AFFECTIVE RESPONSE TO TONAL MODULATION

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Abstract

Tonal modulation is one of the main structural and expressive aspects of music in the European musical tradition. Experiment 1 investigated affective responses to modulations to all twelve major and minor keys of the Western tonal schema. The results indicated dependence of affective response on degree of modulation, on key proximity, modal milieu, and, perhaps, stylistic familiarity. The results agreed with previous studies in affective response to the major and minor modes. Experiment 2 examined affective responses to modulations to the subdominant, dominant, and minor sixth in the major mode only. Modulations to the subdominant were recognized as “weaker” than modulations to the dominant. Modulations to the distant minor sixth were sensed as “tenser” than modulations to the subdominant and dominant, which agrees with the theoretical model of pitch proximity based on the circle of fifths.
While there is a general agreement that music generates emotions (Huron, 2006; Juslin & Sloboda, 2010), the mechanism of communication of affective states by music is still unclear, mostly because of the non-representative nature of music. Tonal modulation is one of the main structural and expressive aspects of Western music since 1600. Freedom of tonal modulation was achieved through the adoption of equal-tempered tuning providing for tonal re-orientation to any of the twelve chromatic steps of the scale (Figure 1). Modulation is an important aspect of musical syntax because it is intimately related to the closure provided by the cadence and thus to the formation of extended musical structures.

![Figure 1. Degrees of modulation on the chromatic steps for C major scale. Tonic (root) is numbered as 0 degree](image)

Tonal modulation, as a principal tool of thematic harmonic development, offers a useful illustration of a “lawful relation between the intensity of emotional qualities experienced in music and structural characteristics of the music at a particular point in time” (Juslin & Sloboda, 2001, pg. 91). Musical practice shows that some modulations are more popular than others and that some modulations are associated with characteristic emotional responses. Tonal modulation can involve major and minor modes whose affective qualities have been examined in many studies (Halpern, Martin, & Reed, 2008; Hevner, 1935, 1936, 1937; Panksepp & Bekkedal, 1997; Peretz, Gagnon, & Bouchard, 1998; Temperley, 2004; Webster & Weir, 2005; Weld, 1912). Whereas the musicological literature and studies in music theory offer rich a priori material on tonal modulation, the scientific evidence bearing on affective responses to modulation is scarce and indirect.

Music perception involves pattern recognition within the tonal system of reference or tonal scale. The pitches of the scale differ in their level of tonal attraction forming a tonal hierarchy (Krumhansl, 1990). In contemporary musical practice, differences among tonalities are explained in terms of the circle of fifths (Chew, 2002;
Lerdahl, 2001; Purwins, 2005; Toiviainen & Krumhansl, 2003). Freedom of tonal reorientation throughout the circle of fifths has been achieved through the adoption of equal temperament (ET) beginning in the 17th century (Barbour, 1932/1953; Schulter, 1998). The adoption of ET went hand in hand with the evolution of musical form that introduced tonal harmony and tonal modulation, thus giving impetus to the desire for tonal reorientation to ever more distant keys (Cazden, 1954; Dahlhous, 1990; Lerdahl, 2001; Scruton, 1997). The number of steps taken from a tonic around the circle of fifths defines key proximity. A greater number of steps results in a smaller number of pitches in common between tonalities and thus in a greater distance in terms of key proximity.

Thanks to equal temperament, each step of the chromatic scale can be the root of a triad. Triads on the tonic (I), subdominant (IV), and dominant (V) include among them all the pitches of the diatonic major scale. When presented in the sequence I-IV-V-I, these triads constitute the fundamental formula of tonal harmony (Riemann, 1883/1969; Schenker, 1954). Other triads can be considered as belonging to a region of one of these three chords. For example, a minor triad on a second step (supertonic) in a major tonality belongs to a subdominant region and thus often appears as a substitute for subdominant in a cadence. In classical functional harmony, a triad on dominant includes the leading tone, the seventh degree of the scale. To produce such a leading tone in the minor mode involves raising its seventh diatonic step. The fundamental formula I(i)- IV(iv)-V-I(i) is also an expression of a conventional or authentic cadence.

A tonic triad represents a conceptual core of tonality. Tonality can be explained as a system of tonal relationships that shape melodic objects and maintain their unity. Tonal modulation is a re-orientation from one tonality to another in the course of musical development within same composition. During this process the tonal schema is shifted to a different tonic. The presence of pitches foreign to the original key signals that the tonality is changing (Janata, Birk, Van Horn, Leman et al, 2002; Platel, Price, Baron.; Ruiz, Koelsch & Bhattacharya, 2009; Steinbeis, Koelsch & Sloboda, 2006; Tillmann, Koelsch, Escoffier, Bigand et al, 2006; Wise et al, 1997).

Studies have demonstrated that listeners are able to follow modulations (Bigand, Madurell, Tillmann & Pineau, 1999; Bigand, Parncutt & Lerdahl, 1996; Firmino, Bueno & Bigand, 2009; Krumhansl & Kessler, 1982; Lerdahl & Krumhansl, 2007; Thompson &
Cuddy, 1989, 1992; Toiviainen & Krumhansl, 2003). Perceptions of tonal modulation imply that listeners are thinking in terms of the language of tonal harmony (Holleran, Jones & Butler, 1995). Tonal modulation can be described as a two-stage process that involves, first, deviating from a given tonality, and then finding a way to resolve the instability in another tonality. This process is guided by musical expectations that are determined by tonal tension and relaxation (Meyer, 1956).

Perceived tonal tension in modulation is related to key proximity (Bigand & Parnicutt, 1999; Bigand, Parnicutt, & Lerdtahl, 1996; Firmino, Bueno, & Bigand, 2009; Thompson & Cuddy, 1989, 1992), to the direction of modulation on the circle of fifths (Thompson & Cuddy, 1989, 1992; Toiviainen & Krumhansl, 2003), and to the major and minor modes (Toiviainen & Krumhansl, 2003). Perceived tension is higher for the minor mode than for the major mode (Toiviainen & Krumhansl, 2003). Thompson and Cuddy showed that accuracy of responses to degree of modulation (key proximity) is higher for counterclockwise and for distant modulations. Accuracy of judgment of perceived key proximity can be enhanced by expressive performance (Thompson & Cuddy, 1997).

Key proximity in modulation has an effect on time estimation, that is, modulation to the distant tonality is perceived as shortened in time as compared to modulation to the close tonality (Firmino, Bueno, & Bigand, 2009). This suggests an association of perceived tension with time estimates.

Depending on context, tonal modulation can take a central role in musical development by arousing the listener. Schachter and Singer’s (1962) study, where the behavior of confederates of the experimenter emotionally cued participants’ arousal, can be used as a metaphorical illustration of how the emotional direction of arousal is influenced by environment and context. The most common large-scale modulations in classical music are modulations to the subdominant and dominant steps. Rosen (1972) writes that the tension between tonic and dominant in the context of the circle of fifths “created a new language of the emotions.” Comparing dominant and subdominant regions, Ribeiro-Pereira (2004) writes in his analysis of Monteverdi’s Lamento d’Arianna about the “feminine” and “warm” subdominant function which is characterized by lesser tension than the dominant. However, as was stated by Nielsen (1983) and demonstrated by Fredrickson (1995), Krumhansl (1996), and Toiviainen and Krumhansl (2003),
perceived tension in real music is a complex phenomenon that is not limited to tonal tension only. While the circle of fifths gives a clear indication of the importance of the dominant and subdominant—each just one step away from the opening tonality—key proximity alone does not predict affective properties of the listener’s response to reorientation in tonal space.

Tonal modulation, as a reorientation on different tonal center, can involve a change in mode. The major and minor modes have been known for their affective qualities for ages (Wielpahl, 1971). To evaluate affective response to the modes, musicians and scholars use the words happy and sad respectively. Hevner (1935) found that affective responsiveness to the major and minor modes was more stable than to tempo, rhythm, and to falling and rising melodic line. Stimuli in same mode but in fast tempo are perceived as happier than in slow tempo (Gagnon & Peretz, 2003). Non-harmonized melodies are perceived as happier than harmonized for both major and minor modes, and music in the minor mode is felt as sadder by females than by males (Webster & Weir, 2005).

Tonal modulation is thought to produce strong emotional effects, but these effects have not yet been thoroughly explored. We conducted two experiments to investigate affective responses to tonal modulation. Experiment 1 examined affective responses to modulation to all twelve major and minor keys of the Western tonal schema. Experiment 2 focused on modulations to subdominant (5), dominant (7), and descending major third (8). These modulations were in major mode only in order to provide ecological validity of the stimuli, particularly those modulating to dominant (Schoenberg, 1954/1969). In addition, Experiment 2 investigated the affective influence of melodic direction in soprano and bass melodic lines.

Experiment 1

Method

Participants

Sixty-nine participants, 54 females and 15 males, ages 19–53 with a mean of 24.8, psychology students from the University of Texas at Dallas, took part in the experiment to fulfill a course requirement. Among them, thirty-seven participants—31 females and 6 males—had four and more years of musical training and were classified as
“experienced.” Musical experience included playing musical instruments such as piano, guitar, violin, and wind instruments, and singing in a choir.

**Stimuli and Apparatus**

The principal experimenter wrote 12 short harmonic choral-like progressions, one for each of the 12 intervals of the chromatic scale (Figure 1). This included the zero-step or non-modulating condition to provide baseline data against which to compare responses to modulations in which the tonal center shifted in pitch. The 12 progressions were then modified to obtain four versions of modulation to each scale degree: from Major to Major mode (M-M), from Major to minor (M-m), from minor to Major (m-M), and from minor to minor (m-m). When composing the progressions, the experimenter tried to make them as much alike as possible. Each progression was 8-chords long; some particular chords appeared more than once in a given progression. The first 3-5 chords in each progression established the opening tonality. The following transitional chords made a smooth modulation to a target tonality via authentic cadence. Some modulations demanded fewer transitional chords than others. There was no sudden unexpected juxtaposition of chords in the progressions, and the tonal reorientation to the other tonal center was always smooth. These 48 progressions differed in degree of modulation, in rhythm (slightly), voice leading, and in the number of functionally different chords. The progressions were alike in tempo, style, sound intensity, timbre, and range.

The degree of modulation is defined by functional distance in tonal space where Tonic (I-i, zero-distance), Subdominant (IV-iv) and Dominant (V-V) represent the hierarchical foundation of functional harmony (Lerdahl, 2001; Riemann, 1893). The stylistic unity of the progressions prevented interaction of mode and texture (Kastner & Crowder, 1990; Webster & Weir, 2005) which composers often use to heighten emotional effects. Several of the progressions had one or two passing tones in the middle of the progressions that helped in creating smooth versions of the cadences. The progressions were 11 sec in duration (MM = 72) and with a slight *ritenuto* at the end to make the modulation sound natural. The last chord was about 3 seconds in duration to emphasize the closing tonality. Each progression was followed by a delay of 10 sec. The duration of each progression was within the “sliding window” of music perception.
(Bigand & Parncutt, 1999; Tillmann & Bigand, 2004; Tillmann, Bigand, & Pineau, 1998) determined by the properties of the immediate auditory memory buffer.

In addition, the participants judged a series of 17 brief excerpts selected from classical music. In comparison with the chordal progressions, the real music excerpts were more varied in length, dynamics, texture, and tempo. They were collected from musical compositions that belong to the traditional classical piano repertoire representing the Romantic period. All 65 stimuli were digitally recorded as CD-quality wave-files by the principal experimenter playing a Yamaha grand piano and presented to participants via loudspeakers with high-quality stereophonic equipment.

**Procedure**

Participants were asked to indicate intensity of their affective response to each stimulus on six bipolar adjective scales with semantic differential (Osgood, Suci & Tannenbaum, 1957). The three groups of adjectives represented valence (Happy-Sad, Pleasant-Unpleasant), potency (Strong-Weak, Firm-Wavering), and synaesthesia (Bright-Dark, Warm-Cold). This choice of semantic differentials did not adhere strictly to the Osgood et al (1957) three main categories of valence, activity, and potency, since previous pilot work in the same laboratory had found that listeners have difficulty using it consistently with music. Among the categories, a greater emphasis was placed on the valence category, since sensory adjectives of Bright-Dark and Warm-Cold are endowed with valence as well. The participants were asked to place a mark to indicate intensity of their feeling about the concluding part of each progression on a 6-point scale. For each stimulus there was a table with the six bi-polar adjective scales presented in various random orders. On each of the eight answer pages, the order of adjective scales in a table was scrambled for each stimulus. During data analysis, the 6-point adjective scale was centered on a midpoint (3.5) to make the graphs more readable.

In the course of a short training session, after the experimenter explained the task and described how to record judgments on the stimuli, the participants heard and rated four sample stimuli with M-M (Major to Major), M-m (Major to minor), m-M (minor to Major), and m-m (minor to minor) modulations. The participants were tested in group sessions, with 2-9 persons per group. During each session, there were altogether 65 trials: the 48 chordal progressions and, after a short break, the 17 real music excerpts. Different
groups heard different random orders of the stimuli within each of those two blocks of trials.

Results

To explore different patterns of affective response to different modulations, the data were subjected to a Principal Components Analysis (PCA) and an analysis of variance (ANOVA).

Principal component analysis of harmonic progressions:

Three important global features emerged in the PCA results (Figure 2): 1. 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. 2. The potency dimension tilted in such a way that for the Major-Major modulations the positive-valence characteristics “happy,” “bright,” and “warm” became related to the “strong” and “firm,” whereas for the minor-minor modulations the “strong” and “firm” became related with the negative-valence characteristics “sad,” “dark,” and “cold.” For the mixed-mode modulations Major-minor and minor-Major the potency dimension is nearly orthogonal. 3. Modulations to the dominant and subdominant steps were well differentiated and perceived as belonging to opposite valence, so that the Dominant (7) was recognized as “sad,” “dark,” “cold,” and “unpleasant”, whereas the Subdominant (5) was recognized as “happy,” “bright,” “warm,” and “pleasant.” The Dominant was the only step that was consistently recognized as “strong” and “firm.”

Principal component analysis of individual steps:

The participants recognized the important Subdominant (5) and Dominant (7) steps and demonstrated sensitivity to modal conditions in modulations to a minor sixth (8), which is a popular target in deceptive cadences in the major mode, and to steps 11 and 1, both of which are the approaching semitones to the tonic. Steps 6 (tritone) and 10 (minor seventh, a lowered leading tone) were consistently perceived as unpleasant. In addition, the plot shows a poor differentiation of upper steps in passages that concluded in the minor mode. The latter can be explained by the volatility in these steps (8, 9, 10, and 11) due to differences in the ascending and descending motion of a minor scale.
Figure 2. PCA for affective responses to individual steps in modulating harmonic progressions in four modal conditions: Major-Major, Major-minor, minor-Major, minor-minor. 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 potency dimension tilted in such a way that for the Major-Major modulations the positive-valence characteristics “happy,” “bright,” and “warm” became related to the “strong” and “firm,” whereas for the minor-minor modulations the “strong” and “firm” became related with the negative-valence characteristics “sad,” “dark,” and “cold.” For the mixed-mode modulations Major-minor and minor-Major the potency dimension is nearly orthogonal. Modulations to the dominant and subdominant steps were well differentiated and perceived as belonging to opposite valence. The Dominant was the only step that was consistently recognized as “strong” and “firm.”

Analysis of variance for harmonic progressions

Among the most interesting results of the analysis of variance (see Appendix 1) was the finding of a cumulative effect of same modal condition in a beginning and an ending of the modulating passages for the Happy-Sad adjective scale (Figure 3). Whereas
the participants responded principally to the major and minor endings of the modulations, the uniformly major progressions were rated as happiest and uniformly minor progressions as saddest. Preceding the major or minor ending with the opposite mode lessened this effect. There was no interaction between a beginning and an ending modal condition for any of the adjective scales. The results also demonstrated a main effect of an ending modal condition for all six adjective scales. However, there was no main effect of a beginning modal condition for the potency-related Firm-Wavering and Strong-Weak adjective scales, unlike for other four adjective scales. Another interesting result for the potency-related scales was the high ratings in perceived firmness and strength for modulations to dominant (7) in the minor-Major and minor-minor conditions (when a modulating passage begins in minor). Tukey pairwise comparisons showed that dominant step was reliably differentiated for the Firm-Wavering and Strong-Weak adjective scales in the minor-Major and minor-minor conditions. Dominant was the only scale degree that showed an increase in the ratings for those modulations that begin in the minor mode.

Figure 3: Uniformly major progressions were rated as happiest and uniformly minor progressions as saddest. Preceding the major or minor ending with the opposite mode lessened this effect. Labeling: M-M = Major-Major; M-m = Major-minor; m-M = minor-Major; m-m = minor-minor. (Standard error of the mean, SD/√ N)

Classification of targeted by modulation steps on Expected, Unexpected, and Ambiguous:

A triad on a root of a given scale represents a conceptual core of tonality. To make sense of the affective responses to the individual steps as roots of triads, these
Target-steps were classified into three categories: Expected, Unexpected, and Ambiguous (TABLE 1).

**TABLE 1.**

Classification of Twelve Target steps into Expected, Unexpected, and Ambiguous

<table>
<thead>
<tr>
<th>Mode</th>
<th>Expected</th>
<th>Unexpected</th>
<th>Ambiguous</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-M</td>
<td>0,7</td>
<td>2,3,6,9,10</td>
<td>1,4,8,11</td>
</tr>
<tr>
<td>M-m</td>
<td>0,2,4,5,9</td>
<td>6,8,10</td>
<td>1,3,7,11</td>
</tr>
<tr>
<td>m-M</td>
<td>0,3,7,8</td>
<td>1,2,6,9,10</td>
<td>4,5,11</td>
</tr>
<tr>
<td>m-m</td>
<td>0,5,7</td>
<td>6,9,10</td>
<td>1,3,2,4,8,11</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

The following criteria were employed: The Expected final triad is built on diatonic steps of an Opening tonality (Lerdahl’s “chordal core” minus the diatonic seventh step [vii]), since neither a major not a minor triad can be built on this step with diatonic tones). There was an exception. Placement of the same-name Major-minor and minor-Major modulations (for example, C-major versus c-minor) into the Expected group was justified by the communality of a root-tone. Musical practice demonstrates the powerful role of root (tonal center) in a zero-step modulation with an altered third (modal change). For example, in the Baroque music, a composition in a minor key often ends on a same-name Major triad (*Picardy third*).

The Unexpected final triad has at least one chromatic tone—a tone that is outside the seven diatonic steps of an opening tonality. This condition, it was assumed, creates a feeling of unnaturalness.

The Ambiguous final triad contains either (i.) a root of the opening tonality as a third in a final triad (for example, C in an A-flat-Major triad vs. an opening C-Major/c-minor triad); or (ii.) a third diatonic step of the opening tonality as a root of a final triad (for example, E in an E-Major triad vs. an opening C-Major triad); or (iii.) contains approaching semitones to a tonic triad of the opening tonality (for example, a tonal “shift” between B-major and c-minor or B-major and C-major). The first two conditions, which involve a root and a mode-defining third, were assumed to produce a comforting—though mild—sense of coming back to an opening tonality. The last condition relies on the reciprocal “leading tone-” qualities of the triads in question. Namely, this condition
utilizes the power of attraction of approaching semitones to a root and to a mode-defining third. These “leading tone-” qualities create a special relationship between tonalities which are remote in functional distance: for example between C-major and D flat-major (difference in five flats), or C-major and B-major (difference in five sharps). There are two exceptions. First is an inclusion in this group of a minor triad on a Dominant tone (7) because of its ambiguous nature: In the classical functional harmony the Dominant triad is expected to be in a major mode. Second is an inclusion of a minor triad on a supertonic in the minor-minor condition which reflects the ambiguity caused by two versions of a minor scale: The minor triad on this step includes diatonic step (a sixth) that becomes altered in the melodic minor.

*Average affective responses for Expected, Unexpected, and Ambiguous triads:*

The overall response was stronger for the Expected group on pleasantness and positive potency (Firm and Strong) (See Figure 4). This speaks for a perceived greater certainty of the Expected triadic endings that are all based on diatonic steps of opening tonalities. The Expected group also demonstrated stronger responses to same-name modulations. In contrast, the Unexpected modulations appeared as less certain, less “pleasant,” and “darker” and “sadder.”

The Unexpected modulations showed very little of “happy” appearance even for Major-Major modulations. In comparison to both the Expected and Unexpected groups, the Ambiguous group showed a better coherence in response to the Major and minor endings in all mode combinations on valence (Happy-Sad, Pleasant-Unpleasant) and synaesthesia (Bright-Dark, Warm-Cold). Modulations to minor produced a “sadder,” “darker,” and “colder” response than modulations to major, which, in comparison, invited “brighter,” “happier,” and “warmer” response. Targets in the Ambiguous group accentuated modal (stemming from the major and minor modes) qualities of tonal modulation. The averages on collapsed modes revealed a general pleasantness of progressions and a *negativity bias* as “sad” surpassed “happy” in intensity in all three groups. Altogether, the Unexpected modulations were perceived as less “pleasant” and less certain, and “colder,” “darker,” and “sadder” than Expected and Ambiguous. It appears that the graphs on the Ambiguous and Unexpected modulations illustrate difference in response to a pleasant tonal surprise versus a not too pleasant surprise.
Tukey pairwise comparisons demonstrated that, unlike the Happy-Sad adjective scale, the Pleasant-Unpleasant scale did not provide much information. This can be explained by the lack of specificity of the Pleasant-Unpleasant scale in relation to the rather uniform musical stimuli. They all were tonal progressions with smooth modulations. Moreover, the influence of major and minor on the Pleasant-Unpleasant scale is difficult to detect, since sad music is not necessarily unpleasant music (Blood & Zatorre, 2001; Panksepp, 1995).

**Figure 4.** Average affective responses for Expected, Unexpected, and Ambiguous triads for each adjective scale and four modal conditions. Ratings for the Ambiguous and Unexpected modulations illustrate difference in response to a pleasant tonal surprise versus a not too pleasant surprise. (Standard error of the mean, SD/√N)
Principal component analysis for real music excerpts:

The projection of real music excerpts as Supplementary elements into factor graphics shows an influence of tempo on affective response to tonal modulation. For example, excerpts from Schumann’s Der dichter spricht and from Beethoven’s Allegretto from Sonata No 30 (op. 109) appear on different valence sides though they modulate in same mode and to same degree. The explanation is in different tempi: the Allegretto is on a positive-valence side and the slow Der dichter spricht is on the negative-Valence side. Still more revealing is a well-differentiated appearance of a fragment from Beethoven’s Sonata No 4 (op. 7, second movement, Largo, Major-Major condition) in the Sad and Dark quadrant of a negative-valence side, even if this beautiful fragment begins and ends in C-major. It seems that in this case the affective response was strongly influenced not only by the fragment’s slow tempo but by the sounds of the piano’s low register as well.

Discussion

The participants sensed different affective content in the different degrees of modulation. They showed sensitivity to key proximity by differentiating the Dominant (7) and Subdominant (5), by indicating the negative feeling about modulations to tritone (6) and flattened leading tone (10), and by indicating the positive feeling about modulations to the distant major keys on the ascending minor second (1), descending minor second (11), and minor sixth (8). This suggests the importance of approaching semitones for perception of the tonal functional relationships. For example, in C-major tonality, an A-flat-major triad contains two approaching semitones to the tonic triad, whereas the Neapolitan and B major triad each contain three approaching semitones. The “leading” qualities of target-triads on the ascending minor second (1), descending minor second (11), and ascending minor sixth (8) seem to create a comforting sense of resolution, thus alleviating the effect of distant tonal relationship in the functional hierarchy. For example, in C major tonality, the D-flat major and B-major tonalities each introduce five new pitches and A-flat major tonality introduces four new pitches, i.e., these three tonalities are situated far away from C-major on the circle of fifths. In contrast, the listeners recognized as less pleasant the modulation to a flattened leading tone (10) even if B-flat major introduces only two new pitches to C major tonality and thus is closer on the circle of fifths than A-flat major, B-major and D-flat major tonalities.
This sensitivity to the flattened leading tone was captured in Experiment 1 in Krumhansl and Kessler’s (1982) study when the profiles of two relative tonalities, C Major and a-minor, were superimposed. In this superimposition, tone A and tone G show the greatest difference of ratings. Tone A is a root in the a-minor scale and hence particularly important in a-minor tonality. Tone G is a flattened leading tone in the harmonic and descending melodic versions of the a-minor scale. The flattened G is “unsuited” for a dominant triad that needs to be a major triad, as it dictated by the rules of conventional harmony. Schoenberg (1954/1969) writes that “The function of a dominant can only be exerted … by a major triad” (pg. 56).

During the categorization of the Target triads on Expected, Unexpected and Ambiguous in the present study (Table 1), the importance of the leading and approaching semitones in relationship between tonic triads was taken into consideration. That is why some distant modulations were included into the Ambiguous group. For instance, in major tonalities, the Neapolitan (second inversion of a major triad on a lowered second), is built on three approaching semitones to the tonic triad in a major tonality, such as D-flat major triad vs. C major triad in C major tonality. In the same way, a major triad on the ascending minor sixth (step 8) has two approaching semitones to the tonic triad in a major tonality, such as A-flat triad vs. C major triad in C major tonality. In this instance, the mode-defining third in a major triad on a lowered sixth (A-flat—C—E-flat) is also the root of a given tonality (C).

According to the principle of the “shortest path” (Lerdahl, 2001), major keys on the ascending semitone (1), descending semitone (11), and ascending minor sixth (8) are situated far away from a tonal center on the key-proximity map. Yet it seems that the special condition—the presence of a leading and approaching semitones (and a shared root for a triad on a lowered sixth)—made the distant modulations to the Neapolitan and the ascending minor sixth into stylistic preferences for a deceptive cadence.

Historically, the crystallization of triadic relationships of functional harmony from the organically interwoven voices of polyphony transformed the meeting point of melodic voices into independent entities — chords. However, the vestiges of polyphonic thinking and the very phylogeny of tonal hierarchy defined by a degree of tonal tension—that involves a leading semitone—seem to remain the important factors in perception of
tonal harmony. Conceivably, this phenomenon underlies the preference for the popular deceptive cadences into major keys on ascending semitone and descending major third, as well as the Picardy third and the major-minor dichotomy.

The PCA shows grouping of responses for the reliable Happy-Sad adjective scale with the responses for the synaesthesia-related Bright-Dark and Warm-Cold adjective scales thus creating the valence dimension (Figure 2). Conversely, the responses for the Strong-Weak and Firm-Wavering adjective scales grouped to form the potency dimension that was not always orthogonal to the valence dimension. Overall, the results demonstrated usefulness of the synaesthesia-related adjective scales Bright-Dark and Warm-Cold and the potency-related adjective scale Strong-Weak.

The musicological literature informs that both a simple musical structure A-B-A′ and a complex Sonata Allegro form, in the music of the First Viennese School and some early Romantic composers, use modulations to the dominant and subdominant on the large structural scale (exposition, development, and recapitulation) and in the juxtaposition of the first and second themes (Rosen, 1988). An analysis of 132 modulating fragments from classical piano repertoire confirmed that the dominant and subdominant are the most frequent targets in brief modulations in classical tonal music (Figure 5). The analysis also revealed that ascending minor sixth (step 8, in major keys) approaches dominant and subdominant in popularity as a target of modulation. In addition, the analysis showed that step 2 (supertonic) is a frequent target in modulations from major to minor keys, whereas step 3 (minor third) is a frequent target of modulations from minor to major keys. A minor triad on supertonic in a major key consists of diatonic steps; this minor triad is an often substitute for a subdominant function in an authentic cadence (for examples, a d-minor triad in C major tonality). A major triad on a minor third in a minor key represents relative tonality, which contains the same set of diatonic steps as an opening tonality (for example, C major triad in a-minor tonality). Therefore, the popularity of steps 2 and 3 as targets of modulation can be explained by close key proximity of tonalities that can be built on these steps.

Overall, the results demonstrate that key proximity alone does not define a character of affective response. For example, affective responses to tonal modulation in real music were influenced by tempo and tessitura.
Experiment 2

The results of Experiment 1 confirmed the listener’s sensitivity to two most important degrees of modulation, the subdominant (5) and dominant (7) (Rosen, 1972), yet the ecological weakness of some of the stimuli demanded further investigation. Research design of Experiment 2 brought into focus the relationship between the effect of key proximity and perceived tension. In addition, Experiment 2 investigated the affective influence of melodic direction in soprano and bass melodic lines.

Experiment 2 explored affective responses to subdominant, dominant, and descending major third using 24 harmonic progressions and 24 real music excerpts. All stimuli were in Major-Major modal condition in order to maintain the ecological validity of the stimuli, namely to avoid modulations to minor key on a dominant (7). The selection of these three target-steps—subdominant, dominant and ascending minor sixth—was based on the existing musicological research and on the analysis of brief modulating fragments found in the piano works by the composers of the First Viennese School and the Romantics (Figure 5).

![Graphs](image)

**Figure 5.** Distribution of modulations in 132 short excerpts from classical piano compositions. The Y-axis shows frequency of modulating fragments; the X-axis shows steps. Modulations to Subdominant (5), Dominant (7), and step 8 are more numerous and are more evenly distributed for the Major-Major condition than for the mixed-mode and minor-minor conditions. These modulating excerpts were selected from the Piano Sonatas of Mozart, Haydn, Beethoven, as well as other collections of piano compositions by Beethoven (Bagatelles), Schubert (Impromptus), Schumann (Humoresque, Kinderszenen, Kreisleriana, Arabesque, Noveletten), Chopin (Ballades, Impromptus), and Brahms (Intermezzos).
The degrees of modulation in the set of 24 progressions (artificial stimuli) were balanced with the degrees of modulation in a set of 24 real music excerpts. In comparison with a single exemplar for each cell of the crossed factors of scale degree and modal condition in Experiment 1, the eight exemplars for each degree of modulation in harmonic progressions and in real music excerpts, as well as a single Major-Major modal condition, warranted a greater certainty of interpretation of the data in Experiment 2. The juxtaposition of the highly controlled and artistically impoverished progressions with the real music excerpts that differed in style, tempo, tessitura, rhythm, and duration, created a possibility of investigating the strength of influence of degree of modulation in different musical contexts.

Method

Participants

Sixty-five participants, 49 females and 16 males, ages 19—47 with a mean 25.2, psychology students from the University of Texas at Dallas, took part in the experiment to fulfill a course requirement. Thirty-one participants—25 females and 6 males—with the musical training more than three years in overall duration were classified as “experienced.” These participants had the experience of playing a musical instrument or singing in a choir.

Stimuli and Apparatus

The principal experimenter wrote 24 short chorale-like progressions: eight modulations each to the Subdominant (5), Dominant (7), and ascending minor sixth (8). For each step, 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. This balanced set was intended to assess the expressive influence of voice-leading (Hevner, 1936; Sloboda, 1991; Toiviainen & Krumhansl, 2003). All progressions were eight-chords long and in the Major-Major mode condition. The experimenter made the progressions as similar as possible. Their duration (11 sec) was within the “sliding window” of music perception (Bigand & Parnscutt, 1999; Tillmann et al, 1998; Tillmann & Bigand, 2004), a duration that was found to warrant a perception of a coherent tonal set relatively unaffected by
tonal events beyond this window. In each harmonic progression, the first 3-5 chords established an opening tonality and the following chords made a smooth modulation to a target tonality, concluding with an authentic cadence. The progressions were played at a moderate tempo (M.M. = 72) with a slight *ritenuto* at the conclusion to make the brief modulations sound more natural.

In addition, the experimenter collected 24 excerpts from classical piano compositions. These 24 real music stimuli represent modulations to the Subdominant (5), Dominant (7), and step 8 in the Major-Major condition. The length of the excerpts was determined by the following selection criteria: 1) short duration, 2) the presence of several different chords, and 3) the relative completeness of the musical thought. The excerpts were between 16 sec and 30 sec in duration, which is, strictly speaking, outside the “sliding window” of music perception. However, the duration of the window can increase when modulation proceeds smoothly (Bigand, Madurell, Tillmann, & Pineau, 1999). To establish a sense of tonality, each trial began with a triad in an opening key of a given excerpt. All 48 stimuli were recorded as CD-quality wave files by the experimenter playing a Yamaha grand piano. The stimuli were presented to participants via loudspeakers with high-quality stereophonic equipment.

**Procedure**

The experimental procedure in Experiment 2 was the same as in Experiment 1. Participants were asked to indicate their affective response to each stimulus on six bipolar adjective scales. These adjective scales differed from those in Experiment 1 only in that the Pleasant-Unpleasant scale was replaced with the Relaxed-Tense scale. This replacement was intended to provide for direct comparison to earlier studies that measured perceived tension (Bigand, Parncutt, & Lerdahl, 1996; Toiviainen & Krumhansl, 2003; Nielsen, 1983). Because Experiment I showed that pattern of responses to the Warm-Cold scale resembled those of the Pleasant-Unpleasant scale, it was expected that this replacement would not result in a loss of valuable information.

**Results**

The detailed analyses of variance for progressions and real music excerpts are in Appendix 2.

*Principal Components Analysis for harmonic progressions*
On the loading plot, three evaluative dimensions were identified as valence, potency, and tension. Neither of them was orthogonal. The positive-valence characteristics Happy, Bright, and Warm are on one side and negative-valence Sad, Dark, and Cold are on the other side of the first component that accounts for the greatest portion of variability. The plot shows a pairing of the potency-related scales Firm-Wavering and Strong-Weak, and a paring of synaesthesia-related scales Bright-dark and Warm-Cold (Figure 6). The Sad-Happy dimension nears the synaesthesia dimension. Step 8 is the “darkest” and “coldest” and also “strongest” and “firmest” among the three steps, whereas the Dominant is at least as “strong” and “firm” as step 8, but also “happy,” “warm,” and “bright.” The Subdominant appears as “weak” and “wavering,” and also as indeterminate in relation to valence, which contrasts to the well-defined positive valence of step 7 and negative valence of step 8.

**Figure 6.** Responses to modulations to the Subdominant (5), Dominant (7) and step 8 in Harmonic Progressions (A, HP) and in Real Music excerpts (B, RM)

Affective responses to modulations in the harmonic progressions were influenced by the direction of melodic contour in the soprano and bass lines, as well as by tessitura (Figures 7 & 8). On PCA plot, the first component was identified as related to valence. The two other dimensions represent potency and tension; both are non-orthogonal. Progressions with the rising soprano and bass lines are on the Bright, Warm, and Happy side (triangles, except HP20 that was written in a relatively low piano register), whereas progressions with the falling soprano and bass lines are on the Sad, Dark, and Cold side (squares, except HP13 which modulated to the “happy” Dominant).
A poorly differentiated HP19 and a “renegade” HP20 are modulations to step 8. The high-tessitura progressions with the mixed-direction contour patterns are on the Bright, Warm, and Happy side (HP8, HP9, & HP15), whereas the low-tessitura progressions with the mixed-direction contour patterns are on the Sad, Dark, and Cold side (HP7, HP23, & HP24).

**Figure 7.** Influence of contour pattern on affective responses. Responses to modulations with the rising soprano and bass lines (triangles) are mostly on a side of positive-valence, whereas responses to modulations with the falling soprano and bass lines (squares) are mostly on the negative-valence side. Labeling: triangles = rising soprano and rising bass, squares = falling soprano and falling bass, dots = rising soprano and falling bass, diamonds = falling soprano and rising bass.
Figure 8: Influence of melodic direction in the soprano and bass lines in Harmonic Progressions for the Happy-Sad and Bright-Dark adjective scales: Pattern of responses is similar for the Dominant (7) and Subdominant (5) as compared to step 8. The distant step 8 was only weakly influenced by the 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)

Principal components analysis for real music excerpts

Comparison of PCA graphs for the real music excerpts and harmonic progressions (Figure 6) showed the similarity of pattern of responses to the degrees of modulation. However there was an important difference in orientation of dimensions for the adjective scales and thus a difference in identification of the principal components. For the harmonic progressions, the first component is synaesthesia-related and the second component is potency-related. For the real music excerpts, the first component is tension-related, whereas the second component is not defined by any of the dimensions. For the real music excerpts, step 8 is the “tensest” and the Dominant is the most “relaxed” and also the “happiest” and “warmest,” whereas the Subdominant is the “weakest.”

Affective responses to modulation in the real music excerpts were influenced by interplay of various aspects of musical expressiveness that included tempo, degree of modulation, and direction of melodic contour, tessitura, and musical style (Figure 9). The distribution of the stimuli on the factor graphics separates Mozart (M) and Haydn (H) from the Romantics—Beethoven (B), Schumann (RS), and Brahms (JB). The Romantics are mostly on the “sad” and “cold” and “dark” side, whereas Mozart and Haydn are on
the “happy,” “warm” and “bright” side. Schubert is represented by both sides. A single excerpt from Chopin’s *Fantasy-Impromptu*, representing a modulation to the Subdominant (C 6), was rather weakly differentiated. The only appearance of Beethoven on a happy side (B 17) also shows a poor differentiation. The “weak-and-wavering” of the potency-related dimension tilts on the side of the Romantics.

![Figure 9](image)

**Figure 9.** Affective responses to modulation in the real music excerpts were influenced by 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 are mostly on the “happy,” “bright,” and “warm” side, whereas the Romantics are mostly on the “sad,” “dark,” and “cold” side.

The two “tensest” real music excerpts both represent a modulation to step 8: One is from Schumann’s *Novelette* (RS 19) and another is from Mozart’s *Fantasia* (M 22), though only the fragment from *Novelette*, (RS 19), which is written in a low piano register, was perceived as truly “tense” (“and “sad,” “dark,” and “cold”).

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Among the four most “relaxed” excerpts, three modulate to a 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). In contrast, an excerpt from Brahms *Intermezzo* (JB 13), in a moderate tempo and in a rather low register, though also modulating to Dominant, is on the “sad” and “dark” side.

A very slow fragment from Schumann’s *Vogel als prophet* appears as definitely “sad” and “dark” (RS 20). Similarly, a slow excerpts from Schubert’s *Sonata in c minor* (FS 8) and a relatively slow excerpts from Schubert’s *Sonata in G major* (FS 4) were also perceived as “sad” and “dark.” The three “happiest” excerpts represent three different degrees of nodulation: 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). All these three excerpts are in fast tempo.

Overall, the factor graphics show that affective responses to modulations in the real music excerpts were influenced by tempo, degree of modulation, tessitura, and musical style. From the previous investigation we know that affective responses to modulation are also influenced by the major and minor modes.

**Discussion**

The results demonstrated that modulations to the distant step 8 (ascending minor sixth) were perceived as the “tensest” in comparison with modulations to the Subdominant (5) and Dominant (7) both in the harmonic progressions and real music excerpts. This is in agreement with the theoretical model of pitch proximity as explained with the circle of fifths and with the results of Bigand et al (1996). Modulations to the Subdominant (5) and Dominant (7) were reliably differentiated for the Relaxed–Tense scale in the excerpts but not in the harmonic progressions. This can be a corroborating evidence of influence of expressive performances, versus non-expressive performances, on perceived key proximity (Thompson & Cuddy, 1997). In comparison with the rather monotonous harmonic progressions, the real music excerpts were richer in artistic cues that could strengthen the sense of perceived key proximity according to the theoretical model based on the circle of fifths. The results showed the greater variance in responses to the real music as compared to the harmonic progressions: the total sum of squares for the real music excerpts was 18% larger than for the harmonic progressions. A test for
equal variance revealed that the difference in standard deviation across all conditions (SD = 1.26 for harmonic progressions versus SD = 1.37 for the excerpts) was significant: \( F = 1.18; p < .001; \) Levene’s Test = 69.25; \( p < .001; a = .05. \)

Both in the harmonic progressions and excerpts, modulations to the Subdominant (5) were recognized as “weaker” than modulations to the Dominant (7). This finding resonates with the musicological research that recognizes a subdominant region as “weaker” as compared to a dominant region (Ribeiro-Pereira, 2004; Rosen, 1972). In the real music excerpts, perceived increase in tension in modulations to the Subdominant (5) appeared in association with increase in negative valence, so that modulations to the Subdominant (5) were recognized as “tenser” and as “sadder,” “colder,” and more “wavering” and “weaker” than modulations to the Dominant (7). This finding complements studies in perceived key proximity that showed asymmetry of key perception in relation to the circle of fifths (Thompson & Cuddy, 1989, 1992, 1997). Whereas in the musicological research the notion of a “weaker” subdominant region is related to the larger-scale modulations that define global structure of a musical composition, the present results revealed that the affective quality of the Subdominant (5) were sensed in brief modulating passages as well.

We also found influence of contour patterns and an interaction of contour pattern and degree of modulation. Affective responses to modulations to step 8 were only weakly influenced by the contour patterns for the Happy-Sad, Bright-Dark, and Warm-Cold adjective scales (for the Happy-Sad the ratings almost converge). In comparison, responses to modulations to the Subdominant (5) and Dominant (7) were clearly influenced by the melodic direction. This difference of responses suggests that the influence of key-distance overpowered the influence of the direction of melodic contour in modulations to the distant minor sixth (step 8). In contrast to step 8, the lesser level of perceived tension for the Subdominant (5) and Dominant (7) resulted in greater sensitivity to the contour patterns for the Happy-Sad scale and the synaesthesia-related Bright-Dark and Warm-Cold scales. An increase in perceived tension for the contour condition 1RR (rising soprano and rising bass lines) in modulations to the Dominant (7) was associated with an increase in the ratings for all five other adjective scales, in a “happier,” “brighter,” “warmer,” “firmer,” and “stronger” direction.
General discussion

The similarity of pattern of responses to the highly controlled harmonic progressions and the much more expressive piano excerpts in Experiment 2 (see Figure 10) demonstrates that tonal modulation plays an essential role along with other expressive elements of music, such as tempo, tessitura, sound volume, timbre, and style in determining affective responses to music.

Figure 10: Similarity of pattern of responses to the plain harmonic progressions (A) and to the much more expressive piano excerpts (B) shows that affective influence of degree of modulation can compete successfully with other expressive aspects of music.

The affective responses to modulations to the Subdominant (5) and Dominant (7) in Experiment 2 differed from those found in Experiment 1 in which the Subdominant (5) was perceived as “happy” and the Dominant (7) was perceived as “sad” (across mode conditions). In contrast, Experiment 2 found that modulations to the Dominant (7) were perceived as “happier” than modulations to the Subdominant (5). These differences in results can perhaps be explained by the powerful effect of the major and minor modes that created a problem of ecological validity for modulations to the Dominant (7) 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. It is plausible that the ecologically weak modulations to a minor dominant step could
negatively influence the perception of the only progression representing this step. This mode-related problem does not exist for the Subdominant (5).

To ensure the ecological strength of melodic stimuli, Experiment 2 focused on the Major-Major mode only. Overall, the Dominant (7) was rated as “happier” and “stronger” than the Subdominant. The results also showed that in the real music excerpts, modulating to the Dominant (7)—in the clockwise direction—was associated with low tension, as contrasted with an increase of tonal tension for counterclockwise motion to the Subdominant (5), and to a greater degree – to ascending minor sixth (8). These results can be interpreted as complementing previous investigations in perceived tonal tension (Toiviainen & Krumhansl, 2003) and perceived key proximity (Thompson & Cuddy, 1989, 1992) that involve association with direction around the circle of fifths. In Toiviainen and Krumhansl’s experiment, the listeners rated continuously perceived tonal tension. While these ratings assessed orientation in tonal space, this was not, strictly speaking, a study in affective responses to modulation since the listeners were assessing their feeling of minute tensions within the immediate tonal context. In comparison, judgment of tonal modulation in our study represents a global assessment of the transition from an opening to a concluding part of a relatively complete structure. Whereas Toiviainen and Krumhansl concluded that clockwise movement around the circle of fifths is associated with an increase in perceived tension and counterclockwise movement with a decrease, our study found the opposite. The secondary analysis of the Toiviainen and Krumhansl’s results suggests that it may have been the influence of the major and minor modes that generated the feeling of low versus high tension (F major: $r = -0.33$ and D-flat major: $r = -0.34$ versus g-sharp minor: $r = 0.37$ and e-minor: $r = 0.42$). Considering the well-documented affective aspect of the major and minor modes, it is reasonable to suggest that the perceived tension they induce is an important ingredient of the modes’ affective influence.

Our results showed that while in the real music modulations to the Subdominant (5) were recognized as “tenser” than modulations to the Dominant (7), in the harmonic progressions these steps were not reliably differentiated on the Relaxed-Tense adjective scale. Thompson and Cuddy (1997) demonstrated that the listeners’ responses to expressive performances corresponded more closely to theoretical predictions based on
the circle of fifths than their responses to non-expressive ("mechanical") performances. Perhaps this more detailed differentiation of perceived tonal tension in the real music excerpts in our study can be attributed to the greater expressiveness of these excerpts as compared to the plain harmonic progressions.

The study also found that the listeners sensed a greater perceived tension in modulations to the distant step 8 both in the real music excerpts and harmonic progressions, as compared to the close modulations to subdominant and dominant steps. This is in agreement with the theoretical model of pitch proximity as explained by the circle of fifths. Additional evidence of the influence of distant key proximity on affective response was provided by reaction 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 the close modulations to subdominant and dominant but not in modulations to the distant step 8 (Figure 9). These results suggest that it was the close key proximity that allowed the listener to be more sensitive to the direction of pitch change for the Subdominant (5) and Dominant (7), whereas an increase in perceived tension in step 8 dampened the listener’s perceptiveness to the influence of melodic contour for these scales. For the Relaxed-Tense and the potency-related adjective scales Firm-Wavering and Strong-Weak, the influence of the contour conditions did not show a comparably consistent pattern for any of the steps.

Musical practice has a wide use of various metaphors. The use of synaesthesia-related adjective scales Bright-Dark and Warm-Cold in our study offers a supporting argument for Ramachandran & Hubbard (2001) suggestion that formation of metaphors is a product of processes that are analogous to "cross-activation of perceptual maps in synaesthesia." In our study, the general similarity of pattern of responses for the quasi-synaesthetic scales to the pattern of responses for the reliable Happy-Sad adjective scale is in agreement with Hevner’s (1935) results that showed consistency of affective word-selection in regard to the major and minor modes. Association of the greater perceived tension in modulations to step 8 with the lower ratings on the synaesthesia-related adjective scales—so that modulations to step 8 were rated as "colder" and "darker" than modulations to the Subdominant (5) and Dominant (7)—connects perceived tension to affective characteristics. This association of perceived tension with affective responses
can have important implications for the research in music perception by connecting emotions in music with the theory of tonal expectations—as determined by interplay of tonal tension and resolution (Meyer, 1956)—and with psychophysiological measurements of perceived tension (Fredrickson, 1995; Krumhansl, 1996; Madsen & Fredrickson, 1993; Nielsen, 1983; Toiviainen & Krumhansl, 2003).

The finding by Firmino et al (2009) of the shortened time estimates for distant modulations, as compared to close-key modulations, provides additional information on the intertwined nature of time- and tonal organization in music and illuminates the affective aspect of musical syntax. The musical syntax (order in tonal harmony) seems to be determined by perceived tension. Therefore, the greatest difference between linguistic language and music is their morphological principles: Whereas language has syntax that operates with semantic units, music has fluid tonal relationships characterized by interplay of different levels of tonal tension (in addition to differences in pitch). While language provides translatable words, music offers pattern of tones, each tone acquiring its meaning only in relation to other musical sounds. The involvement of the time parameter in the perception of tonal modulation (Firmino et al, 2009) as well as the minor vs. major modes (Halpern et al, 2008) demonstrates subtleties and complexity of processing tonal relationships.

While it is very tempting to make a direct connection between spoken language and music, particularly when we recognize phrasing and intonational envelope as integral features of melodic thinking, the main morphological principle that defines musical syntax—namely tonal attraction—also suggests a strong metaphorical link with quasi-spatial characteristics of the tonal space and musical structures. The very principle of tonal expectancy (Meyer, 1956) can be compared to the representational momentum (Freyd & Finke, 1984) that involves an image of a final position and implies velocity of motion. Confirmation of auditory momentum (Freyd, Kelly & DeKay, 1990) offers a new perspective to understanding musical syntax. Similar to the perception of the force of gravity, perception of tonal attraction—and related to it tonal tension—is an intuitive process of following an elemental logical path. Like a rolling-down ball can have an intricate trajectory explained by a gravitational force leading the ball to a point of
stability, a conventional cadence, however artfully suspended, can be visualized as a motion toward a lowest level of tonal potential energy – a tonic triad.

We propose a model of emotional processing that attempts to explain music’s directness in communicating emotions by connecting perceived tension to affective response (Panksepp 1998, 2004). This model draws on recognition of the strong pre-cognitive aspect in music perception (Panksepp & Bernatsky, 2002; Shewmon et al, 1999; Zatorre, 2005) and suggests that affective responses in music are generated by the pre-cognitive 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 paleomammalian brain, which integrates minute somato- and viscero-motor responses to the environment. Following this concept, our 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. From this perspective, music can be explained as a temporal sequence of tonal events that induce emotion by imitating the dynamics of the integration of the patterns of somato- and viscero-motor 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; however, their artfully controlled pattern can trigger emotional responses that can occur at different levels in the psychophysiological system. The emotion is built into a musical composition by means of employing the most primitive mechanism of reaction of a living organism to environment. The same primitive mechanism is involved during re-construction of an emotion by the listener. The interplay of different levels of perceived tension is related to the main morphological principles of music: tonal attraction and structured time. The value of these principles is revealed when they are utilized to affect our psychological state concurrent with the presentation of forms and ideas that appeal to our aesthetic judgment. The latter involves, as the secondary and tertiary levels of perception, a detection of various cultural signs offered by expertise.
In regard to the philosophy of music, our study’s findings offer strong support to the emotivist position by demonstrating that affective properties of different degrees of tonal modulation—which is a sophisticated structural aspect of Western classical music—can be reliably differentiated by people with no musical training, and that emotional responses to music seem to be formed as the result of minute affective responses to the expressive tonal elements of music, such as the major and minor modes, degrees of modulation, and an interaction between mode and tonal distance.

We need further investigations of the influence of such expressive aspects of music as tempo, melodic contour, tessitura, and sound intensity and timbre on the affective response to different degrees of modulation. Learning more about perception of tonal modulation, which is an essential aspect of musical structure and expressiveness, contributes important information to our understanding of music cognition and the communicative properties of the art of music.

APPENDIX 1

Analyses of variance for Experiment 1

An omnibus 2 levels of experience X 12 steps X 6 adjective scales X 4 mode conditions analysis of variance (ANOVA) showed a main effect of step, $F(11, 286) = 4.16$, $p < .001$, $R-Sq = 1%$; a main effect of mode, $F(3, 78) = 53.92$, $p < .001$, $R-Sq = 3%$; and a main effect of scale, $F(5, 130) = 10.66$, $p < .001$, $R-Sq = 1%$. There was no main effect of experience. The ANOVA showed an interaction of step X mode, $F(33, 858) = 2.04$, $p < .001$, $R-Sq = 1%$; an interaction of step X scale, $F(55, 1430) = 4.16$, $p < .001$, $R-Sq = 2%$; an interaction of mode X scale, $F(15, 390) = 9.75$, $p < .001$, $R-Sq = 2%$; an interaction step X mode X scale, $F(165, 4290) = 1.81$, $p < .001$, $R-Sq = 3%$; and an interaction of mode X scale X experience, $F(15, 390) = 2.15$, $p < .001$, $R-Sq = 3%$.

Given the complexity of all these interactions, the analysis was broken into separate ANOVAs focusing on particular areas of interest in the data. First was the pattern of the four mode conditions on the six adjective scales. A separate 4 mode X 6 adjective scales analysis of variance showed a reliable main effect of mode condition, $F(3, 75) = 46.35$, $p < .001$, $R-Sq = 6%$, and a main effect of scale, $F(5, 125) = 8.51$, $p < .001$, $R-Sq = 15%$, as well as an interaction between mode condition and scale: $F(15, 375) = 8.45$, $p < .001$, $R-Sq = 11%$. The results agree with the previous studies of major
and minor modes showing that listeners perceive the major mode as “happy” and the minor mode as “sad” (Hevner, 1935, 1936; Peretz, 1998; Dalla Bella et al, 2001; Halpern, 2007). Tukey pairwise comparisons revealed that major and minor modes were reliably differentiated for the Happy-Sad adjective scale.

A more detailed analysis with three separate 4 modes X 2 adjective scales ANOVAs, one for each pair of the adjective scales (the valence-related Happy-Sad and Pleasant–Unpleasant, the synaesthesia-related Bright-Dark and Warm-Cold, and the potency-related Firm-Wavering and Strong-Weak) showed that there was no main affect of mode condition for the potency-related scales. In comparison, responses for the adjective scales that are related to valence and synaesthesia were affected by the major and minor modes: Happy-Sad, $F(3, 272) = 77.24, p < .000$, $R-Sq = 46\%$; Pleasant-Unpleasant, $F(3, 272) = 18.11, p < .000$, $R-Sq = 17\%$; Bright-Dark, $F(3, 272) = 76.49, p < .000$, $R-Sq = 46\%$; Warm-Cold, $F(3, 272) = 36.64, p < .000$, $R-Sq = 29\%$.

**TABLE 2.**
ANOVA Results for Beginning and Ending Modal Conditions (48 Harmonic Progressions)
Abbreviations: H-S=Happy-Sad, P-U= Pleasant-Unpleasant, B-D=Bright-Dark, W-C=Warm-Cold, F-W=Firm-Wavering, S-W=Strong-Weak

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<td>Ending mode P-U</td>
<td>1.3308</td>
<td>150.85</td>
<td>4.55</td>
<td>0.000</td>
</tr>
<tr>
<td>Beginning mode B-D</td>
<td>1.3308</td>
<td>44.69</td>
<td>1.35</td>
<td>0.000</td>
</tr>
<tr>
<td>Ending mode B-D</td>
<td>1.3308</td>
<td>473.08</td>
<td>14.31</td>
<td>0.000</td>
</tr>
<tr>
<td>Beginning mode W-C</td>
<td>1.3308</td>
<td>39.08</td>
<td>1.18</td>
<td>0.000</td>
</tr>
<tr>
<td>Ending mode W-C</td>
<td>1.3308</td>
<td>231.59</td>
<td>7.00</td>
<td>0.000</td>
</tr>
<tr>
<td>Beginning mode F-W</td>
<td>1.3308</td>
<td>1.25</td>
<td>0.263</td>
<td>0.000</td>
</tr>
<tr>
<td>Ending mode F-W</td>
<td>1.3308</td>
<td>4.89</td>
<td>0.14</td>
<td>0.027</td>
</tr>
<tr>
<td>Beginning mode S-W</td>
<td>1.3308</td>
<td>1.68</td>
<td>0.195</td>
<td>0.006</td>
</tr>
<tr>
<td>Ending mode S-W</td>
<td>1.3308</td>
<td>7.43</td>
<td>0.22</td>
<td>0.000</td>
</tr>
</tbody>
</table>

To examine influence of a beginning mode on responses to an ending modal condition, the data were subjected to the six 2 beginning-mode conditions X 2 ending-mode conditions analyses of variance, one for each adjective scale. The results revealed a main effect of a beginning modal condition for the valence-related Happy-Sad and Pleasant–Unpleasant adjective scales and synaesthesia-related Bright-Dark and Warm-
Cold scales but not for the potency-related Form-Wavering and Strong-Weak scales. There was a main effect of an ending modal condition for all six scales (see details in TABLE 3). There was no interaction between a beginning and an ending modal condition for any of the scales. Figure 3 shows that the participants responded principally to the major and minor endings of the modulations. Uniformly major progressions were rated as happiest and uniformly minor progressions as saddest. Preceding the major or minor ending with the opposite mode lessened this effect.

**TABLE 3.**
ANOVA Results for Step and Mode (48 Harmonic Progressions)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>F</th>
<th>R-SQ</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happy-Sad</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>19.98</td>
<td>4.15%</td>
<td>0.000</td>
</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>254.17</td>
<td>14.38%</td>
<td>0.000</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>4.52</td>
<td>2.82%</td>
<td>0.000</td>
</tr>
<tr>
<td>Pleasant-Unpleasant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>7.38</td>
<td>1.62%</td>
<td>0.000</td>
</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>81.08</td>
<td>4.84%</td>
<td>0.000</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>2.88</td>
<td>1.89%</td>
<td>0.000</td>
</tr>
<tr>
<td>Bright-Dark</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>19.80</td>
<td>4.29%</td>
<td>0.000</td>
</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>229.35</td>
<td>13.55%</td>
<td>0.000</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>5.36</td>
<td>3.48%</td>
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</tr>
<tr>
<td>Warm-Cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>6.59</td>
<td>1.53%</td>
<td>0.000</td>
</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>119.60</td>
<td>7.57%</td>
<td>0.000</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>3.00</td>
<td>2.09%</td>
<td>0.000</td>
</tr>
<tr>
<td>Firm-Wavering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>8.57</td>
<td>2.53%</td>
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</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>2.98</td>
<td>0.22%</td>
<td>0.030</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>0.98</td>
<td>0.95%</td>
<td>0.245</td>
</tr>
<tr>
<td>Strong-Weak</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>step</td>
<td>11, 2244</td>
<td>6.91</td>
<td>1.92%</td>
<td>0.001</td>
</tr>
<tr>
<td>mode</td>
<td>3, 2244</td>
<td>3.65</td>
<td>0.28%</td>
<td>0.025</td>
</tr>
<tr>
<td>step x mode</td>
<td>33, 2244</td>
<td>1.77</td>
<td>1.47%</td>
<td>0.004</td>
</tr>
</tbody>
</table>

To examine the listeners’ sense of degree of modulation, the data were subjected to six 12 steps X 4 modes ANOVAs, one for each of the six adjective scales. The results revealed a main effect of mode and a main effect of step for each of the scales, and an interaction between mode and step for all scales but the Firm-Wavering (TABLE 4).
The final 12 steps X 2 beginning modes X 2 ending modes individual ANOVAs, one for each of the six adjective scales, investigated an effect of a beginning and an ending modal condition on perception of degree of modulation. The results (TABLE 4) demonstrate a main effect of an ending modal condition for all six adjective scales. For the potency-related scales (Firm-Wavering and Strong-Weak), there was no main effect of a beginning modal condition and no interaction between steps and either the beginning or the ending modal condition.

**TABLE 4.**
ANOVA Results for Beginning and Ending Modal Conditions and Their Interaction for 12 Steps

<table>
<thead>
<tr>
<th>Anova</th>
<th>Happy-Sad</th>
<th></th>
<th>Pleasant-Unpleasant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source</td>
<td>DF</td>
<td>F</td>
<td>R-Sq</td>
</tr>
<tr>
<td>Step</td>
<td>11</td>
<td>15.64</td>
<td>4.15%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bmode</td>
<td>1</td>
<td>65.11</td>
<td>1.57%</td>
<td>0.00</td>
</tr>
<tr>
<td>Emode</td>
<td>1</td>
<td>531.69</td>
<td>12.81%</td>
<td>0.00</td>
</tr>
<tr>
<td>Step*Bmode</td>
<td>11</td>
<td>2.80</td>
<td>0.74%</td>
<td>0.00</td>
</tr>
<tr>
<td>Step*Emode</td>
<td>11</td>
<td>6.37</td>
<td>1.69%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bmode*Emode</td>
<td>1</td>
<td>0.05</td>
<td>0.00%</td>
<td>0.82</td>
</tr>
<tr>
<td>Step<em>Bmode</em>Emode</td>
<td>11</td>
<td>1.46</td>
<td>0.39%</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Tukey Comparisons**

<table>
<thead>
<tr>
<th>Bmode, B1 vs. B2</th>
<th>Means</th>
<th>Diff</th>
<th>T-Value</th>
<th>P-Value</th>
<th>Emode, E1 vs. E2</th>
<th>Means</th>
<th>Diff</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.306</td>
<td>0.038</td>
<td>8.069</td>
<td>0.000</td>
<td>0.873</td>
<td>0.038</td>
<td>-23.060</td>
<td>0.000</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Anova</th>
<th>Bright-Dark</th>
<th></th>
<th>Warm-Cold</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source</td>
<td>DF</td>
<td>F</td>
<td>R-Sq</td>
</tr>
<tr>
<td>Step</td>
<td>11</td>
<td>16.18</td>
<td>4.29%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bmode</td>
<td>1</td>
<td>48.40</td>
<td>1.17%</td>
<td>0.00</td>
</tr>
<tr>
<td>Emode</td>
<td>1</td>
<td>512.90</td>
<td>12.36%</td>
<td>0.00</td>
</tr>
<tr>
<td>Step*Bmode</td>
<td>11</td>
<td>4.89</td>
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</tr>
<tr>
<td>Step*Emode</td>
<td>11</td>
<td>6.40</td>
<td>1.70%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bmode*Emode</td>
<td>1</td>
<td>0.76</td>
<td>0.02%</td>
<td>0.38</td>
</tr>
<tr>
<td>Step<em>Bmode</em>Emode</td>
<td>11</td>
<td>1.84</td>
<td>0.49%</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**Tukey Comparisons**

<table>
<thead>
<tr>
<th>Bmode, B1 vs. B2</th>
<th>Means</th>
<th>Diff</th>
<th>T-Value</th>
<th>P-Value</th>
<th>Emode, E1 vs. E2</th>
<th>Means</th>
<th>Diff</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.048</td>
<td>0.043</td>
<td>1.131</td>
<td>0.000</td>
<td>-0.095</td>
<td>0.043</td>
<td>-2.234</td>
<td>0.026</td>
<td>-0.111</td>
</tr>
</tbody>
</table>
There was found a sensitivity of the potency scales to an ending modal condition, which was rather unexpected. Another interesting result for the potency-related scales was the high ratings in perceived firmness and strength for modulations to the Dominant (7) when a modulating passage begins in minor. Whereas there was no main effect of a beginning mode for the potency scales and no interaction between step and mode, Tukey pairwise comparisons showed that the Dominant (7) was reliably differentiated for the Firm-Wavering and Strong-Weak adjective scales in the minor-Major and minor-minor conditions. The Dominant (7) was the only step that showed this increase in the ratings for those modulations that begin in the minor mode.

**Analysis of variance for harmonic progressions for Experiment 2**

An omnibus 3 steps X 4 contour patterns X 2 levels of experience X 6 adjective scales ANOVA for harmonic progressions showed a main effect of step, $F(2, 9244) = 53.47, R^2 = 1.04\%, p < .001$; a main effect of contour, $F(3, 9244) = 29.25, R^2 = 0.86\%, p < .001$; a main effect of experience $F(1, 9244) = 10.75, R^2 = 0.10\%, p = .001$; and a main effect of scale, $F(5, 9297) = 7.63, R^2 = 0.37\%, p < .001$. The preceding main effects and an interaction of step X contour, $F(6, 9244) = 8.00, R^2 = 0.47\%, p < .001$ and an interaction of step X experience, $F(6, 9244) = 3.85, R^2 = 0.08\%, p = .026$ are not meaningful since they collapse the data across the different adjective scales. What is important are interactions involving adjective scales: the interaction of scale X step, $F(10, 9244) = 7.51, R^2 = 0.73\%, p < .001$; the interaction of scale X contour, $F(15, 9244) = 3.90, R^2 = 0.57\%, p < .001$; the interaction of scale X experience, $F(5, 9244) = 4.45, R^2 = 0.22\%, p = .001$; and the interaction of scale X step X contour, $F(30, 9244) = 2.49, R^2 = 0.76\%, p < .001$. Since the omnibus ANOVA demonstrated interactions between scale and other factors, the data were subjected to six separate 3 steps X 4 contour patterns X 2 levels of experience ANOVAs, one for each adjective scale.

**Happy-Sad**

For the Happy-Sad scale, the 3 steps X 4 contour patterns X 2 levels of experience ANOVA revealed a main effect of step, $F(2, 1479) = 20.07, R^2 = 2.26\%, p < .001$; a main effect of contour $F(3, 1479) = 19.14, R^2 = 1.00\%, p < .001$; an interaction of step X contour, $F(6, 1479) = 4.16, R^2 = 1.5\%, p < .001$. There was no main effect of musical experience. Tukey pairwise comparisons showed that for the Happy-Sad scale the
Dominant (7) was reliably differentiated both from the Subdominant (5) and step 8 and recognized as the “happiest.” The Subdominant (5) was not differentiated from step 8. Tukey pairwise comparisons revealed that only the same-direction contours 1RR (rising soprano and rising bass lines) and 4FF (falling soprano and falling bass lines) were reliably different. An interaction plot for the Happy-Sad scale (Figure 9) shows the resemblance of the pattern of responses for the Dominant (7) and Subdominant (5), as compared to step 8, and demonstrates that the direction of melodic contour in the soprano and bass lines had only a weak influence on affective responses to step 8. A separate 6 scales X 4 contour patterns ANOVA revealed that for the Happy-Sad scale the contour patterns were reliably differentiated for the Subdominant (5) and Dominant (7) but not for step 8 (TABLE 5).

Relaxed-Tense

A 3 steps X 4 contour patterns X 2 levels of experience ANOVA for the Relaxed-Tense adjective scale revealed a main effect of step, $F(2, 1479) = 22.93, R^2 = 2.50\%, p < .001$, and an interaction of step X contour, $F(6, 1479) = 3.83, R^2 = 1.24\%, p < .001$. There was no main effect of contour and no main effect of experience (main effect of experience approaches significance, $p = 0.07$). Tukey pairwise comparisons showed that steps 5 and 7 were not differentiated from each other but were different from the very tense step 8. The interaction plot for step and contour showed that step 8 was influenced by the 2RF contour condition (rising soprano line and falling bass line). A separate 6 scales X 4 contour patterns ANOVA revealed that the contour patterns were not reliably differentiated for the Subdominant (5) (TABLE 5).

Bright-Dark

A 3 steps X 4 contours X 2 levels of experience ANOVA for the Bright-Dark scale showed a main effect of step, $F(2, 1479) = 21.61, R^2 = 1.20\%, p < .001$; a main effect of contour $F(3, 1479) = 18.96, R^2 = 1.05\%, p < .001$; an interaction of step X contour, $F(6, 1479) = 4.14, R^2 = 1.50\%, p < .001$; and an interaction of step X experience, $F(6, 1479) = 3.03, R^2 = .36\%, p = .048$. There was no main effect of experience. These results for the Bright-Dark scale strongly resemble the results for the Happy-Sad scale. Tukey pairwise comparisons revealed that each of the three steps was reliably differentiated from other two steps. Step 8 was perceived as “darker” than steps 5 and 7.
Pairwise comparisons showed that only same-direction (1RR and 2FF) contour patterns were reliably differentiated. An interaction plot shows that for the Bright-Dark scale, contour-related ratings for step 8 almost converge, which means that affective responses to modulation to step 8 were not influenced by melodic contour patterns (Figure 8). A separate 6 scales X 4 contour patterns ANOVA revealed that the contour patterns were not reliably differentiated for step 8 (TABLE 5), whereas the patterns were differentiated for the Subdominant (5) and the Dominant (7).

**Warm-Cold**

For the Warm-Cold, a 3 steps X 4 contours X 2 levels of experience ANOVA demonstrated a main effect of step, $F(2, 1479) = 13.95$, $R^2 = 0.79\%$, $p < .001$; a main effect of contour, $F(3, 1479) = 8.70$, $R^2 = 0.48\%$, $p < .001$; and interaction step X contour, $F(6, 1479) = 2.99$, $R^2 = 1.12\%$, $p = .007$. There was no main effect of experience. Tukey pairwise comparisons showed that all three steps were reliably differentiated, with step 8 rated as “colder” than steps 5 and 7. The pairwise comparisons revealed that for the Warm-Cold scale only “1-1” (rising soprano and bass lines) was reliably differentiated among the four contour patterns. The interaction plot shows that responses to different contour patterns in modulations to the Subdominant (5) and Dominant (7) are somewhat similar as compared to step 8. A separate 6 scales X 4 contour patterns ANOVA revealed that for the Warm-Cold scale the contour patterns were reliably differentiated for all three steps (TABLE 5).

**Firm-Wavering**

A 3 steps X 4 contour patterns x 2 levels of experience ANOVA for the Firm-Wavering adjective scale showed a main effect of step, $F(2, 1479) = 4.93$, $R^2 = 0.30\%$, $p = .007$, a main effect of experience $F(2, 1490) = 7.09$, $R^2 = 0.43\%$, $p = .008$), and an interaction of step X contour, $F(6, 1490) = 2.25$, $R^2 = 0.86\%$, $p = .036$. There was no main effect of contour. Tukey pairwise comparisons showed that step 8 was not reliably differentiated from steps 5 and 7. The Dominant (7) was reliably recognized as “firmer” than the Subdominant (5). As compared with the experienced listeners, the inexperienced listeners perceived all the modulations as “firmer.” The interaction plot shows that the rising direction in pitch changes for both soprano and melodic lines (1RR) generated an increase in perceived firmness for the Dominant (7). A separate 6 scales X 4 contour
patterns analysis of variance showed that for the Firm-Wavering adjective scale the direction of pitch-change was reliably differentiated for the Dominant (7) only (TABLE 5).

**Strong-Weak**

A 3 steps X 4 contour patterns X 2 levels of experience ANOVA for the Strong-Weak scale demonstrated a main effect of step, $F(2, 1479) = 11.77, R^2 = 0.67\%, p < .001$, a main effect of experience, $F(1, 1479) = 20.47, R^2 = 1.18\%, p < .001$, and an interaction of step X contour, $F(6, 1479) = 2.59, R^2 = 0.97\%, p = .017$. There was no main effect of contour for the Strong-Weak scale. Tukey pairwise comparisons demonstrated that the Subdominant (5) was differentiated from the Dominant (7) and step 8, but that step 8 did not differ from the Dominant (7). Modulations to the Dominant (7) were recognized as “stronger” than modulations to the Subdominant (5). The inexperienced listeners had higher ratings for the Strong-Weak scale than the experienced. An interaction plot showed that modulations with rising soprano and bass lines (1RR) to the Dominant (7) generated an increase in perceived “strength.” A separate 6 scales X 4 contour patterns ANOVA revealed that the contour patterns were reliably differentiated for step 8 only ($p$-value approaches significance for the Dominant (7), (TABLE 5).

Overall, the ANOVAs for the harmonic progressions revealed that the Dominant (7) was recognized as the “happiest” step and as “firmer” and “stronger” than the Subdominant (5). Modulations to step 8 were perceived as the “tensest,” whereas the Subdominant (5) and Dominant (7) were not differentiated on the Tense-Relaxed adjective scale. For the Happy-Sad and the synaesthesia-related scales Bright-Dark and Warm-Cold, progressions with simultaneous upward direction in the soprano and bass lines and modulating to the Dominant (7) and Subdominant (5) generated higher ratings, i.e., were recognized as “happier,” “brighter,” and “warmer” than modulations with other contour patterns. For the Happy-Sad and Bright-Dark scales, affective responses to step 8 were not influenced by the melodic patterns, which suggests that for these scales the influence of distant tonal relationship was stronger than influence of the direction of pitch change.
TABLE 5.
ANOVA Results for Contour Patterns in Harmonic Progressions for each Scale/Step
Abbreviations:  H-S=Happy-Sad,  P-U= Pleasant-Unpleasant,  B-D=Bright-Dark,  W-C=Warm-Cold,  F-W=Firm-Wavering,  S-W=Strong-Weak

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>F</th>
<th>P-value</th>
<th>R-Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contour_BD-5</td>
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<td>13.37</td>
<td>0.000</td>
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</tr>
<tr>
<td>Contour_FW-5</td>
<td>3</td>
<td>0.95</td>
<td>0.415</td>
<td>0.55%</td>
</tr>
<tr>
<td>Contour_HS-5</td>
<td>3</td>
<td>15.29</td>
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</tr>
<tr>
<td>Contour_RT-5</td>
<td>3</td>
<td>1.76</td>
<td>0.153</td>
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</tr>
<tr>
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<td>1.21%</td>
</tr>
<tr>
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<td>3</td>
<td>6.04</td>
<td>0.000</td>
<td>3.39%</td>
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</table>

<table>
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<th>P</th>
<th>R-Sq</th>
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<td>11.93</td>
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<tr>
<td>Contour_FW-7</td>
<td>3</td>
<td>3.22</td>
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</tr>
<tr>
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<td>3</td>
<td>9.39</td>
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</tr>
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<td>Contour_RT-7</td>
<td>3</td>
<td>2.65</td>
<td>0.048</td>
<td>1.52%</td>
</tr>
<tr>
<td>Contour_SW-7</td>
<td>3</td>
<td>2.40</td>
<td>0.067</td>
<td>1.38%</td>
</tr>
<tr>
<td>Contour_WC-7</td>
<td>3</td>
<td>5.44</td>
<td>0.001</td>
<td>3.06%</td>
</tr>
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</table>

<table>
<thead>
<tr>
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<th>F</th>
<th>P</th>
<th>R-Sq</th>
</tr>
</thead>
<tbody>
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<td>1.12</td>
<td>0.340</td>
<td>0.65%</td>
</tr>
<tr>
<td>Contour_FW-8</td>
<td>3</td>
<td>1.45</td>
<td>0.228</td>
<td>0.83%</td>
</tr>
<tr>
<td>Contour_HS-8</td>
<td>3</td>
<td>0.92</td>
<td>0.429</td>
<td>0.53%</td>
</tr>
<tr>
<td>Contour_RT-8</td>
<td>3</td>
<td>4.91</td>
<td>0.002</td>
<td>2.78%</td>
</tr>
<tr>
<td>Contour_SW-8</td>
<td>3</td>
<td>3.01</td>
<td>0.030</td>
<td>1.72%</td>
</tr>
<tr>
<td>Contour_WC-8</td>
<td>3</td>
<td>2.58</td>
<td>0.053</td>
<td>1.48%</td>
</tr>
</tbody>
</table>

Analysis of variance for real music excerpts for Experiment 2.

A 3 steps X 2 levels of music experience X 6 adjective scales ANOVA for real music excerpts revealed a main effect of step, $F (2, 9271) = 17.40, R^2 = 0.36\%$, $p < .001$; a main effect of experience, $F (1, 9271) = 13.66, R^2 = 0.14\%$, $p < .001$; a main effect of scale, $F (5, 9271) = 48.57, R^2 = 2.51\%$, $p < .001$; an interaction of step X scale, $F (10, 9271) = 7.80, R^2 = 0.80\%$, $p < .001$; and an interaction of experience X scale, $F (10, 9271) = 3.24, R^2 = 0.16\%$, $p = .008$. More detailed analyses with six separate 3 steps X 2 levels of music experience ANOVAs, one for each adjective scale, and Tukey pairwise comparisons revealed the following:

Happy-Sad

A 3 steps X 2 levels of experience ANOVA demonstrated a main effect of step, $F (2, 1491) = 5.42, R^2 = .72 \%$, $p = .005$. There was no main effect of experience. Tukey pairwise comparisons revealed that the Dominant (7) was different both from the Subdominant (5) and step 8, whereas the Subdominant (5) and step 8 were not reliably
differentiated. The Dominant (7) was recognized as the “happiest” among the three steps. For the Happy-Sad scale, the patterns of responses to steps were generally similar for the real music excerpts and the harmonic progressions (Figure 10).

**Relaxed-Tense**

For the Relaxed-Tense scale a 3 steps X 2 levels of experience ANOVA showed a main effect of step, $F(2, 1491) = 24.51$, $R^2 = 2.99$, $p < .001$ and a main effect of experience $F(1, 1491) = 13.28$, $R^2 = 0.82$, $p < .001$. Tukey pairwise comparisons revealed that all three steps were reliably differentiated from each other. Modulations to distant step 8 were recognized as the “tensest.” Modulations to the Subdominant (5) were recognized as “tenser” than modulations to the Dominant (7). The inexperienced listeners perceived all modulations as more “relaxed.”

**Bright-Dark**

None of the steps were reliably differentiated for real music excerpts for the Bright-Dark adjective scale. This suggests influence of such features of musical expressiveness in the real music excerpt as a very low and a very high range of piano registers and a more varied interplay of sound timbres and volumes—as compared to the controlled artificial stimuli.

**Warm-Cold**

A 3 steps X 2 levels of experience ANOVA demonstrated a main effect of step, $F(2, 1491) = 7.39$, $R^2 = 0.99$, $p = .001$, a main effect of experience $F(1, 1491) = 5.16$, $R^2 = 0.33$, $p = .023$, and an interaction of step X experience, $F(2, 1491) = 3.32$, $R^2 = 0.42$, $p = .036$. The Dominant (7) was reliably different from the Subdominant (5) and step 8. The Subdominant (5) and step 8 were not differentiated. The Dominant (7) was perceived as “warmer” than the Subdominant (5) and step 8. The responses were influenced by the level of experience: the inexperienced listeners recognized the Dominant (7) as “warmer” as compared to the experienced listeners.

**Firm-Wavering**

For the Firm-Wavering scale a 3 steps X 2 levels of experience ANOVA demonstrated a main effect of step, $F(2, 1491) = 4.71$, $R^2 = 0.59$, $p = .009$. There was no main effect of experience. Modulations to step 8 were perceived as “firmer” than
modulations to the Subdominant (5) and Dominant (7). Modulations to the Subdominant (5) and Dominant (7) were not reliably differentiated.

**Strong-Weak**

For the Strong-Weak scale a 3 steps X 2 levels of experience ANOVA showed a main effect of step $F (2, 1491) = 11.67, R^2 = 1.47\%, \ p < .001$ and a main effect of experience $F (1, 1491) = 7.97, R^2 = 0.50\%, \ p = .005$. The Dominant (7) was reliably perceived as “stronger” than the Subdominant (5). Step 8 and the Dominant (7) were not reliably differentiated. The inexperienced listeners perceived the modulations as “stronger” when compared to the experienced listeners.

**APPENDIX 2**

*List of real music excerpts for Experiment 1*

2. Schumann, *Arabesque, Minore I*, B -e, M-m, 5
3. Schubert, *Impromptu 4*, Op. 90, Cis – cis, M-m, 0
4. Schubert, *Impromptu, 2*, Op. 142, As – As, M-M, 0
7. Schubert, *Allegro, Sonata in c minor*, As – C, M-M, 4
8. Schumann, *Arabesque, Minore II*, Fis - e, M-m, 2
11. Schumann, *Humoresque (Semplice e teneramente)*, g - D, m-M, 7
12. Schumann, *Viennese Carnival, Allegro*, g – B, m-M, 3
17. Schumann, *Kinderszenen*, Op. 15, Der dichter spricht, G - a, M-m, 2
List of real music excerpts for Experiment 2

Subdominant (5)

1. Beethoven, Sonata No. 14, opus 27 (2), Allegretto, As-Des
2. Haydn, Sonata in C Major, HOB. Xvi/35; l48, first movement, C-F
3. Haydn, Sonata in A Major, Hob. No. 5, E-A
4. Schubert, Sonata in G-Major, Opus 78, D 894, second movement, D-G
5. Schubert, Sonata in A-major, finale, D-G
6. Chopin, Fantaisie-Impromptu, opus 66, As-Des
7. Schumann, Phantasiestucke, Fable, opus 12, G-C
8. Schubert, Sonata in c-minor, second movement, As-Des

Dominant (7)

1. Beethoven, Bagatelles, opus 119, No. 4, 64, A-E
2. Mozart, Sonata in a minor, K. V. 300 (d), Presto (finale), A-E
3. Mozart, Sonata in D Major, K.V. 205, Var., XII, D-A
4. Mozart, Sonata in D Major, K.V. 205, Variations, Tema, D-A
5. Brahms, Intermezzo II, opus 118, A-E
6. Haydn, Sonata in C Major, No. 40 (Hob.), first movement, G-D
7. Haydn, Sonata in E flat Major, No. 49 (Hob.), Finale, Es-B
8. Beethoven, Sonata No. 8, Opus 13, Rondo (finale), As-Des

Ascending minor sixth (8)

1. Beethoven, Sonata No. 9, opus 14, first movement, E-C
2. Beethoven, Sonata No. 9, opus 14, first movement, A-F
3. Schumann, Noveletten, No. 4, opus 21, A-F
4. Schumann, Waldszenen, Vogel als prophet, opus 82, G-Es
5. Schubert, Sonata G-Major, Opus 78, D 894, Allegretto (finale), G – Es
6. Mozart, Fantasia IV, F-Des
7. Schubert, Waltz No. 14, Opus 9/a, Des-A
8. Schubert, Sonata in B flat Major, D960, Scherzo, Des-A

REFERENCES


