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JUDGMENTS OF HAPPINESS, BRIGHTNESS, SPEED AND TEMPO CHANGE OF AUDITORY STIMULI VARYING IN PITCH AND TEMPO

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The effects of pitch height, tempo, and pitch contour (ascending and descending C major scale) on ratings of happiness, brightness, speed and tempo change were examined. Higher pitch tones (1046.4 Hz [C6]) were rated as happier, brighter, faster and as speeding up more than lower pitch tones (261.6 Hz [C4]). Tones at a faster tempo (120 beats per minute, bpm) were also rated as happier, brighter, faster and as speeding up more than tones at a slower tempo (60 bpm). In addition, ascending tones (from the C major scale) were rated as being happier, brighter, faster and as speeding up more than descending tones (from the C major scale). In addition to these main effects, there are a number of interactions on ratings indicating that some characteristics of music may combine in different ways to produce different perceptions of music. The data replicate and extend previous studies on music and affect.

For centuries humans have enjoyed the experience of music, and music has been an integral part of our lives. All of us have felt shivers tingle up our spines when a certain tune is played. We experience what seems to be an instant emotional response to a few notes played in a certain way, but what is it in music that calls forth our emotions so readily? The relationship between music and emotion has been an area of speculation for some time, and the question of how music may evoke emotional responses has been addressed in several ways (for reviews, see Radocy & Boyle, 1997; Sloboda, 1992). One possible explanation is that music, like language, has prosodic gestures that include such factors as timing, stress, amplitude, and pitch variation that may underlie the effects of music on emotion (e.g., Crowder, 1984); however, potential confounding effects of connotation, tempo, pitch, and key in many of the previous studies make it difficult to determine which of these factors is most crucial to the emotional experience of music. For example, musical pieces with sad connotations tend to be slower in tempo, lower in pitch, and harmonized in a minor mode (see Crowder, 1984), but which of these factors individually or in combination contributes to the emotional experience? In the research reported here, we begin to disentangle these elements.

The initial empirical investigations of the relationship between emotion and music were carried out a number of years ago. For example, Hevner (1937) presented participants with orchestral compositions and a checklist of adjectives, and participants indicated which adjectives they perceived as being appropriate for each composition. Overall, slow tempi were rated by the participants as more serene, dignified, dreamy, and sad. Fast tempi, in contrast, were rated as more exciting and happy, as well as slightly more graceful and vigorous. Participants rated higher octaves as being more graceful, and slightly more serene, happy, and dreamy, and rated lower octaves as being more sad and vigorous, as well as slightly more exciting and dignified. Similarly, Watson (1942) presented orchestral excerpts and a checklist of adjectives to twenty musicians (all instructors in college departments of music), and the participants indicated which adjectives were appropriate to each excerpt and what the musical attributes of each excerpt were. The musical selections rated as happy, very happy, exciting, or very exciting all had higher pitch and faster tempi than did musical selections rated as sad, serious, or tragic.

In a more recent attempt to investigate the relationship between emotion and music, Sloboda (1991) asked participants to provide the names of particular pieces of music, and the specific passages within each piece of music, to which they could recall experiencing physical manifestations indicative of emotional reactions (i.e., crying, goose pimples, etc.) while previously hearing the music. "Crying" or "a lump in the throat" passages seemed to be characterized by successions of harmonic tension or dissonance that were resolved and then repeated. "Goose pimples" or "a shiver down the spine" passages seemed to be characterized by an expected (repeated) event and an unexpected (new) event occurring simultaneously in the music, such as an expected tempo change with an unexpected crescendo (increase in loudness). "Racing heart" or "a pit in the stomach" passages seemed to be characterized by an anticipated accent arriving earlier than expected. Although highly suggestive, the conclusions from Sloboda's study have not yet been examined in more controlled studies.

In an examination of potential developmental differences in the relationship between music and emotion, Trehub, Cohen, and Guerriero (1987, cited in Trehub, 1993) played simple melodic passages (which consisted of a repeating set of two notes which varied in pitch range and in tempo) to children either four or eight years of age and to adults. Participants rotated a pointer to a sad, happy, or neutral face in response to the melodic passages. For all ages, the high pitch and fast tempo conditions were rated as happy, and the low pitch and slow tempo conditions were rated as sad. Trehub et al. (1987, cited in Trehub, 1993) found that participants who listened to ascending or descending note sequences from major and minor scales rated the ascending sequences as happy, and the descending sequences as sad. Musically trained adults rated the major scales as being happy and the minor scales as being sad, but neither adults without musical training nor children consistently rated major scales as being happy and minor scales as being sad.

In addition to studies that investigated the relationship between emotion and music, some studies also have investigated whether the relationship between music and emotion was related to either visual color or brightness. For example, Odbert, Karwoski, and Eckerson (1942) had participants select which adjectives best fit each of several short orchestral excerpts and also report which color they experienced or thought was most appropriate for that excerpt. Odbert et al. reported a trend for participants to associate tender and more leisurely musical excerpts with lighter colors and more solemn and sad musical excerpts with darker colors. Lehman (1972) had participants listen to a series of orchestral excerpts and rate how well each excerpt was described by each of 18 color words and each of 18 adjectives. Lehman classified participants as "seers" if they reported an ability to visualize colors in response to the excerpts or as "nonseers" if they reported they did not visualize colors in response to the excerpts, and he found the color choices of nonseers were very similar to the color choices of seers. Seers and nonseers also responded similarly in the adjective rating task, and Lehman suggested that there was a constant relationship between color and emotion in response to hearing music.

Marks (1974) found that participants consistently matched low auditory pitches with visually dark stimuli and high auditory pitches with visually bright stimuli. When participants selected a tone that matched a gray surface (varying in overall brightness), they consistently matched higher pitched tones with brighter surfaces and lower pitched tones with darker visual surfaces. When participants also matched the loudness of a tone to the brightness of a gray surface, most matched increasing auditory loudness to increasing visual brightness (although some instead matched increasing auditory loudness to decreasing visual brightness). In a related study, Melara (1989) presented two stimuli (both visual, both auditory, or one from each modality) in succession to participants. The visual stimuli were white or black dots presented in the middle of a gray background and were presented high or low in the visual field (i.e., above or below the midline of the screen). The auditory stimuli were high or low frequency tones. Participants rated the white dots, high frequency tones, and high positions as more similar to each other; they also rated the black dots, low frequency tones, and low positions as more similar to each other.

Hubbard (1996) replicated Marks' and Melara's findings that individuals rate brighter visual stimuli as more similar to higher auditory pitch, and darker visual stimuli as more similar to lower auditory pitch, and extended this visual brightness-auditory pitch relationship to include two-tone auditory intervals. Two frequency ranges (high and low) were used for the intervals, and interval size between the tones varied from one to twelve semitones. Each participant was presented with a gray scale figure that consisted of equal-sized columns, and the lightness of the columns varied from white (on one side) to black (on the other side) in equal-sized steps. Participants, after listening to each two-tone sequence, chose which of the eleven columns in the gray scale figure seemed to best fit the melodic interval. Participants judged lighter visual stimuli as fitting high pitched or ascending intervals, and darker visual stimuli as fitting low pitched or descending intervals. Furthermore, larger interval sizes were judged as fitting with a more extreme visual brightness (i.e., larger ascending intervals were brighter than smaller ascending intervals, and larger descending intervals were darker than smaller descending intervals).

Although several studies have suggested that higher pitch, faster tempi, and ascending tone sequences are judged as happier and brighter than descending tone sequences, more controlled study is needed because many of the initial studies that used orchestral excerpts as stimuli did not control for factors such as pitch range, the presence of melodic or harmonic information, loudness, timbre, or other musical qualities. Indeed, a consideration of these potential confounds led McMullen (1996) to suggest that researchers needed to reexamine "...whether using components of music (such as intervals, pitch, or tempo) in the research framework provide any insight into this relationship between music and affective/aesthetic behavior?" (p. 388). Accordingly, the studies reported here presented either (a) a single auditory tone repeated at different frequencies and/or tempi or (b) ascending and descending scales at different octaves and/or tempi. By examining responses to single tones and to scales, a useful complement to previous studies may be provided, and it should be clearer whether the apparent affect observed in previous studies arises from the level of tone, scale, or harmony. An examination at multiple levels is important because music can take many different forms (e.g., even the simple beat of a drum may be considered "real" music and should not be dismissed from investigation on the assumption that it is not "musical"), and researchers cannot know a priori which elements of music may elicit emotional responses.

A second reason why more controlled study is needed is that past research on emotional effects of music (e.g., Hevner, 1937; Rigg, 1940; Watson, 1942; Wedin, 1972) used a wide variety of emotion word (adjective) checklists, and this inconsistency has resulted in more difficulty in determining the precise emotional effect music may have on listeners. Barrett and Russell (1999) recently summarized a developing consensus that affect is composed primarily of two dimensions: a happy/sad hedonistic or pleasure dimension, and an activation dimension. Ratings of happiness/sadness are consistent with previous research on emotion and music (e.g., Collier & Hubbard, 2001; Gerardi & Gerken, 1995; McMullen, 1996; Trehub et al., 1987). The exact nature of the activation dimension of emotion is still not fully understood (e.g., Barrett & Russell, 1999), and so in the studies reported here, we focused on a rating for the happy/sad dimension of affect. Participants are expected to rate higher frequency, faster, ascending tone sequences as being happy and lower frequency, slower, descending tone sequences as being sad. McMullen (1996) suggested that research on the relationship between emotion and music should also include consideration of listeners' current subjective states. Accordingly, participants' ratings of current levels of arousal and pleasure were obtained using the *affect grid,* a fast single-item scale to assess participants' current affect along two dimensions: pleasure-displeasure and arousal-sleepiness (see Russell, Weiss, & Mendelsohn, 1989).

A third reason why more controlled study is needed is that previous studies on the relationship of auditory frequency with either visual color or brightness have not presented sequences of tones more typical of music, nor have effects of tempo on the relationship of auditory frequency with either visual color or brightness been systematically investigated. Accordingly, the experiments reported here also obtained ratings of brightness/darkness from participants. Past research has found that higher pitches and two-tone ascending sequences are rated as brighter than lower pitches and descending two-tone sequences (Hubbard, 1996), and the current study will examine the effect of longer ascending and descending tone sequences. It is predicted that higher frequency, faster, ascending tone sequences will be rated as brighter than lower frequency, slower, descending tone sequences. In addition to offering a useful extension of results on pitch direction and lightness, the current experiment will provide an opportunity to examine effects of pitch direction on ratings of emotion. Finally, participants will also rate each sequence of tones for perceived speed and tempo change. If participants rate high frequency, faster, ascending sequences as happier and brighter, this may also influence their ratings of speed and tempo change or vice versa. Participants' ratings of speed and tempo change also served as a check for possible carryover effects. If participants accurately rated the faster tone sequences as being fast and the slower tone sequences as being slow it would be an indication that participants were attending to the experimental stimuli.

Experiment 1

In this experiment, participants' perceptions of happiness, brightness, speed and tempo change of note sequences differing in pitch and tempo were measured. On each trial, participants heard a tone at one of three pitches, and the tone was repeated at a slow, medium, or fast tempo. Consistent with Hevner (1937), Rigg (1940), Trehub et al. (1987), and Marks (1982), we predicted that higher tones and tones at the faster tempo would be perceived as being more happy, bright, fast and as speeding up, and we predicted that lower tones and tones at the slower tempo would be perceived as being more sad, dark, slow and as slowing down. At the beginning of the session, participants completed an affect grid, and the scores on the affect grid were used to examine whether or not participants varied in their ratings of the note sequences based on individual differences in the participants' initial levels of arousal or pleasure. In addition, participants were assigned to either a high or low musical experience group (on the basis of a post-experimental questionnaire) in order to examine possible differences resulting from musical experience.

Method

Participants. Participants were 21 undergraduate students attending Texas Christian University, and were unselected for musical ability or background. Each participant received experimental credit to partially fulfill a psychology course requirement.

Apparatus. The auditory stimuli were generated by a Macintosh IIsi computer and presented through headphones connected directly to the computer, and the rating scales were displayed on a RGB color monitor connected to the Macintosh. The computer recorded the participants' responses.

Stimuli. Three different auditory sine wave frequencies were used: 261.6 Hz, 523.2 Hz, or 1046.4 Hz (corresponding to middle C or C4, an octave above at C5, and an octave higher at C6 respectively)[1]; only one frequency was used on each trial. Three different tempi were used: slow (60 beats per minute [bpm]), medium (90 bpm), and fast (120 bpm). Only one tempo was used on each trial. Each tone was equivalent to one quarter note (one s in duration at tempo 60, three quarters of a s in duration at tempo 90, and one half s at tempo 120). Given that the duration of a trial was constant (6 s), six tones were presented in each slow trial, nine tones were presented in each medium trial, and twelve tones were presented in each fast trial. The affect grid is a Pleasure x Arousal two dimensional grid; the horizontal axis was labeled *extremely unpleasant feelings* on the left and *extremely pleasant feelings* on the right, and the vertical axis was labeled *extremely low arousal* at the bottom and *extremely high arousal* at the top (adapted from Russell, Weiss, & Mendelsohn, 1989). Ratings on the affect grid resulted in two scores (both on a 1 - 9 scale): one score for pleasantness, and one score for arousal. The rating scales for the auditory stimuli were 7 point Likert scales on which participants rated how happy (7) or sad (1) they perceived the set of tones to be, how bright (7) or dark (1) they perceived the set of tones to be, how fast (7) or slow (1) they perceived the set of tones to be, and whether they perceived the set of tones as speeding up (7) or slowing down (1). Each participant received 180 trials (3 frequency x 3 tempo x 4 ratings x 5 replications) in a different random order.

Procedure. Participants were run individually. Shortly after arrival at the laboratory, participants used the affect grid to rate the pleasantness and arousal level of their current state. After completing the affect grid, participants were introduced to the experiment and completed five training trials (randomly chosen from the total 180 trials) before proceeding to the experiment itself. The experimenter was present and available for questions throughout the experiment, but remained behind and out of the immediate view of the participants. To begin each trial, participants pressed the space bar. The tonal stimuli were immediately presented, and after the tones were presented, one of the rating scales immediately appeared on the monitor. Participants typed in their rating on the computer keyboard, and were then prompted to go on to the next trial. After completing the experimental trials, subjects completed a brief musical background questionnaire regarding how many years they had (a) training on a musical instrument, (b) vocal training, (c) played in a band, (d) sung with a choir, and (e) studied music theory.

Results

Two types of analyses are presented: median split analyses and within analyses. Median splits of scores on the affect grid classified participants' subjective states as either aroused (range: 5 - 9) or unaroused (range: 3 - 4), and as either pleasant (range: 6 - 8) or unpleasant (range: 2 - 5). The responses to each of the five questions on the musical background questionnaire were averaged for each participant to provide a musical experience score for that participant, and a median split of the musical experience classified participants as either high (range: 1.6 - 7.2 years) or low (range: 0 - 1.2 years) in musical experience. Within analyses collapsed across the median split variables. To control for individual differences in interpretation of the affect grid or the rating scales, all responses were transformed into z scores and subsequent analyses were based on these z scores.

Median Split Analyses

Ratings of Happiness. No differences were found for ratings of happiness.

Ratings of Brightness. Participants with high and low arousal differed in their ratings of brightness in the middle frequency tones with slow tempo condition (high arousal $M = -0.04$, low arousal $M = -0.50$; $t\,[19] = -2.71, p < .02$); and in the low frequency tones with medium tempo condition (high arousal $M = -1.03$, low arousal $M = -0.66$; $t\,[19] = 2.22, p < .04$). In addition, participants with high ($M = 0.83$) and low ($M = 1.19$) musical experience differed in their ratings of brightness in the high frequency with slow tempo condition, $t\,(19) = 2.26, p < .04$.

Ratings of Speed. Participants with high ($M = -0.78$) and low ($M = -0.53$) musical experience rated speed significantly differently in the high frequency with slow tempo condition, $t\,(19) = 2.26, p < .04$; and low frequency with fast tempo condition (high music experience $M = 0.81$, low music experience $M = 0.52$; $t\,[19] = -2.6, p < .02$).

Ratings of Tempo Change. Participants with high ($M = 1.08$) and low ($M = 0.55$) musical experience differed in their ratings of a change in tempo in the high frequency with fast tempo condition, $t\,(19) = -3.06, p < .01$.

Within Analyses

Ratings of Happiness. Ratings for happiness were analyzed in a 3 (frequency) x 3 (tempo) repeated measures ANOVA. The 3 (frequency) x 3 (tempo) interaction was not significant. The frequency main effect, however, was significant, $F\,(2, 40) = 63.24, p < .0001$. High frequency tones ($M = 0.56$) were rated as happier than middle ($M = 0.15$) or low frequency tones ($M = -0.70$). Post hoc analyses found that high frequency tones were rated as happier than middle frequency tones (Bonferroni corrected $t\,[20] = -4.49, p < .0001$), and middle frequency tones were rated as happier than low frequency tones (Bonferroni corrected $t\,[20] = -9.61, p < .0001$). Additionally, the high frequency tones were rated as happier than the low frequency tones (Bonferroni corrected $t\,[20] = -8.30, p < .0001$). The tempo main effect was significant, $F\,(2, 40) = 69.72$, $p < .0001$. Tones at the fast tempo ($M = 0.50$) were rated as happier than tones at medium ($M = -0.04$) or slow tempi ($M = -0.45$). Post hoc analyses found that fast tempo tones were rated as happier than medium tempo tones (Bonferroni corrected $t\,[20] = -8.68, p < .0001$), and medium tempo tones were rated as happier than slow tempo tones (Bonferroni corrected $t\,[20] = -5.36, p < .0001$). Additionally, fast tempo tones were rated as happier than slow tempo tones (Bonferroni corrected $t\,[20] = -9.58$, $p < .0001$).

Ratings of Brightness. Ratings for brightness were analyzed in a 3 (frequency) x 3 (tempo) repeated measures ANOVA. The 3 (frequency) x 3 (tempo) interaction was not significant for ratings of brightness. The frequency main effect was significant, $F\,(2, 40) = 161.08, p < .0001$. High frequency tones ($M = 0.74$) were rated as brighter than low frequency tones ($M = -0.85$) with middle frequency tones in between ($M = 0.12$). Post hoc analyses found that higher frequency tones were rated as brighter than middle frequency tones (Bonferroni corrected $t\,[20] = -9.33, p < .0001$), and middle frequency tones were rated as brighter than low frequency tones (Bonferroni corrected $t\,[20] = -10.59, p < .0001$). Additionally, high frequency tones were rated as brighter than low frequency tones (Bonferroni corrected $t\,[20] = -15.08, p < .0001$). The tempo main effect was also significant, $F\,(2, 40) = 58.02, p < .0001$. Tones at the fast tempo ($M = 0.36$) were rated as brighter than tones at the slow tempo ($M = -0.34$) with medium tempo tones ($M = -0.02$) in between. Post hoc tests found that fast tempo tones were rated as brighter than medium tempo tones (Bonferroni corrected $t\,[20] = -5.34, p < .0001$), and medium tempo tones were rated as brighter than slow tempo tones (Bonferroni corrected $t\,[20] = -5.95, p < .0001$). Additionally, fast tempo tones were rated as brighter than slow tempo tones (Bonferroni corrected $t\,[20] = -10.19, p < .0001$).

Ratings of Speed. Ratings for speed were analyzed in a 3 (frequency) x 3 (tempo) repeated measures ANOVA. The 3 x 3 interaction was significant, $F\,(4, 80) = 2.52, p < .05$); as shown in Table 1, higher frequency tones at the fast tempo ($M = 1.09$) were rated as faster than lower frequency tones at the slow tempo ($M = -1.09$). The simple effects of tempo with low frequency tones ($F\,[2, 40] = 186.80, p < .0001$), middle frequency tones ($F\,[2, 40] = 112.40, p < .0001$), and high frequency tones ($F\,[2, 40] = 112.40, p < .0001$) were significant. Thus, tempo influenced participants' ratings of speed at low, middle, and high frequencies, and participants were appropriately rating different tempi as being different speeds. The simple effects of frequency with slow tempo tones ($F\,[2, 40] = 11.62, p < .0001$), medium tempo tones ($F\,[2, 40] = 20.88, p < .0001$), and fast tempo tones ($F\,[2, 40] = 10.28, p < .0001$) were significant. Thus frequency influenced participants' ratings of speed across tempo as well.

Ratings of Tempo Change. Ratings of tempo change were analyzed in a 3 (frequency) x 3 (tempo) repeated measures ANOVA. The 3 (frequency) x 3 (tempo) interaction was not significant for ratings of tempo change. The frequency main effect, however, was significant, $F\,(2, 40) = 4.04, p < .03$. High frequency tones ($M = 0.12$) were rated as speeding up more than low

Table 1

Z Score Ratings of Speed for the 3 (Frequency) x 3 (Tempo) Interaction in Experiment 1

Frequency Level[b]	Tempo[a]		
	Slow	Medium	Fast
High	-0.65	0.22	1.09
Medium	-0.63	-0.04	0.85
Low	-1.09	-0.41	0.65

[a] In Experiment 1, the slow tempo was 60 bpm (beats per minute), the medium tempo 90 bpm, and the fast tempo 120 bpm.
[b] In Experiment 1, the low frequency level was 261.6 Hz, the medium frequency level 523.2 Hz, and the high frequency level 1046.4 Hz.

frequency tones ($M = -0.13$) with middle frequency tones ($M = 0.01$) intermediate, F (2, 40) = 4.04, $p < .03$. Post hoc analyses found that high frequency tones were not rated as speeding up more than middle frequency tones (Bonferroni corrected t [20] = -1.36, $p = .19$), and middle frequency tones also were not rated as speeding up more than low frequency tones (Bonferroni corrected t [20] = -1.93, $p = .07$). High frequency tones, however, were rated as speeding up more than low frequency tones (Bonferroni corrected t [20] = -2.36, $p < .03$). Additionally, the tempo main effect was significant, F (2, 40) = 62.46, $p < .0001$. Tones at the fast tempo ($M = 0.62$) were rated as speeding up more than tones at the medium ($M = -0.18$) or slow ($M = -0.44$) tempi. Further post hoc analyses found that fast tempo tones were rated as speeding up more than medium tempo tones (Bonferroni corrected t [20] = -9.00, $p < .0001$), and medium tempo tones were also rated as speeding up more than slow tempo tones (Bonferroni corrected t [20] = -3.46, $p < .002$). Additionally, fast tempo tones were rated as speeding up more than slow tempo tones (Bonferroni corrected t [20] = -8.41, $p < .0001$). This indicates that participants judged the faster tempo tones as speeding up and the slower tempo tones as slowing down.

Discussion

Experiment 1 isolated the effects of frequency and tempo on ratings of happiness, brightness, speed, and tempo change of auditory tones. The results generally were consistent with previous findings that (a) higher frequency tones were rated as happier than lower frequency tones, (b) tones at a faster tempo were rated as happier than tones at a slower tempo, and (c) higher frequency tones were rated as brighter than lower frequency tones. This gives us greater confidence that these previously reported patterns did not result from confounds of pitch height, key, harmony, and other musical elements that may have been present in the orchestral excerpts used in many of the prior studies. More importantly, replication of patterns previously found in studies that used orchestral excerpts suggests that many of the salient properties of music can be systemically controlled and examined within laboratory settings, and that experimental precision and control does not necessarily destroy the effects of music. Interestingly, median split analyses between the high and low pleasantness groups, high and low arousal groups, and high and low musical experience groups, yielded no broadly consistent pattern. This suggests that affective interpretations of musical stimuli are not necessarily influenced by a person's current emotional state or level of arousal, at least for the range of such states considered in this study. Also, affective interpretations of musical stimuli are not necessarily influenced by a person's level of musical experience.

In addition to the replicated patterns mentioned above, other results from Experiment 1 constitute new contributions to the literature. In general, tones at a faster tempo were rated as brighter than tones at a slower tempo, and higher frequency tones were rated as faster than lower frequency tones. Not surprisingly, tones at a faster tempo were rated as faster than tones at a slower tempo. Intriguingly, frequency and tempo interacted in ratings of speed. Frequency seems to have combined with tempo and helped to exaggerate participants' judgments of speed; that is, high frequency seems to push ratings of speed for fast tempo tones to be faster and low frequency seems to push ratings of speed for slow tempo tones to be slower. The interaction of frequency and tempo in ratings of speed is also consistent with the possibility that the combination of higher frequency tones with a faster tempo may contribute to participants rating those tones as being happy and bright. In a related finding, higher frequency tones were rated as speeding up more than were lower frequency tones, and tones at a faster tempo were rated as speeding up more than were tones at a slower tempo. If participants perceived higher, faster tones as speeding up more than lower, slower tones, then this perception may contribute to the participants rating the higher, faster tones as being more happy and bright.

Experiment 2

Experiment 1 presented auditory tones that maintained a constant frequency within each trial, but in nonpercussive music the pitches of subsequent notes typically change. Therefore, Experiment 2 presented tonal stimuli that ascended or descended in frequency within each trial, and participants' perceptions of happiness, brightness, speed and tempo change as a function of direction, octave, and tempo were measured. Participants were presented with a sequence of ascending or descending tones from two octave ranges (high or low), and consistent with Trehub et al. (1987) and Hubbard (1996) we predicted the participants would perceive faster, higher octave, ascending tone sequences as being more happy and bright. We also predicted that the slower, lower octave, descending tone sequences would be perceived as being more sad and dark. In addition, we predicted that participants would perceive the faster, higher octave, ascending tone sequences as being faster and as speeding up more than the slower, lower octave, descending tone sequences.

Method

Participants. Twenty-two participants from the same subject pool used in Experiment 1 were recruited, and none had participated in Experiment 1.

Apparatus. The apparatus was the same as in Experiment 1.

Stimuli. On each trial, the participants heard either an ascending or descending C major scale (based on an equal-tempered tuning scale). The scale was either from a relatively low octave (C4 to C5; 261.6, 293.7, 329.6, 349.3, 392, 440, 493.9, and 523.2 Hz) or from a relatively high octave (C5 to C6; 523.2, 587.4, 659.2, 698.6, 784, 880, 987.8, and 1046.4 Hz). On each trial the scale was played at one of two tempi: 60 bpm (slow), or 120 bpm (fast). Each tone was equivalent to one quarter note (one s in duration at tempo 60, and one half s at tempo 120). Each participant received 160 trials (2 octave x 2 direction x 2 tempo x 4 ratings x 5 replications) in a different random order.

Procedure. The procedure was the same as in Experiment 1.

Results

The analyses paralleled that in Experiment 1: Median split analyses of scores on the affect grid and musical background questionnaire classified participants as aroused (range: 6 - 9) or unaroused (range: 1 - 5), pleasant (range: 6 - 9) or unpleasant (range: 1 - 5), and high (range: 0.6 -7.0 years) or low (range: 0.0 - 0.4 years) in musical experience, and within analyses collapsed across these variables. As in Experiment 1, transforming all responses into z scores controlled individual differences in the interpretation of the affect grid and rating scales.

Median Split Analyses

Ratings of Happiness. Participants in the high (M = -1.35) and low (M = -1.07) pleasantness groups rated happiness marginally differently in the descending, low octave, and slow tempo condition, t (20) = 1.86, p < .08.

Ratings of Brightness. Participants with high (M = -0.04) and low (M = -0.35) pleasantness rated brightness significantly differently in the descending, low octave, and fast tempo condition, t (20) = -2.38, p < .03. Participants with high (M = -0.09) and low (M = -0.33) musical experience rated brightness marginally differently in the descending, low octave, and fast tempo condition, t (20) = -1.81, p < .09.

Ratings of Speed. Participants in the high (M = 1.06) and low (M = 0.76) pleasantness groups rated speed significantly differently in the descending, high octave, and fast tempo condition, t (20) = -2.25, p < .04. Participants with high (M = 0.62) and low (M = 0.25) musical experience rated speed significantly differently in the descending, low octave, and fast tempo condition, t (20) = -2.60, p < .02, as well as marginally differently in the ascending, high octave, slow tempo condition (high musical experience, M = -0.67; low musical experience, M = -0.33; t (20) = 1.93, p < .07).

Ratings of Tempo Change. Participants in the high (M = 0.73) and low (M =1.01) pleasantness groups rated tempo change significantly different in the ascending, high octave, and fast tempo condition, t (20) = 2.21, p < .04. Participants in the high (M = 0.09) and low (M = 0.54) musical experience groups rated tempo change significantly different in the descending, high octave, and fast tempo condition, t (20) = 2.28, p < .04. Additionally, participants in high (M = -0.62) and low (M = -1.05) musical experience groups rated tempo change significantly different in the descending, low octave, and slow tempo condition, t (20) = -2.12, p < .05.

Within Analyses

Ratings of Happiness. Ratings for happiness were analyzed in a 2 (octave) x 2 (direction) x 2 (tempo) repeated measures ANOVA. The 2 (direction) x 2 (tempo) interaction approached significance (F [1, 21] = 4.06, p < .06); and as shown in Table 2, ascending tones at the fast tempo (M = 0.7) were rated as happier than descending tones at the slow tempo (M = -0.81). The simple effects of tempo at both the descending (F [1, 21] = 158.40, p < .0001) and ascending directions (F [1, 21] = 148.18, p < .0001) were significant, indicating that tempo influenced ratings of happiness in both ascending and descending tones. In addition, the simple effects of direction at both the slow (F [1, 21] = 32.56, p < .0001) and fast levels of tempo (F [1, 21] = 20.77, p < .0001) were significant, indicating that direction influenced ratings of happiness at both slow and fast tempi. In addition, the octave main effect was significant, F (1, 21) = 94.89, p < .0001. High octave tones (M = 0.37) were rated as happier than low octave tones (M = -0.37).

Table 2

Z Score Ratings of Happiness for the 2 (Scale Direction) x 2 (Tempo) Interaction in Experiment 2

Scale Direction	Tempo[a]	
	Slow	Fast
Ascending	-0.17	0.70
Descending	-0.81	0.27

[a] In Experiment 2, the slow tempo was 60 bpm and the fast tempo was 120 bpm.

Ratings of Brightness. Ratings for brightness were analyzed in a 2 (octave) x 2 (direction) x 2 (tempo) repeated measures ANOVA. The 2 (direction) x 2 (tempo) interaction was significant, $F(1, 21) = 8.33, p < .01$; and as shown in Table 3, ascending tones at the fast tempo ($M = 0.57$) were rated as brighter than descending tones at the slow tempo ($M = -0.69$). The simple effects of tempo with descending ($F [1, 21] = 107.17, p < .0001$) and ascending ($F [1, 21] = 60.12, p < .0001$) tones were significant, and this indicated that tempo influenced ratings of brightness in both ascending and descending tones. Both simple effects of direction with slow ($F [1, 21] = 35.24, p < .0001$) and fast ($F (1, 21) = 15.71, p < .001$) tempi were also significant, indicating that direction influenced ratings of brightness at both slow and fast tempi. Furthermore, the 2 (octave) x 2 (tempo) interaction was significant ($F [1, 21] = 16.87, p < .001$); and as shown in Table 4, high octave tones at the fast tempo ($M = 0.80$) were rated as brighter than low octave tones at the slow tempo ($M = -1.0$). Additional analyses found that the simple effects of tempo at both low octave ($F [1, 21] = 147.41, p < .0001$) and high octave ($F [1, 21] = 33.66, p < .0001$) levels were significant, indicating that tempo influenced ratings of brightness in both high and low octave tones. Simple effects for octave at slow ($F [1, 21] = 111.77, p < .0001$) and fast ($F [1, 21] = 105.38, p < .001$] tempi were also significant. This indicates that octave influenced participants' ratings of brightness at both slow and fast tempi.

Table 3

Z Score Ratings of Brightness for the 2 (Scale Direction) x 2 (Tempo) Interaction in Experiment 2

Scale Direction	Tempo	
	Slow	Fast
Ascending	-0.12	0.57
Descending	-0.69	0.23

Ratings of Speed. Ratings for speed were analyzed in a 2 (octave) x 2 (direction) x 2 (tempo) repeated measures ANOVA. Tones at the fast tempo ($M = 0.75$) were rated as faster than tones at the slow tempo ($M = -0.76; F [1, 21] = 659.22, p < .0001$), and this is a useful confirmation that participants attended to the stimuli. In addition, the 2 (direction) x 2 (octave) interaction was significant ($F [1, 21] = 4.23, p = .05$), and as shown in Table 5, ascending high octave range tones ($M = 0.25$) were rated as faster than descending low octave range tones ($M = -0.33$). The simple effect of direction at the high octave level was not significant ($F [1, 21] = 2.08, p = .17$); however, the simple effect of direction at the low octave level was significant ($F [1, 21] = 22.70, p < .0001$). This indicates that the direction of the tones (ascending or descending) particularly influenced participants' ratings of speed at the low octave. In addition, simple effects of octave with descending ($F [1, 21] = 42.20, p < .0001$) and ascending tones ($F [1, 21] = 17.48, p < .0001$) were significant, indicating that octave influenced participants' ratings of speed in both ascending and descending tones.

Table 4

Z Score Ratings of Brightness for the 2 (Octave) x 2 (Tempo) Interaction in Experiment 2

Octave[a]	Tempo	
	Slow	Fast
High	0.20	0.80
Low	-1.00	0.01

[a] In Experiment 2, the low octave ranged from C4 to C5 (261.6, 293.7, 329.6, 349.3, 392, 440, 493.9, and 523.2 Hz), and the high octave ranged from C5 to C6 (523.2, 587.4, 659.2, 698.6, 784, 880, 987.8, and 1046.4 Hz).

Table 5

Z Score Ratings of Speed for the 2 (Octave) x 2 (Scale Direction) Interaction in Experiment 2

Octave	Scale Direction	
	Descending	Ascending
High	0.13	0.25
Low	-0.33	-0.05

Ratings of Tempo Change. Ratings for tempo change were analyzed in a 2 (octave) x 2 (direction) x 2 (tempo) repeated measures ANOVA. The 2 x 2 x 2 interaction was significant ($F [1, 21] = 7.99, p < .01$), and as shown in Table 6, ascending, high octave tones at the fast tempo ($M = 0.88$) were rated as speeding up more than descending, low octave tones at the slow tempo ($M = -0.84$). Further analyses found that simple effects of direction at low ($F [1, 21] = 35.42, p < .0001$) and high octaves ($F [1, 21] = 14.68, p < .001$) were significant, indicating that the direction of the tones influenced participants' ratings of tempo change for both low and high octaves. In addition, simple effects of tempo at both the low ($F [1, 21] = 92.38, p <$

Table 6

Z Score Ratings of Tempo Change for the 2 (Octave) x 2 (Scale Direction) x 2 (Tempo) Interaction in Experiment 2

Octave	Direction	Tempo	
		Slow	Fast
High	Ascending	-0.41	0.88
	Descending	-0.56	0.32
Low	Ascending	-0.27	0.66
	Descending	-0.84	0.21

.0001) and high (*F* [1, 21] = 110.28, *p* < .0001) octave were significant, indicating that tempo influenced ratings of tempo change at both low and high octaves. Furthermore, simple effects of tempo at the descending (*F* [1, 21] = 62.34, *p* < .0001) and ascending (*F* [1, 21] = 140.88, *p* < .0001) levels were significant, and indicated that tempo influenced ratings of tempo change in both the ascending and descending conditions. Lastly, the simple effects of direction with slow tempo tones (*F* [1, 21] = 10.34, *p* < .004) and fast tempo tones (*F* [1, 21] = 58.48, *p* < .0001) were significant, indicating that direction of the tones influenced ratings of tempo change for both the slow and fast tempo tones.

Discussion

The results of Experiment 2 were generally consistent with the results of Experiment 1 and with previous research. Tones at the high octave were rated as happier than were tones at the low octave, and ascending tones at the fast tempo were rated as happier than were descending tones at the slow tempo (see Table 2). This finding suggests that direction and tempo interacted in ratings of happiness. Ascending tones at the fast tempo were also rated as brighter than were descending tones at the slow tempo (see Table 3), and high octave tones at the fast tempo were rated as brighter than were the low octave tones at the slow tempo (see Table 4). In addition, ascending, high octave tones were rated as faster than were descending, low octave tones (see Table 5). It may be that participants rated the ascending, high octave tones as being happy and bright because they perceived them as being faster than tones at the descending, low octave. Ascending, high octave tones at the fast tempo were also rated as speeding up more than were descending, low octave tones at the slow tempo (see Table 6). As in Experiment 1, if participants rated higher, faster tones as speeding up more than the lower, slower tones, then this may contribute to participants rating the higher, faster tones as being more happy and bright. As in Experiment 1, Experiment 2 also found no consistent overall pattern in the median split analyses between the high and low pleasantness groups, high and low arousal groups, or high and low musical experience groups.

General Discussion

In Experiment 1, tones at faster tempi and tones at higher frequencies were rated as happier, brighter, faster and as speeding up, whereas tones at slower tempi or lower frequencies were rated as sadder, darker, slower and as slowing down; these patterns are consistent with previous findings by Hevner (1937), Rigg (1940), Trehub et al. (1987), and Marks (1974). In Experiment 2, ascending tones, higher octave tones, and tones at the fast tempo were rated as happier, brighter, faster and as speeding up, whereas descending tones, lower octave tones, and tones at the slow tempo were rated as sadder, darker, slower and as slowing down; these patterns are consistent with previous findings by Collier and Hubbard (2001), Trehub et al. (1987), and Hubbard (1996). In addition to these main effects, there were a number of interactions (e.g., in Experiment 1, frequency and tempo interacted to influence ratings of speed; in Experiment 2, direction interacted with octave and with tempo on ratings of happiness, brightness, speed and tempo change). The presence of both main effects and interactions indicates some characteristics of music may combine in different ways to produce different perceptions or judgments of music. Such findings are quite relevant to research using orchestral or other musical excerpts; indeed, the findings of several interactions influencing ratings of happiness, brightness and speed indicate that it is important for future investigations to examine how the characteristics of different dimensions of music may combine to influence the perceptions of listeners.

Tempo interacted with frequency (in Experiment 1) and direction interacted with octave (in Experiment 2) in ratings of speed. In Experiment 1, higher frequency, fast tempo tones were rated as being faster than lower frequency, slow tempo tones (see Table 1). In Experiment 2, high octave, ascending tone sequences were rated as being faster than low octave, descending tone sequences (see Table 5). Also in Experiment 2, high octave, ascending, fast tempo tones were rated as speeding up, and low octave, descending, slow tempo tone sequences were rated as slowing down (see Table 6). The ratings of speed and tempo change might be explained by analogy with the speed and velocity change of ascending and descending physical objects: When a physical object is ascending and at a greater height, observers would typically expect that object to decelerate and subsequently fall back to Earth; similarly, when an object is falling, that object accelerates until it reaches the Earth (or attains its terminal velocity). It may be that participants have implicit expectations that ascending objects will gradually decelerate and that descending objects will gradually accelerate (see Hubbard, 2001). Given that tones in Experiment 2 ascended or descended at a constant velocity (constant tempo), that constant velocity would have been faster than expected for ascending sequences and slower than expected for descending sequences, thus ascending sequences were perceived as faster and speeding up, and descending sequences were perceived as slower and slowing down^2.

Consistent differences across Experiments 1 and 2 were not found for the median splits on initial pleasure or arousal levels. It should be noted, however, that Experiments 1 and 2 measured affect only at the beginning of each experiment. It is possible that the experimental stimuli influenced participants' affect as the experiment continued, and so future research should consider also assessing participants' affect after stimuli have been presented. The only significant differences in the median split data that were consistent across Experiments 1 and 2 involve ratings of speed and tempo change by high and low musical experience groups. In Experiment 1, participants with high musical experience rated tones in the high frequency, slow tempo condition as slower than did participants with low musical experience, and tones in the low frequency, fast tempo condition as faster than did participants with low musical experience. In Experiment 2, participants with high musical experience rated tones in the ascending, high octave, slow tempo condition as slower than did participants with low musical experience, and tones in the descending, low octave, fast tempo condition as faster than did participants with low musical experience. In Experiment 1, participants in the high musical experience group rated tones in the high frequency, fast tempo condition as speeding up more than did participants in the low musical experience group. In Experiment 2, participants in the high musical experience group rated tones in the descending, high octave, fast tempo condition as speeding up more than did participants in the low musical experience group.

One possible explanation for the effects of musical experience on the ratings of speed and tempo change is that participants with more musical experience overestimated the speed of the tones, or alternatively, participants with less musical experience underestimated the speed of the tones. It may be that participants with more musical experience are better able to anticipate the subsequent note of the ascending and descending scales, and this anticipation may lead to harmonic priming that would facilitate the processing of each subsequent note (cf. Bharucha, 1987). If the perceived speed of the sequence is influenced by the amount of time required to process each note, then perhaps the priming that would result from increased musical experience would result in an estimated faster speed of the stimuli. A different but equally cognitive account might suggest that lower frequencies are typically associated with solemn or sad affect, and that solemn and sad events usually involve slower motion. Participants with more musical experience might be more aware of these types of associations, or perhaps have stronger associations, and so greater experience with Western music may lead to a processing of tones that is more easily or deeply penetrated by such semantic associations. Such semantic effects would also be consistent with the lack of any effect of musical experience on judgments of happiness or brightness.

The results of the current experiments replicate and extend the findings of previous studies on the relationship of music and affect. By using precisely controlled examples of pitch and scale, confounds in previous research that used orchestral excerpts were avoided. By using a consistent measure of affect based on the emerging consensus regarding the dimensions underlying emotional experience (e.g., the affect grid), the confusion regarding which aspect of emotion seemed most related to musical stimuli was avoided; furthermore, the happy-sad dimension was found to have possible interactions with qualities such as brightness in ways not previously demonstrated. By obtaining ratings of brightness, speed, and tempo change, as well as ratings of happiness, some potential connections between music, affect, and other perceptual dimensions were uncovered. Encouragingly, many of the properties suggested by previous research using orchestral excerpts were found in these controlled current studies, and this should diminish fears that study of the psychology of music cannot be carried out using controlled laboratory methods. However, the interaction of some factors (e.g., frequency and tempo) in some types of judgments highlights the need for precise experimental control. Even more encouragingly, aspects of music were found to relate to aspects of affect and qualities such as brightness and tempo change in both expected and unexpected ways. This promises to be an area for fruitful further investigation.

References

Barrett, L. F., & Russell, J. A. (1999). The structure of current affect: Controversies and emerging consensus. *Current Directions in Psychological Science, 8,* 10-14.

Bharucha, J. J. (1987). Music cognition and perceptual facilitation: A connectionist framework. *Music Perception, 5,* 1-30.

Collier, W. G., & Hubbard, T. L. (2001). Musical scales and happiness/awkwardness evaluations: Effects of pitch, direction, and scale mode. *American Journal of Psychology, 114,* 355-375.

Crowder, R. G. (1984). Perception of the major/minor distinction: I. Historical and theoretical foundations. *Psychomusicology, 4,* 3-12.

Gerardi, G. M., & Gerken, L. (1995). The development of affective responses to modality and melodic contour. *Music Perception, 12,* 279-290.

Hevner, K. (1937). The affective value of pitch and tempo in music. *American Journal of Psychology, 49,* 621-630.

Hubbard, T. L. (2001). The effect of height in the picture plane on the forward displacement of ascending and descending targets. *Canadian Journal of Experimental Psychology, 55,* 325-329.

Hubbard, T. L. (1996). Synesthesia-like mapping of lightness, pitch, and melodic interval. *American Journal of Psychology, 109,* 219-238.

Lehman, R. S. (1972). A multivariate model of synesthesia. *Multivariate Behavioral Research, 7,* 403-439.

Marks, L. E. (1974). On association of light and sound: The mediation of brightness, pitch, and loudness. *American Journal of Psychology, 87,* 173-188.

Marks, L. E. (1982). Bright sneezes and dark coughs, loud sunlight and soft moonlight. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 177-193.

McMullen, P. T. (1996). The musical experience and affective/aesthetic responses: A theoretical framework for empirical research. In D. A. Hodges (Ed.) *Handbook of music psychology.* San Antonio, TX: IMR Press.

Melara, R. D. (1989). Similarity relations among synesthetic stimuli and their attributes. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 212-231.

Odbert, H. S., Karwoski, T. F., & Eckerson, A. B. (1942). Studies in synesthetic thinking: I. Musical and verbal associations of color and mood. *The Journal of General Psychology, 26,* 153-173.

Pierce, J. (1999). Sound waves and sine waves. In P. R. Cook (Ed.) *Music, cognition, and computerized sound: An introduction to psychoacoustics.* Cambridge, MA: The MIT Press.

Radocy, R. E., & Boyle, J. D. (1997). *Psychological foundations of musical behavior* (3rd ed.). Springfield, IL: Charles C. Thomas.

Rigg, M. G. (1940). Speed as a determiner of musical mood. *Journal of Experimental Psychology, 27,* 566-571.

Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57,* 493-502.

Sloboda, J. A. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music, 19,* 110-120.

Sloboda, J. A. (1992). Empirical studies of emotional response to music. In M. R. Jones & S. Holleran (Eds.) *Cognitive bases of musical communication.* Washington, DC: American Psychological Association.

Trehub, S. E. (1993). The music listening skills of infants and young children. In T. J. Tighe & W. J. Dowling (Eds.) *Psychology and music: The understanding of melody and rhythm.* Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Trehub, S. E., Cohen, A. J., & Guerriero, L. (1987, April). Children's understanding of the emotional meaning of music. Paper presented at the meeting of the Society for Research in Child Development, Baltimore.

Watson, K. B. (1942). The nature and measurement of musical meanings. *Psychological Monographs, 54,* 1-43.

Wedin, L. (1972). A multidimensional study of perceptual-emotional qualities in music. *Scandinavian Journal of Psychology, 13,* 241-257.

Author Notes

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Footnotes

[1] There may be objections that sine waves are not appropriately "musical." However, both sine waves and the sounds produced by conventional musical instruments are consistent with linearity, and a sine wave can be regarded as an approximation to the perceived fundamental frequency of a particular musical note (for discussion, see Pierce, 1999). Thus, the use of sine wave stimuli provides a starting point for a focus on pitch per se, and an investigation of the relationship of timbre and affect is left for future research.

[2] It might be argued that the perception of speed and of tempo change reflect the frequency spacing of the individual notes. By using equal-tempered tuning, the frequency difference was much greater between adjacent higher pitches than between adjacent lower pitches, and it might be suggested that perhaps having to move across a larger frequency distance in an equivalent amount of time could be perceived as a faster frequency velocity. However, equal-tempered spacing would have insured perceived frequency differences between adjacent tones were equal in magnitude regardless of the pitch height, and so the pitch distance between adjacent notes should have been equal. Equal pitch distances would not have contributed to differences in perceived pitch velocity, and so an explanation based on the tuning of stimulus notes is highly unlikely.