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Interval Distributions, Mode, and Tonal Strength of Melodies as Predictors of Perceived Emotion

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Fifty-one tonal and atonal classical melodies were evaluated by 29 students on 10 bipolar adjective scales that focused on emotional evaluation along four factors: *valence, aesthetic judgment, activity, and potency*. Significant predictors for each factor were obtained through ridge regression analyses. Predictors were quantified characteristics of each melody: the distribution of intervals according to interval size, the mode, and tonal strength (C. L. Krumhansl, 1990). Valence was best predicted by mode. Aesthetic judgment was predicted by the interval distribution and by tonal strength. Melodies judged pleasant contained more perfect fourths and minor sevenths and fewer augmented fourths; they were also high in tonal strength. Activity and potency were best predicted by the interval distribution. Activity, a sense of instability and motion, was conveyed by a greater occurrence of minor seconds, augmented fourths, and intervals larger than the octave. Potency, an expression of vigor and power, was marked by a greater occurrence of unisons and octaves. Thus the emotional expression of a melody appears to be related to the distributions of its interval categories, its mode, and its tonal strength.

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THE most famous example of an attempt to ascribe a particular emotional connotation to musical intervals is that described by Cooke (1959). Examining tensions induced by pitch, he distinguished between tonal tension and intervallic tension, the first being induced by harmonic properties of the scale degrees, and the second by directionality and dis-

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tance between two melodic notes. Using a large sample from the Western European repertoire, Cooke isolated the basic expressive functions of the intervals ranging from unison to major seventh. Cooke's approach, however, was descriptive and lacked any systematic criteria. Some of his assertions, furthermore, were not confirmed when empirically tested (Clive, 1978).

Other investigations have explored relations between ratings of evaluative and descriptive dimensions of musical intervals (e.g., ugly-beautiful, wide-narrow) and their objectively measurable characteristics (Kameoka & Kuriyagawa, 1969a, 1969b; Levelt, van de Geer, & Plomp, 1966; Plomp & Levelt, 1965). Most of these studies used dissonant and consonant harmonic intervals (both notes presented simultaneously, as opposed to successively). Another approach to the study of intervals by van de Geer, Levelt, and Plomp (1962) focused on the interrelations between various ratings for musical intervals on a number of semantic continua.

Still other investigators have studied whether a listener can discriminate between different musical intervals on an emotional basis (Maher, 1976; Maher & Jairazbhoy, 1975). Later, Maher (1980) compared harmonic intervals formed at different geometric mean frequencies (e.g., 500 Hz and 250 Hz) using 10-item, bipolar adjective rating scales in four categories: evaluative, uncertainty, arousal-potency, and psychophysical. The results showed that seconds and minor ninths were identified as distinct from other intervals, especially thirds, fourths, fifths, sixths, and octaves, whereas the intervals from the minor third to the major sixth were not distinguished from one another in any of the four categories. In another study, Maher and Berlyne (1982) focused on melodic instead of harmonic musical intervals. Listeners' responses to these melodic intervals seemed to correspond rather closely to descriptions of the special characters of the harmonic intervals as found in his previous study.

More recently, Costa, Ricci Bitti, and Bonfiglioli (2000) studied the expression of emotions associated with the 12 harmonic intervals within an octave presented in harmonic form both in a low register (mean = 183.13 Hz) and a high register (mean = 1510.38 Hz). Intervals were judged on a semantic differential as adopted by Bozzi (1985), formed by adjectives taken from Cooke (1959) and other theorists who have dealt with the emotional meaning of musical intervals. Costa et al. (2000) found a significant interaction between interval and register for thirds, perfect fourths, and sixths. A high register presentation tended to result in the expression of positive emotions, whereas a low register presentation tended to be associated with the expression of moderately negative emotions. For clearly consonant (octaves, fifths) or dissonant (seconds, augmented fourths, and major sevenths) intervals, the emotional expressions were similar for high and low register presentation. Dissonant intervals were clearly perceived as more negative, unstable, and tense than consonant ones, which were perceived as neutral. Expanding on this work, we set out to investigate the relations between the statistical occurrence of different musical intervals in a melody and the corresponding expressed emotions. Our hypothesis was that the expression of a particular emotion in music is associated with a distinct pattern of interval occurrences.

Method

PARTICIPANTS

Twenty-nine undergraduates taking an introductory course in psychology, with no specific musical training, were recruited on a voluntary basis to provide emotional evaluations of the melodies in the experiment. The participant sample included 17 females with a mean age of 21.7 years (*SD* = 3.4) and 12 males with a mean age of 22.5 years (*SD* = 4.8).

STIMULI AND APPARATUS

Fifty-one tonal and atonal musical excerpts covering a wide range of emotional content were selected from an Internet source of classical MIDI files (see Appendix). As the study focused on melodies, only one melodic line was selected when multiple instruments were present, and in the case of piano compositions or piano reductions only the melodic line was considered. In order to eliminate the effect of tempo, all excerpts were presented at 100 beats per minute. The timbre was set to MIDI sound number 49/127 (string ensemble) for all excerpts. All harmonic and timbral components were therefore excluded from the experiment. The melodic stimuli were analyzed for interval occurrence and were modified and presented using the audio software Cubase Score 3.0 by Steinberg, linked by a MIDI input-output card to a Roland expander model SC 880.

Participants evaluated emotions expressed by the musical excerpts on a battery of 10 bipolar scales. This battery was a reduced version of that used by Costa et al. (2000). In that study, the scales were divided into three categories relating to emotional content (valence, activity, and potency), plus a further category for aesthetic judgment. Four scales were focused on valence: happy-unhappy, bold-fearful, serene-gloomy, carefree-anguished; three scales were focused on activity: stable-unstable, relaxed-restless, calm-furious; and one scale was focused on potency: weak-powerful. Aesthetic judgment was assessed on two scales: pleasant-unpleasant and agreeable-disgusting.[1] Each scale consisted of a neutral choice and three possible degrees toward each polarity, that is, from –3 to +3. Polarity (i.e., which adjective was on the right or left side of the scale) and order of presentation were randomized. When given instructions for filling in the questionnaire, it was made clear to listeners that they should rate the perceived emotional expression of the melodies and not their own emotional and aesthetic response evoked by them.

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1. The original Italian words for the different emotion adjectives were: *felice-triste* (happy-unhappy), *sereno-cupo* (serene-gloomy), *sicuro-pauroso* (bold-fearful), *spensierato-angosciato* (carefree-anguished), *stabile-instabile* (stable-unstable), *rilassato-agitato* (relaxed-restless), *calmo-rabbioso* (calm-furious), *debole-potente* (weak-powerful), *piacevole-spiacevole* (pleasant-unpleasant), *gradevole-disgustoso* (agreeable-disgusting).

PROCEDURE

Participants were tested in groups. To avoid memory effects, each excerpt was presented repeatedly until each participant had completed the entire battery for that excerpt. In addition, the excerpts were presented according to a randomized list that was reversed for half the participants to counterbalance any effect deriving from order of presentation. Stimuli were generated by computer and presented over loudspeakers.

DATA REDUCTION AND ANALYSES

For each excerpt, the distribution of musical interval categories was calculated. Melodic intervals were identified sequentially without considering rest values and were classified into one of the following 14 categories: unison (P1), minor second (m2), major second (M2), minor third (m3), major third (M3), perfect fourth (P4), augmented fourth (a4), perfect fifth (P5), minor sixth (m6), major sixth (M6), minor seventh (m7), major seventh (M7), perfect octave (P8), and compound (intervals larger than the octave, >P8). Each nonunison interval was also classified as ascending or descending. The mean number of intervals analyzed per excerpt was 141.

The proportional occurrence of the ascending and descending intervals for all 13 interval categories are reported in Table 1. Descending seconds significantly outnumbered ascending seconds, confirming the data obtained by Vos and Troost (1989). However, the distribution of intervals in both ascending and descending directions was similar, so direction was not included as a variable in further analyses. Unisons and seconds alone accounted for 61.6% of all intervals; intervals from unisons up to and including fifths accounted for 85.5%.

A predictor named *tonal strength* was derived from the assumption that the emotional rating of a melody could be influenced by the degree to which the tones of a melody adhere to a specific tonality.

By using a key-finding algorithm developed by Krumhansl and Schmuckler and described in Krumhansl (1990), input vectors specifying the total durations of the 12 chromatic scale tones in each melody were correlated with tonal hierarchy vectors for every major and minor key as derived from Krumhansl and Kessler's (1982) study. As in Cuddy and Lunney (1995), the highest significant correlation (with at least $p < .10$) between the input vector and the tonal hierarchy vectors was used to create a tonal strength predictor. For each excerpt, a zero was entered if there were no significant correlations for that melody (7 cases out of 51). Thus, the tonal strength predictor was a measure of the extent to which the durational distribution of notes of a melody fit into a particular key.

TABLE 1

Percentage Occurrences for the 13 Interval Categories Distinguishing Between Ascending and Descending Intervals

Interval Category	% Ascending	% Descending	Binomial Test
Minor second	12.04	14.86	$z = -1.78$, $p < .04$
Major second	12.91	17.64	$z = -2.00$, $p < .03$
Minor third	5.38	4.53	*ns*
Major third	2.77	3.55	*ns*
Perfect fourth	4.24	2.69	*ns*
Augmented fourth	1.03	0.99	*ns*
Perfect fifth	1.60	1.66	*ns*
Minor sixth	1.14	0.81	*ns*
Major sixth	0.96	1.12	*ns*
Minor seventh	0.54	0.66	*ns*
Major seventh	0.48	0.74	*ns*
Octave	1.41	1.18	*ns*
> Octave	2.55	2.39	*ns*

Each excerpt was categorized in terms of its mode by using tonal strength correlation data. If the largest correlation corresponded to a major scale, then the melody was assigned to the Major group. If the largest correlation corresponded to a minor scale then the melody was assigned to the Minor group. If there were no significant correlations, then the melody was classified as Atonal. When these criteria were used, 20 (39%) excerpts were classified as belonging to the Major group, and 24 (47%) were classified as belonging to the Minor group, and 7 (14%) were classified as belonging to the Atonal group.

Regarding the semantic differential, 4 of the 10 scales were reversed so that negative values were homogeneously ascribed to the negative polarity of the adjective pair (unhappy, fearful, gloomy, anguished, unstable, restless, furious, powerful, unpleasant, disgusting). Each evaluation was scored on a scale ranging from –3 to 3, including 0 for the neutral choice. The raw data were submitted to a principal component analysis and then, for each participant, the scales relating to each factor were averaged.

Results

PRINCIPAL COMPONENT ANALYSIS

Emotional rating data, not averaged across participants, were submitted to a principal component analysis for the extraction of principal components. Inspection of the scree plot and eigenvalues analysis yielded four factors that accounted for 77.9% of all variance. Normalized factor loadings were rotated by performing a varimax. Each bipolar adjective rating scale was assigned to a factor if its loading was greater than .70. The main factor, designated as valence, accounted for 41.5% of the variance and included the following scales: happy-unhappy (loading = .86), carefree-anguished (loading = .83), and serene-gloomy (loading = .82). The second factor, designated as aesthetic judgment, included those scales that probed the pleasantness of the melody, apart from its emotional content: agreeable-disgusting (loading = .92) and pleasant-unpleasant (loading = .90). Aesthetic judgment accounted for 15.7% of the variance. The third factor, designated as activity, included those scales that probed the sense of movement, activity, and instability expressed by a melody. Stable-unstable (loading = .85) and relaxed-restless (loading = .74) were included in this factor, which explained 12.7% of the variance. The fourth factor was named potency and included the scale weak-powerful (loading .91), therefore reflecting the intensity of energy, strength, and force expressed by a melody. Potency accounted for 8% of the variance.

Two scales did not reach a loading greater than .70 and were therefore discarded: calm-furious and bold-fearful.[2]

2. In the study by Costa et al. (2000) calm-furious belonged to the activity factor, bold-fearful belonged to the potency factor, and both were significant. The threshold for a bipolar scale to enter a factor was, however, set to .50, and therefore the criterion was less severe than in the present study where the threshold was set to .70.

INTERSUBJECT CORRELATIONS

To determine the extent of intersubject agreement, the ratings for each participant were correlated with those of every other participant. The overall mean intersubject correlation coefficient was .34 (range = .06 to .59, *SD* = .11). Of the total number of pairwise intersubject correlations examined (*N* = 399), all but 4 were statistically significant. The mean correlation is fairly similar to that found by Cuddy and Lunney (1995) and Eerola, Järvinen, Louhivuori, and Toiviainen (2001). That result suggested that there was no effect of order, familiarity, or musical background, and thus the data from all listeners were pooled into a single group for analysis.

RIDGE REGRESSION ANALYSES

Scale ratings for valence, aesthetic judgment, activity, and potency were each regressed on the predictor variables of occurrence data for each of the 14 interval categories, mode, and tonal strength. To deal with the higher intercorrelation of some interval categories that resulted in a high collinearity of input variables, the data were submitted to ridge regression, a statistical method developed for the purpose of circumventing the weakness of least squares regression with regard to overlapping predictors (Fox, 1991; Maxwell, 1977; Pagel & Lunneborg, 1985). Lambda was set equal to 0.1.

Predictors for Valence

The overall prediction rate of the model for Valence was significant, R^2 = .45, $F(16, 34) = 1.96$, $p < .04$. Mode was the only significant predictor. The detailed results of the ridge regression analysis are reported in Table 2.

TABLE 2
Ridge Regression Results for Valence

	β	*t*	*p*
Mode	**.46**	**2.93**	**.005**
Tonal strength	.21	1.28	.21
Unison	–.80	–0.36	.71
Minor second	–.06	–0.27	.78
Major second	–.01	–0.07	.93
Minor third	.09	0.49	.62
Major third	.04	0.26	.79
Perfect fourth	.009	0.05	.95
Augmented fourth	–.06	–0.31	.75
Perfect fifth	.07	0.40	.68
Minor sixth	.04	0.23	.82
Major sixth	–.03	–0.20	.83
Minor seventh	–.11	–0.53	.59
Major seventh	–.18	–0.97	.33
Octave	.003	0.02	.98
> Octave	.21	1.008	.32

Overall model: $R^2 = .45$, $F = 1.96$, $df = 16, 34$, $p < .04$.

Predictors for Aesthetic Judgment

The overall model for Aesthetic Judgment was also significant, R^2 = .51, $F(16, 34) = 2.18$, $p < .02$. The significant predictors were Tonal Strength, Perfect Fourth, Augmented Fourth, and Minor Seventh. Melodies that strictly adhere to a tonality, without tritones, and with a greater occurrence of perfect fourths and minor sevenths, were evaluated as more pleasant and agreeable than melodies that did not do so (Table 3).

Predictors for Activity

The overall model for Activity was also significant, $R^2 = .46$, $F(16, 34) = 2.15$, $p < .03$. The significant predictors were Minor Second, Augmented Fourth, and Compound Intervals. Thus melodies with a greater occurrence of minor seconds and a relatively high frequency of tritones and intervals larger than the octave were evaluated as expressing more dynamism and instability (Table 4).

Predictors for Potency

Potency was the dependent variable best predicted by the regression analysis, accounting for 56% of the variance, $F(16, 34) = 2.69$, $p < .007$. There were two significant predictors: Unison and Perfect Octave. A sense of vigor and power can therefore be expressed in melodies by a frequent repetition of the same note or by the use of the octave (Table 5).

TABLE 3
Ridge Regression Results for Aesthetic Judgment

	β	*t*	*p*
Mode	–.15	–0.99	.32
Tonal strength	**.39**	**2.35**	**.02**
Unison	.12	0.48	.63
Minor second	.05	0.19	.84
Major second	–.03	–0.11	.90
Minor third	–.16	–0.78	.44
Major third	.05	0.29	.77
Perfect fourth	**.35**	**1.96**	**.05**
Augmented fourth	**–.42**	**–2.57**	**.01**
Perfect fifth	–.01	0.05	.95
Minor sixth	–.09	–0.50	.61
Major sixth	–.02	–0.12	.90
Minor seventh	**.37**	**2.10**	**.04**
Major seventh	–.02	–0.12	.89
Octave	–.11	–0.69	.49
> Octave	–.15	–0.67	.50

Overall model: $R^2 = .51$, $F = 2.18$, $df = 16, 34$, $p < .02$.

TABLE 4
Ridge Regression Results for Activity

	β	*t*	*p*
Mode	–.03	–0.19	.84
Tonal strength	.02	0.16	.87
Unison	–.02	–0.13	.89
Minor second	**.37**	**2.07**	**.04**
Major second	–.26	–1.08	.26
Minor third	.05	0.27	.78
Major third	.03	0.17	.86
Perfect fourth	–.27	–1.59	.12
Augmented fourth	**.34**	**2.02**	**.05**
Perfect fifth	–.04	–0.25	.80
Minor sixth	.17	0.95	.34
Major sixth	–.14	–0.86	.39
Minor seventh	–.12	–0.59	.55
Major seventh	–.008	–0.04	.96
Octave	–.12	–0.76	.44
> Octave	**.52**	**2.33**	**.02**

Overall model: $R^2 = .46$, $F = 2.15$, $df = 16, 34$, $p < .03$.

TABLE 5
Ridge Regression Results for Potency

	β	*t*	*p*
Mode	–.09	–0.62	.53
Tonal strength	.08	0.53	.59
Unison	**.33**	**2.04**	**.05**
Minor second	.31	1.19	.24
Major second	.04	0.15	.87
Minor third	.08	0.41	.68
Major third	.30	1.77	.08
Perfect fourth	–.03	–0.18	.85
Augmented fourth	–.18	–0.99	.32
Perfect fifth	–.05	–0.34	.73
Minor sixth	.20	1.19	.23
Major sixth	–.16	–1.05	.29
Minor seventh	.02	0.12	.90
Major seventh	–.01	–0.06	.95
Octave	**.29**	**1.98**	**.05**
> Octave	–.02	–0.09	.92

Overall model: $R^2 = .56$, $F = 2.69$, $df = 16, 34$, $p < .007$.

Discussion

The analysis of statistical properties of melodies is an efficacious method for the classification of musical styles (Crerar, 1985), the study of perceptual similarity (Eerola et al., 2001), and statistical classification in ethnomusicology (Freeman & Merriam, 1956). This study demonstrates its use also in the field of emotional expression in music.

Taking into account the fact that participants in this study were students with no particular musical training, emotional ratings were shown to be related to distinct interval occurrence patterns for the four factors that emerged from the principal component analysis of the 10 bipolar adjective scales questionnaire: valence, aesthetic judgment, activity, and potency.

The attribution of happiness and serenity was associated with the major mode, in line with previous results on this subject. The major-minor distinction paralleled the happy-sad one as found by Hevner (1935), Kastner and Crowder (1990), Gerardi and Gerken (1995), Gregory, Worral, and Sarge (1996) and Peretz, Gagnon, and Bouchard (1998).

Expressions of potency, energy, and vigor were positively associated with more frequent occurrences of unisons and octaves. By repeating the same note, a composer can emphasize the rhythmical aspects of a melody, and, through a succession of beats, convey a sense of insistence, stress, and emphasis. The octave has a direct link to the unison, being the repetition of the same note with the addition of a 12-semitone interval. The key role of the octave in expressing potency was emphasized also by Stefani, Marconi, and Ferrari (1990), who dealt with the relationship between musical intervals and their psychological meanings from a musicological perspective. Pleasant and agreeable music was found to be positively correlated with more perfect fourths and minor sevenths and was negatively related to the use of augmented fourths. Finally, expressions of movement, dynamism, activity, and instability were conveyed by a greater occurrence of compound intervals, minor seconds, and augmented fourths.

The tritone has emerged as a significant predictor for aesthetic judgment and activity, and as the tritone is a prototypical example of diminished or augmented interval, it can be suggested that these intervals tend to be perceived as unpleasant and expressing tension.

Tonal strength (Cuddy & Lunney, 1995), the degree to which the pattern of notes in any melody suggests a particular tonality, has emerged as one predictor of aesthetic judgment. Melodies whose notes more strictly adhere to a particular key were evaluated as being more pleasant and expressing more positive emotions and a greater sense of stability. Atonal excerpts were evaluated as less pleasant and agreeable, confirming the results obtained by Smith and Witt (1989). Their study focused on the fact that audiences consistently reject contemporary orchestral music. When comparing the responses of a group of listeners to tonal and serial works by the same composers (Schönberg and Webern), these authors found that listeners rejected the atonal works and found them less rich in referential meanings. Furthermore, Smith and Cuddy (1986) found an association between pleasingness and level of harmonic structure, with highest ratings of pleasingness associated with the highest level of structure, a property that is significantly reduced in atonal music. Another reason for this rejection may lie in the complexity of melodic structure and syntax that causes listeners to have cognitive difficulties in extracting cues. Cuddy, Cohen, and Mewhort (1981) have, for instance, shown that ratings of structure decreased in a regular manner as complexity, defined as different levels of harmonic structures, increased. The lack of predictability that characterizes atonal music can also be translated, in psychological terms, into expressions of tension, instability, movement, and dynamism, as shown by the higher activity ratings for excerpts with a greater frequency of augmented fourths in the current study.

Relationships between interval occurrence and expression of emotions in melodies could be more rigorously tested in future research in which melodies are composed according to different interval occurrences, as done for example by Oram and Cuddy (1995), and the emotional responses are then predicted.

The study of interval occurrences is also important from a historical point of view. We know, for example, that there has been a progressive increase in the use of larger intervals by composers, from Greek melodies and Gregorian chant in which unisons and seconds were prevailing, to contemporary compositions in which jumps greater than two octaves sometimes occur.

The statistical distribution of intervals is doubtless only one of several factors influencing emotional expression in music. Gabrielsson and Lindstrom (2001) have reviewed the literature investigating the effects of many such factors, including loudness dynamics, tempo, rhythmic patterns, tessitura (pitch height), and orchestral texture. In the present experiment, harmonic complexity and orchestral timbre were held constant, by using the same MIDI sound and single line melodies. It is possible, however, that uncontrolled factors, such as rhythmic patterns, pitch levels, or loudness dynamics, could have covaried with interval occurrences influencing emotional evaluations. It is unlikely, however, that the effects obtained in this study can be attributed only to variables other than interval distribution.

In a future study, a richer variety of musical categories that include a broader range of historical musical samples could be investigated from the same perspective of correlating the interval frequency distribution with the emotional attributes. It can be suggested, for example, that the sense of solemnity, austerity, resigned pain, and lament that a listener generally attributes to Gregorian chant is mainly due to the fact that this music consists primarily of small intervals, in particular seconds, and in contrast, that the pathos and passion that characterize Beethoven's compositions could be explained by the fast oscillation between occurrences of small and large intervals. These considerations underline another aspect of music that can strongly influence the emotions expressed in a melody: the time distribution of the different intervals. Intervals per se cannot be considered as semantic units in a melody. The order in which intervals occur is determinant. If a particular interval distribution is built in accordance with the results outlined in this article, one cannot randomize the order and position of these intervals and expect to obtain a musically reasonable melody. Furthermore, the role a musical interval could play in determining the emotional impact of a melody might depend on which note (if either) is placed on an accented beat. In Gregorian chant, the distribution of interval occurrences is fairly constant along the entire composition, and for the listener, this is translated into expressions of stability. This music evokes a unique and constant emotion in all its temporal development. In a richer and more sophisticated fashion, the same could be encountered in renaissance and baroque music, where the strong use of recurrent interval patterns determines a constant interval frequency distribution along the entire composition that, from a psychological perspective, corresponds to the perception of the same emotion for the whole duration of a melody. On the contrary, in classical, romantic, and even contemporary music, a listener can usually distinguish a succession of different emotions over time. This music is experienced as an alternating of tension and relaxation, as a continuously evolving emotional pattern. Most contemporary music has emphasized this characteristic, and listeners are frequently subjected to abrupt changes between expressions of serenity, weakness, and tenderness and expressions of potency, fury, and instability. A future investigation that consists of a time-series analysis of the interval frequency distributions, therefore, could be important for a more complete understanding of the relationships between interval occurrence and perceived emotions.[3]

References

Bozzi, P. (1985). Semantica dei bicordi. In G. Stefani & F. Ferrari (Eds.), *La psicologia della musica in Europa e in Italia.* Bologna: CLUEB.

Clive, G. (1978). An experimental study of Deryck Cooke's theory of music and meaning. *Psychology of Music, 6,* 13–20.

Cooke, D. (1959). *The language of music.* New York: Oxford University Press.

Costa, M., Ricci Bitti, P. E., & Bonfiglioli, L. (2000). Psychological connotations of harmonic musical intervals. *Psychology of Music, 28,* 4–22.

Crerar, M. A. (1985). Elements of a statistical approach to the question of authorship in music. *Computers and the Humanities, 3,* 175–182.

Cuddy, L. L., Cohen, A. J., & Mewhort, D. J. K. (1981). Perception of structure in short melodic sequences. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 869–883.

Cuddy, L. L., & Lunney, C. A. (1995). Expectancies generated by melodic intervals: Perceptual judgments of melodic continuity. *Perception and Psychophysics, 57,* 451–462.

3. The authors are grateful to three anonymous referees and to the editor for their valuable suggestions on data analysis and interpretation.

Eerola, T., Järvinen, T., Louhivuori, J., & Toiviainen, P. (2001). Statistical features and perceived similarity of folk melodies. *Music Perception, 18,* 275–296.
Fox, J. (1991). *Regression diagnostics.* Thousand Oaks, CA: Sage Publications.
Freeman, L. C., & Merriam, A. P. (1956). Statistical classification in anthropology: An application to ethnomusicology. *American Anthropologist, 58,* 464-472.
Gabrielsson, A., & Lindstrom, E. (2001). The influence of musical structure on emotional expression. In P. N. Juslin & J. A. Sloboda (Eds.), *Music and emotion: theory and research.* Oxford: Oxford University Press.
Gerardi, G. M., & Gerken, L. (1995). The development of affective response to modality and melodic contour. *Music Perception, 12,* 279–290.
Gregory, A., Worral, L., & Sarge, A. (1996). The development of emotional responses to music in young children. *Motivation and Emotion, 20,* 341–349.
Hevner, K. (1935). The affective character of the major and minor modes in music. *American Journal of Psychology, 47,* 103-118.
Kameoka, A., & Kuriyagawa, M. (1969a). Consonance theory part I: Consonance of dyads. *Journal of the Acoustical Society of America, 45,* 1451–1459.
Kameoka, A., & Kuriyagawa, M. (1969b). Consonance theory part II: Consonance of complex tones and its calculation method. *Journal of the Acoustical Society of America, 45,* 1460–1469.
Kastner, M. P., Crowder, R. G. (1990). Perception of the major/minor distinction: IV. Emotional connotations in young children. *Music Perception, 8,* 189–202.
Krumhansl, C. L. (1990). *Cognitive foundations of musical pitch.* New York: Oxford University Press.
Krumhansl, C. L., & Kessler, E. J. (1982). Tracing the dynamic changes in perceived tonal organization in a spatial representation of musical keys. *Psychological Review, 89,* 334–368.
Levelt, W. J. M., van de Geer, J. P., & Plomp, R. (1966). Triadic comparison of musical intervals. *British Journal of Mathematical and Statistical Psychology, 19,* 163–179.
Maher, T. F. (1976). "Need for Resolution" ratings for harmonic musical intervals: A comparison between Indians and Canadians. *Journal of Cross-Cultural Psychology, 7,* 259–276.
Maher, T. F. (1980). A rigorous test of the proposition that musical intervals have different psychological effects. *American Journal of Psychology, 93,* 309–327.
Maher, T. F., & Berlyne, D. E. (1982). Verbal and explanatory responses to melodic musical intervals. *Psychology of Music, 10,* 11–27.
Maher, T. F., & Jairazbhoy, N. A. (1975). Need for resolution of musical intervals, part I: Static context. *Sangeet Natak, 36,* 5–20.
Maxwell, A. E. (1977). Multiple regression and poorly conditioned matrices. *British Journal of Mathematical and Statistical Psychology, 30,* 210–212.
Oram, N., & Cuddy, L. L. (1995). Responsiveness of Western adults to pitch-distributional information in melodic sequences. *Psychological Research, 57,* 103–118.
Pagel, M. D., & Lunneborg, C. E. (1985). Empirical evaluation of ridge regression. *Psychological Bulletin, 97,* 342–355.
Peretz, I., Gagnon, L., & Bouchard, B. (1998). Music and emotion: Perceptual determinants, immediacy, and isolation after brain damage. *Cognition, 68,* 111–141.
Plomp, R., & Levelt, W. J. M. (1965). Tonal consonance and critical bandwidth. *Journal of the Acoustical Society of America, 38,* 548–560.
Smith, J. D., & Witt, J. N. (1989). Spun steel and stardust: The rejection of contemporary compositions. *Music Perception, 7,* 169–185.
Smith, K. C., & Cuddy, L. L. (1986). The pleasingness of melodic sequences: Contrasting effects of repetition and rule-familiarity. *Psychology of Music, 14,* 17–32.
Stefani, G., Marconi, L., & Ferrari, F. (1990). *Gli intervalli musicali: dall'esperienza alla teoria.* Milano: Bompiani.
van de Geer, J. P., Levelt, W. J. M., & Plomp, R. (1962). The connotation of musical consonance. *Acta Psychologica, 20,* 308–309.
Vos, P. G., & Troost, J. M. (1989). Ascending and descending melodic intervals: Statistical findings and their perceptual relevance. *Music Perception, 6,* 383–396.

Appendix
Excerpt List

Information on excerpts is reported in the following order: Author, Title, Editor (if any), Author of the MIDI file, Instrument (in case of orchestral composition), starting and ending measure numbers.

1. I. Albeniz, *Pavane-Capricho,* Op. 12 (guitar arrangement by Tarrega), M. Knezevic, measures 1–17
2. I. Albeniz, *Spanish suite,* Op. 47 from Asturia (edited by Leyenda), R. H. Czwiertnia, measures 1–60
3. I. Albeniz, *Spanish suite,* Op. 47 from Cataluna (edited by Curranda), M. Knezevic, measures 4–25
4. P. Boulez, *Notations I-XII for Piano, I. Fantasque-Moderé,* J. Franganillo, measures 1–12
5. B. Britten, *A Ceremony of Carols, Op. 28, 1. Procession,* D. Robinson, alto, measures 4–43
6. M. Bruch, *Scottish fantasy for Violin and Piano, Op. 46, Allegro,* R. J. Fisher, violin, measures 20–39
7. M. Bruch, *Concerto for Violin No. 1 in G—Allegro moderato,* R. J. Fisher, violin, measures 4–21
8. J. B. Cabanilles, *Organ work, Italian corrente,* F. Villanueva, measures 75–90
9. A. Corelli, *The craziness,* W. Scherman, measures 1–32
10. A. Dvorak, *Serenade for Strings in E, Op. 22—Moderato,* R. Pajares Box, violin, measures 5–14
11. E. Elgar, *The Enigma Variations*, Op. 36, orchestra version. Introduction—Andante, S.A. Nielsen, flute, measures 2–19
12. G. Fauré, *Madrigal*, Op. 35, C. Ikenove, measures 25–42
13. J. Harrington, *Mockingsongbird Soliloquy for Solo Oboe,* measures 1–125
14. J. N. Hummel, *Paul and Virginie, Op. 41—Quintour des Negres,* Piano reduction by Hummel M. Tao, measures 1–9
15. J. N. Hummel, *Trumpet concerto in E—Andante,* M. Tao, trumpet, measures 8–34
16. J. N. Hummel, *Three variations, Op. 1 for Piano Solo—La Belle Catherine,* M. Tao, measures 2–25
17. F. Mendelssohn Bartholdy, *Venetian Boat Song,* No. 6, B. Lovell, measures 1–19
18. F. Mendelssohn Bartholdy, *Overture from Die erste Walpurgisnacht—Allegro con fuoco,* M. Abelson, first violins, measures 4–32
19. F. Mendelssohn Bartholdy, *Fingal's Cave Overture (Hebrides),* Op. 26, N. Surgimura, first violins, measures 2–19
20. F. Mendelssohn Bartholdy, *A Midsummer Night's Dream, Op. 61—Nocturne,* R. Finley, measures 2–28
21. F. Mendelssohn Bartholdy, *Spring Song*, Op. 62, No. 2, C. Meesangnin, french horn, measures 1–20
22. F. Mendelssohn Bartholdy, *Venetian Boat Song,* No. 2, C. Meesangnin, measures 1–90
23. S. Mercadante, *Clarinet Concerto in B♭—Andante con variazioni,* G. Parmigiani, clarinet, measures 1–32
24. O. Messiaen, *Vingt Regards sur l'Enfant Jésus, XIII. Noël*, E. Breton, measures 1–24
25. O. Messiaen, *Vingt Regards sur l'Enfant Jésus, III. L'échange,* E. Breton, measures 1–31
26. D. Milhaud, *"Petit" Symphony No. 5 for Ten Wind Instruments, Op. 75, Rude,* J. G. Mayer, oboe, measures 1–16
27. D. Milhaud, *"Petit" Symphony No. 5 for Ten Wind Instruments, Op. 75, Lent,* J.G. Mayer, clarinet, measures 1–18

28. D. Milhaud, *"Petit" Symphony No. 5 for Ten Wind Instruments, Op. 75, Violent,* J. G. Mayer, clarinet, measures 1–38

29/30. M. P. Mussorgsky, *A Night on Bald Mountain in D,* R. Chichakly and M. Weimer, first violins, measures 1–30, and trombone, measures 15–26

31. C. Orff, *O Fortuna from "Carmina Burana,"* H. Kobayashi, measures 2–41

32/33. N. Paganini, *Witches' Dance—Andante,* M. Dikmen, measures 5–12 and measures 22–30

34. S. Prokofiev, *Fugitive Vision, Op. 22—Dolente,* C. Todd, measures 1–18

35. H. Purcell, *Dido and Aeneas—Lament,* W. K. Harshman, Dido, measures 1–10

36. S. V. Rachmaninov, *Piano concerto No. 2, Op. 18—Adagio sostenuto,* R. Finley, clarinet, measures 42–67

37. X. Scharwenka, *Andante,* C. Meesangnin, guitar, measures 1–32

38/39/40/41. A. Schönberg, *Pierrot lunaire,* Op. 21; 1. *Mondestrunken,* flute, measures 1–40; 2. *Colombine,* violin, measures 1–41; 3. *Der Dandy,* clarinet, measures 1–32; 4. *Valse de Chopin,* flute, measures 1–42

42. A. Schönberg, *Piece for Piano, Op. 33a, Mässig,* J. Franganillo, measures 1–40

43. F. Sor, *Andante in C,* Op. 61, No. 1, D. Lovell, treble clarinet, measures 1–40

44. F. Sor, *Largo,* Op. 5, No. 5, D. Lovell, measures 1–18

45. K. Stockhausen, *12 Melodies of the Star Signs: 6. Sagittarius,* J. Franganillo, measures 1–16

46. P. I. Tchaikovsky, *Marche slave,* Op. 31—Full Orchestral score, P. Ostrup, oboe, measures 22–36

47/48. A. Vivaldi, *Sonata in A for violoncello and piano*—1. Largo, J. Carter, cello, measures 1–15; 3. Largo, J. Carter, cello, measures 1–16

49. C. M. von Weber, *Clarinet concerto No. 2 in E♭,* Op. 74—Adagio con moto, G. Parmigiani, measures 1–16

50. A. Webern, *Lied, Op. 3 No. 1, "Dies ist ein Lied,"* J. Franganillo, measures 1–10

51. A. Webern, *5 Movements for Strings, Op. 5, 2nd movt. "Sehr Langsam,"* D. Ahlin, violin, measures 1–15