All modulations started and ended in the major mode. For each of the three modulation types, four progressions had a rising soprano line and four progressions had a falling soprano line. Each of these sets of four progressions had two progressions with a falling bass line and two progressions with a rising bass line, giving two progressions for each combination of rising and falling soprano and bass lines. All progressions were eight chords long and 11 seconds in duration at a moderate tempo (MM = 72). In addition, the principal experimenter collected and recorded 24 modulating excerpts from classical piano compositions, eight modulations each to the subdominant (step 5), dominant (step 7), and ascending minor sixth (step 8); all modulations were in the major-major condition. The excerpts were between 16 and 30 seconds in duration. To establish a sense of tonality, each trial began with a triad in the opening key of a given excerpt. All 48 stimuli were recorded as CD-quality WAV files by the principal experimenter, playing a grand piano.

3) Procedure. The experimental procedure in Experiment 2 was the same as in Experiment 1. Participants were asked to indicate their affective responses to each stimulus on six bipolar adjective scales. For Experiment 2, the *pleasant/unpleasant* scale from Experiment 1 was replaced with the *relaxed/tense* scale. This replacement was intended to provide for direct comparison with the earlier studies in perceived tension (Nielsen, 1983; Madsen & Fredrickson, 1993; Bigand, Parncutt, & Lerdahl, 1996; Toiviainen & Krumhansl, 2003).

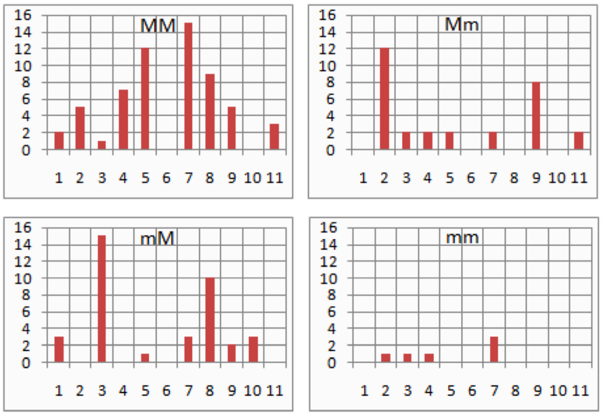

Figure 4. Distribution of modulations in 132 short excerpts from classical piano compositions. The y-axis shows the frequency of modulating fragments; the x-axis shows steps. Modulations to the subdominant (step 5) and dominant (step 7) and to step 8 are more numerous and more evenly distributed for the major-major condition than for the mixed-mode and minor-minor conditions. These modulations were selected from the piano sonatas of Mozart, Haydn, and Beethoven, as well as from collections of piano compositions by Beethoven (*Bagatelles*), Schubert (*Impromptus*), Schumann (*Humoresque*, *Kinderszenen*, *Kreisleriana*, *Arabesque*, and *Noveletten*), Chopin (*Ballades*, *Impromptus*), and Brahms (*Intermezzos*).

D. Results for Experiment 2

The obtained data were subjected to principal component analysis (PCA), analysis of variance (ANOVA), and Tukey pairwise comparisons.

1) Principal component analysis for Harmonic Progressions for Experiment 2. The greatest portion of variability (τ 1 = 73.1%) was related to valence (see Figure 5). A loading plot shows a pairing of the synaesthesia-related scales *bright/dark* and *warm/cold* and a paring of the potency-related scales *firm/wavering* and *strong/weak*. Modulations to the distant step 8 fall on the negative-connotation side of the first component (sad, dark, and cold), while modulations to the dominant fall on the positive-connotation side (happy, warm, and bright). Modulations to steps 7 and 8 were sensed by the participants as "strong" and "firm," whereas modulations to the subdominant (step 5) were sensed as "weak" and "wavering."

The affective responses to modulation were influenced by melodic direction. The progressions with rising soprano and bass lines fell mostly on the “bright,” “warm,” and “happy” side of the first component, while the progressions with the falling soprano and bass lines fell mostly on the “sad,” “dark,” and “cold” side (see Figure 6). The high-tessitura progressions with the mixed-direction contour patterns fell on the “bright,” “warm,” and “happy” side (HP 8, HP 9, and HP 15), whereas the low-tessitura progressions with the mixed-direction contour patterns fell on the “sad,” “dark,” and “cold” side (HP 7, HP 23, and HP 24).

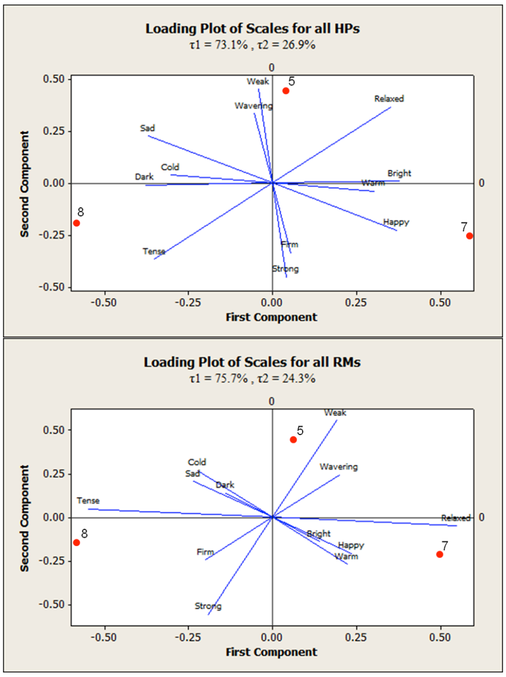

Figure 5. Responses to modulations to the subdominant (step 5), the dominant (step 7), and step 8 in 24 harmonic progressions (HP) and 24 real music excerpts (RM).

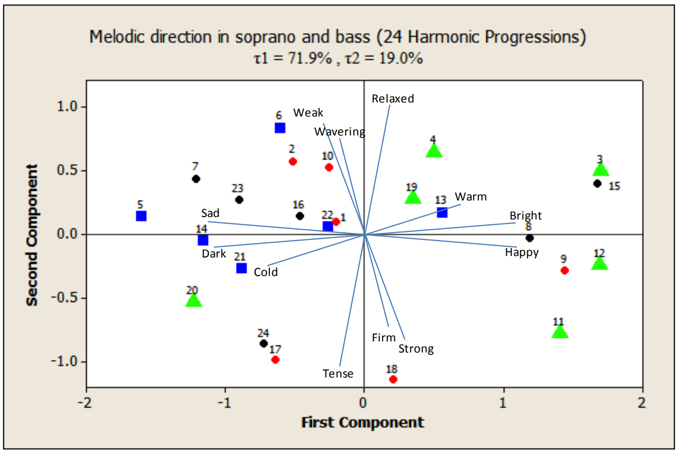

Figure 6. Influence of melodic direction on affective responses to Harmonic Progressions: rising/rising = triangles, falling/falling = squares, rising/falling = dots, falling/rising = diamonds. Responses to modulations with rising soprano and bass lines (triangles) were mostly on the positive-valence side, whereas responses to modulations with falling soprano and bass lines (squares) were mostly on the negative-valence side.

2) Analysis of variance for Harmonic Progressions for Experiment 2. An omnibus ANOVA with three steps X four contour patterns X two levels of experience X six adjective scales for harmonic progressions showed a main effect of step, $F(2, 9{,}244) = 53.47$, $R^2 = 1.04\%$, $p < .001$; a main effect of contour, $F(3, 9{,}244) = 29.25$, $R^2 = 0.86\%$, $p < .001$; a main effect of experience $F(1, 9{,}244) = 10.75$, $R^2 = 0.10\%$, $p = .001$; and a main effect of scale, $F(5, 9{,}297) = 7.63$, $R^2 = 0.37\%$, $p < .001$. Among the found interactions, of particular interest were interactions involving adjective scales: the interaction of scale X step, $F(10, 9{,}244) = 7.51$, $R^2 = 0.73\%$, $p < .001$; the interaction of scale X contour, $F(15, 9{,}244) = 3.90$, $R^2 = 0.57\%$, $p < .001$; the interaction of scale X experience, $F(5, 9{,}244) = 4.45$, $R^2 = 0.22\%$, $p = .001$; and the interaction of scale X step X contour, $F(30, 9{,}244) = 2.49$, $R^2 = 0.76\%$, $p < .001$. Six separate ANOVAs with three steps X four contour patterns X two levels of experience (one for each adjective scale) revealed that the dominant was reliably recognized as the “happiest” step, $F(2, 1{,}479) = 20.07$, $R^2 = 2.26\%$, $p < .001$ and that the dominant, as compared with the subdominant, was sensed as “firmer,” $F(2, 1{,}479) = 4.93$, $R^2 = 0.30\%$, $p = .007$ and “stronger,” $F(2, 1{,}479) = 11.77$, $R^2 = 0.67\%$, $p < .001$. Modulations to the distant step 8 were perceived as the “tensest,” $F(2, 1{,}479) = 22.93$, $R^2 = 2.50\%$, $p < .001$, whereas the close-proximity subdominant and dominant were not differentiated on the *tense*/*relaxed* adjective scale. To examine the influence of the contour patterns for each of the three degrees of modulation, the data were subjected to separate ANOVAs with six scales X four contour patterns. The results revealed that progressions with simultaneous upward direction in the soprano and bass lines and modulating to the dominant and subdominant were recognized as “happier,” “brighter,” and “warmer” than modulations with other contour patterns. In comparison, affective responses to step 8 for the *happy*/*sad* and *bright*/*dark* scales were not influenced by the melodic patterns, which suggests that for these scales the influence of tonal distance was stronger than the influence of the direction of pitch change (see Figure 7).

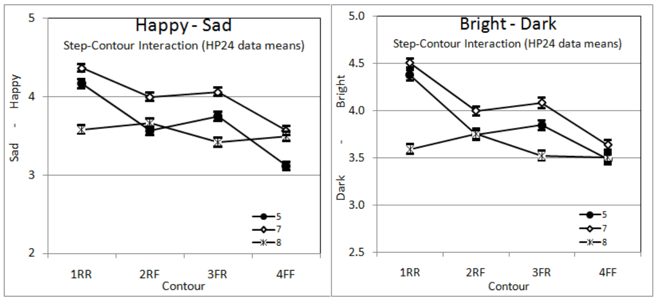

Figure 7. Influence of melodic direction in the soprano and bass lines in Harmonic Progressions for the *happy*/*sad* and *bright*/*dark* adjective scales. The pattern of responses is similar for the dominant (step 7) and subdominant (step 5) but different than that for step 8. The distant step 8 was only weakly influenced by melodic direction. Labeling: 1RR = rising soprano and rising bass; 2RF = rising soprano and falling bass; 3FR = falling soprano and rising bass; 4FF = falling soprano and falling bass. (Standard error of the mean, SD/√ N)

3) Principal components analysis for Real Music excerpts. Though the PCA graphs for the real music excerpts and “artificial” harmonic progressions demonstrate a similarity in the pattern of responses to the degrees of modulation, there is an important difference in the orientation of dimensions for the adjective scales, and therefore there is a difference in identification of the principal components (see Figure 5). Whereas for the harmonic progressions the first component is synesthesia-related (τ 1 = 73.1%) and the second component is potency-related (τ 2 = 26.9%), for the real music excerpts the first component is tension-related (τ 1 = 75.7%) and the second component is not defined by any of the dimensions. For the real music excerpts, step 8 was perceived as the "tensest" (similar to the results for the harmonic progressions) and the dominant was the most "relaxed" and also the "happiest" and "warmest," whereas the subdominant step is the "weakest."

The results also showed the participants' surprisingly fine sensitivity to musical style: The distribution of the stimuli on the factor graphics separates Mozart (M) and Haydn (H) from Beethoven (B), Schumann (RS), and Brahms (JB) (see Figure 9). The Romantics fell mostly on the "sad," "cold," and "dark" side, whereas Mozart and Haydn fell on the "happy," "warm," and "bright" side. Schubert's music was distributed on both sides; this corresponds to an a priori classification of Schubert's music as belonging both to the First Viennese School and the Romantics (highly trained classical pianists often acknowledge this classification in their performing practice). The "weak and wavering" pole of the potency-related dimension tilted on the Romantics' side. The two "tensest" real music excerpts, from Schumann's *Novelette* (RS 19) and Mozart's *Fantasia* (M 22), both modulate to the distant step 8. Among the four most "relaxed" excerpts, three modulate to the dominant: the excerpts from Mozart's Sonata in D Major (M 12), from Haydn's Sonata in E-flat Major (H 15), and from Beethoven's Sonata in C minor (B 16). A rather slow fragment from Brahms's *Intermezzo* (JB 13), though also modulating to the dominant step, fell on the "sad" and "dark" side; here the fragment's low register and slow tempo "overrode" the influence of degree of modulation. Similarly, a very slow fragment from Schumann's "Vogel als prophet" (RS 20), a slow excerpt from Schubert's Sonata in C minor (FS 8), and a relatively slow excerpt from Schubert's Sonata in G Major (FS 4) were perceived as "sad" and "dark." The three "happiest" excerpts are all in fast tempi and represent three different degrees of modulation: a subdominant step in Haydn's Sonata in C major (H 2), a dominant step in Mozart's Sonata in A minor (M 10), and step 8 in Schubert's Sonata in B-flat Major (FS 24). Overall, the factor graphics demonstrate that affective responses to the real music excerpts were influenced by degree of modulation, tempo, tessitura, and musical style.

4) Analysis of variance for Real Music excerpts. The data were subjected to a three steps X two levels of music experience X six adjective scales ANOVA that revealed a main effect of step, F (2, 9,271) = 17.40, R^2 = 0.36%, p < .001; a main effect of experience, F (1, 9,271) = 13.66, R^2 = 0.14%, p < .001; a main effect of scale, F (5, 9,271) = 48.57, R^2 = 2.51%, p < .001; an interaction of step X scale, F (10, 9,271) = 7.80, R^2 = 0.80%, p < .001; and an interaction of experience X scale, F (10, 9,271) = 3.24, R^2 = 0.16%, p = .008. The more detailed analysis with six separate three steps X two levels of music experience ANOVAs (one for each adjective scale) and Tukey pairwise comparisons revealed that the dominant was recognized as the "happiest," (2, 1,491) = 5.42, R^2 = 0.72 %, p = .005 and the "warmest," F (2, 1,491) = 7.39, R^2 = 0.99, p = .001; that modulations to the distant step 8 were recognized as the "firmest," F (2, 1,491) = 4.71, R^2 = 0.59, p = .009 and the "tensest," F (2, 1,491) = 24.51, R^2 = 2.99, p < .001; and that modulations to the subdominant were recognized as "tenser" than modulations to the dominant. The dominant was reliably perceived as "stronger" than the subdominant, F (2, 1,491) = 11.67, R^2 = 1.47%, p < .001.

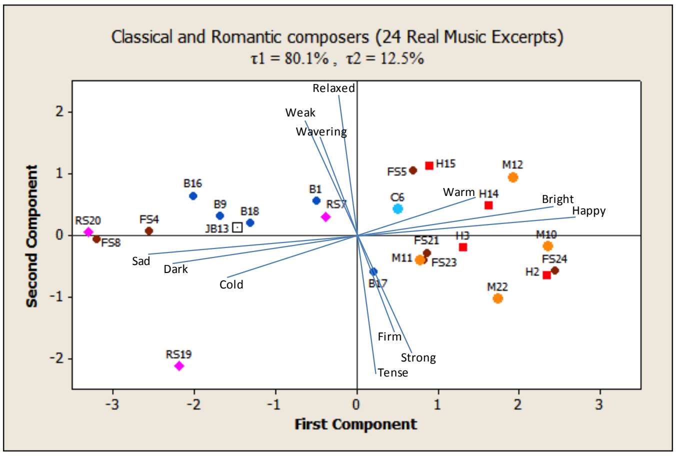

Figure 8. Affective responses to modulation in the real music excerpts were influenced by the interplay of various aspects of musical expressiveness that included tempo, degree of modulation, register, direction of melodic contour, and musical style. Labeling: RS = Robert Schumann, FS = Franz Schubert, B = Beethoven, JB= Johannes Brahms, C = Chopin, M = Mozart, H = Haydn. The composers of the First Viennese School fell mostly on the *happy, bright,* and *warm* side, whereas the Romantics were mostly on the *sad, dark,* and *cold* side.

III. DISCUSSION

A. Discussion for Experiment 1

The results of Experiment 1 revealed that the participants sensed different affective content in the different degrees of modulation. The listeners sensed the importance of the subdominant (step 5) and dominant (step 7), and they indicated negative feelings about modulation to the distant tritone (step 6) and the flattened leading tone (step 10). The listeners indicated positive feelings about the distant modulations to steps 1, 8, and 11 in a major mode. On the key-proximity map, major keys on the ascending semitone (step 1), leading tone (step 11), and ascending minor sixth (step 8) are situated far away from the tonal center. The presence of the leading and approaching semitones (for the steps 1 and 11) and the conversion of an opening-key tonic into a mode-defining third in modulation to step 8, however, made the distant modulations to the Neapolitan and an ascending minor sixth into stylistic preferences for a deceptive cadence in a major mode. The listeners sensed modulation to the distant Neapolitan (step 1) as the "warmest" and most "pleasant"; this modulation utilizes the power of approaching semitones. In contrast, the listeners recognized the modulation to a flattened leading tone (10) in a major mode as less "pleasant," even if this modulation introduces only two new pitches as compared with the five new pitches introduced by a modulation to the Neapolitan. When the leading tone is flattened, it looses its special status in the tonal hierarchy by becoming "unsuited" for a dominant triad, since according to the rules of conventional harmony "the function of a dominant can only be exerted…by a major triad" (Schoenberg (1954/1969, p. 56).

B. Discussion for Experiment 2

The results of Experiment 2 demonstrated that modulations to the distant step 8 (the ascending minor sixth) were perceived as the "tensest" in comparison with modulations to the subdominant and dominant, both in the harmonic progressions and the real music excerpts. This is in agreement with the theoretical model of pitch proximity, as explained using the circle of fifths, and with the results of previous investigations (Bigand et al., 1996; Bigand & Parncutt, 1999). Modulations to the subdominant and dominant were reliably differentiated for the *relaxed*/*tense* scale in the real music excerpts but not in the harmonic progressions. This can be interpreted as corroborating evidence for the influence of expressive performances versus nonexpressive performances on perceived key proximity (Thompson & Cuddy, 1997). In comparison with the monotonous harmonic progressions, the real music excerpts were richer in artistic cues, which could strengthen the sense of perceived key proximity. The finding that modulation to the subdominant was sensed as "weaker" than modulation to the dominant (both in the progressions and the real music excerpts) resonates with the musicological research that recognizes a subdominant region as "weaker" as compared with a dominant region (Rosen, 1972; Ribeiro-Pereira, 2004). In the real music excerpts, a perceived increase in tension in modulations to the subdominant appeared in association with an increase in negative valence and decreased potency, so that the modulations to the subdominant were recognized as "tenser," "sadder," "colder," "weaker," and more "wavering" than the modulations to the dominant. This finding complements the previous studies in perceived key proximity, which showed asymmetry of key perception in relation to the circle of fifths (Thompson & Cuddy, 1989, 1992, 1997). Whereas the musicological research defines a subdominant region as "weaker" in relation to large-scale modulations determining the overall structure of a complex musical composition, the present results revealed that this affective quality of the subdominant was sensed in the brief modulating passages as well.

Another new finding was related to the affective influence of melodic direction and to an interaction between contour pattern and degree of modulation. While the melodic direction clearly influenced affective responses to the modulations to the close-proximity steps, the dominant and the subdominant, melodic contour had only a weak influence on the responses for the distant step 8. This difference in responses suggests that the influence of key distance overpowered the influence of melodic direction in modulations to the "tensest" step, step 8. In contrast to step 8, the lower level of perceived tension for the dominant and subdominant steps resulted in a greater sensitivity to the contour patterns in the modulations to the close-proximity subdominant and dominant steps for the *happy*/*sad* scale and the synaesthesia-related *bright*/*dark* and *warm*/*cold* scales (see Figure 7).

C. General Discussion

The similarity in the pattern of responses to the controlled harmonic progressions and the much more expressive piano excerpts in Experiment 2 demonstrates that tonal modulation plays an essential role in determining affective responses to music. One of the unexpected and interesting findings of the presented studies was the difference in responses to the two most important degrees of modulation in Experiment 1 as compared with Experiment 2. In Experiment 1, the subdominant was perceived as "happy" and the dominant was perceived as "sad" (across modal conditions). In contrast, Experiment 2 found that modulations to the dominant were perceived as "happier" than modulations to the subdominant. These differences can be explained by the powerful effect of the major and minor modes, which creates a problem of ecological validity for modulations to the dominant in Experiment 1: Modulations to a dominant step in the minor mode are not orthodox in classical functional harmony (Schoenberg, 1954) and are rare in classical music. This mode-related problem does not exist for the subdominant. To ensure the ecological strength of its stimuli, Experiment 2 focused on the major mode only. The results demonstrated that modulation to the dominant was rated as "happier" and "stronger" than modulation to the subdominant. The results also showed that in the real music excerpts, modulation to the dominant—in the clockwise direction on the circle of fifths was associated with low tension as contrasted with an increase of tonal tension for counterclockwise motion to the subdominant and, to a greater degree, to step 8 (the ascending minor sixth). These results complement the previous investigations in perceived tonal tension (Toiviainen & Krumhansl, 2003) and perceived key proximity (Thompson & Cuddy, 1989, 1992). In addition, the finding of a reliable differentiation between degree of perceived tension in modulation to the dominant and to the subdominant for the real music excerpts (modulations to the subdominant were recognized as "tenser" than modulations to the dominant) but not for the harmonic progressions (the dominant and subdominant steps were not reliably differentiated on the relaxed/tense scale for the progressions) corroborated a finding of the previous study by Thompson and Cuddy (1997), which demonstrated that the listeners' responses to expressive performance corresponded more closely to theoretical predictions based on the circle of fifths than their responses to nonexpressive performance. It is possible that the more detailed differentiation of perceived tension in the real music excerpts in our study could be due to the greater expressiveness of these excerpts as compared with the plain progressions. The greater perceived tension found in modulations to the distant step 8 (both in the real music excerpts and the progressions) as compared with the close modulations to subdominant and dominant steps is in agreement with the theoretical model of pitch proximity as explained by the circle of fifths; this finding also agrees with the results of previous investigations (Bigand et al., 1996; Bigand & Parncutt, 1999). Additional evidence for the influence of distant key proximity on affective response was provided by the participants' reactions to the contour patterns. For the *happy/sad* and, to a lesser degree, for the *bright/dark* and *warm/cold* adjective scales, the listeners showed sensitivity to the contour patterns in modulation to the close subdominant and dominant steps but not to the distant step 8. These results suggest that, for these scales, an increase in perceived tension for the distant step 8 dampened the listener's sensitivity to the influence of melodic contour.

Perhaps the most important discovery of our study was the association between perceived tension and affective characteristics. This association may have important implications for research in music perception because it connects emotions in music with the theory of tonal expectations (determined by the interplay of tonal tension and release (Meyer, 1956; Lerdahl & Krumhansl, 2007) and with psychophysiological measurements of perceived tension (Fredrickson, 1995; Krumhansl, 1996; Madsen & Fredrickson, 1993; Nielsen, 1983; Toiviainen & Krumhansl, 2003).

To explain music's directness in communicating emotions, we propose the archaic model of emotional processing (Korsakova-Kreyn, 2009), which connects perceived tension and affective response (Panksepp 1998). This model draws on the recognition of a strong precognitive aspect of music perception (Shewmon, Holmes, & Byrne, 1999; Panksepp & Bernatsky, 2002; Zatorre, 2005) and suggests that affective responses in music are generated by the precognitive integration of "gut-felt" sensations induced by the temporally organized interplay of tonal tension and release. This model employs Panksepp's concept of a virtual body image, or the "virtual self" within our paleo-mammalian brain, which integrates minute somato- and visceromotor responses to the environment (Panksepp, 2004). Relying on this concept, the archaic model of emotional processing proposes that the listener's minute sensations of differences in perceived tension acquire affective properties because the sequencing of these sensations in music mimics the way the "virtual self" reflects and integrates the experience of the living organism. Minute reactions to the environment generate streams of tension and release. From this perspective, music can be explained as a sequence of tonal events that induce emotion by imitating the dynamics of the integration of somato- and visceromotor information in the midbrain. The integration of these sensations according to the tonal-temporal program of a particular musical composition results in the generation of a particular emotion. The gut-felt sensations are not emotions (Krumhansl, 1997); their artfully controlled sequences, however, can trigger emotional responses. The archaic model suggests that aesthetic emotion is built into musical composition as the "logic of emotion" (Langer, 1942/1957), employing the most primitive mechanism of reaction of the living organism to its environment: the degree of tension. Listening to music activates in the listener the same primitive mechanism, and this results in the "reconstruction" of an emotion. The interplay of different levels of perceived tension is related to the two main morphological principles of music: tonal attraction and structured time. When these principles are artfully employed to create melodic ideas and structures, the results affect our psychological state and aesthetic judgment.

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