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Experiential and Cognitive Changes Following Seven Minutes Exposure to Music and Speech

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In two experiments, we assessed the experiential and cognitive consequences of seven minutes exposure to music (Experiment 1) and speech (Experiment 2). In Experiment 1, participants listened to music for seven minutes and reported their emotional experiences based on ratings of valence (pleasant-unpleasant) and two types of arousal: energy (energetic-boring) and tension (tense-calm). They were then assessed on two cognitive skills: speed of processing and creativity. Music varied in pitch height (high or low pitched), rate (fast or slow), and intensity (loud or soft). Experiment 2 replicated Experiment 1 using male and female speech. Experiential and cognitive consequences of stimulus manipulations were overlapping in the two experiments, suggesting that music and speech draw on a common emotional code. There were also divergent effects, however, implicating domain-specific influences on emotion induction. We discuss the results in view of a psychological framework for understanding auditory signals of emotion.

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Music and speech are both acoustic signals that can communicate emotional meaning and induce emotional states. As such, they may share a common code for expressing emotion. Among the attributes that contribute to this code, rate, pitch height, and intensity are likely candidates because they are associated with emotional communication in both domains (Frick, 1985; Gabrielsson & Lindström, 2001; Ilie & Thompson, 2006; Johnstone & Scherer, 2000; Planalp, 1998; Scherer 1986, 2003). In this investigation, we manipulated these attributes in seven-minute excerpts of music (Experiment 1) and speech (Experiment 2). We observed the effects of our manipulations on two well-documented outcomes of emotion induction: emotional *feelings* or experience, and *cognitive* changes.

Juslin and Laukka's (2003) common-coding hypothesis suggests that the same cues for communicating emotion are used in music and speech prosody (tone of voice). In a direct evaluation of this idea, Ilie and Thompson (2006) examined the perceptual effects of manipulating the rate, pitch height, and intensity of brief excerpts of music and speech. Manipulations had overlapping effects on emotion perception in the two domains. In this investigation, we examined whether this overlap between music and speech extends to emotional *experience*. We assessed this possibility by exposing participants to music or speech for seven minutes. This long exposure length ensured full and authentic induction of emotion.

Although other studies have addressed the issue of "felt" emotion in response to music, most have involved brief excerpts or no exposure to auditory stimuli (Blood, Zatorre, Bermudez, & Evans, 1999; Juslin & Västfjäll, 2008; Khalfa, Isabella, Jean-Pierre, & Manon, 2002; Kreutz, Ott, Teichmann, Osawa, & Vaitl, 2008; Krumhansl, 1997; Schubert, 2007). For example, Zentner, Grandjean, and Scherer (2008) examined felt emotion in response to music. Studies 1 and 2 used free recall of prior experiences, Study 3 administered questionnaires to participants at a music festival, and Study 4 had participants complete questionnaires after they listened to two-minute music excerpts at home or in the laboratory. Such procedures shed light on how individuals conceptualize felt emotions in response to music, but there is no guarantee that retrospective judgments accurately reflect the emotional states that arise after exposure to music in the real-world or under experimentally controlled conditions. As such, there is a need for research that involves reliable procedures for inducing emotional states.

Such procedures have been described in a large body of research concerned with "mood induction." In a typical mood-induction procedure, participants are exposed to music (or other emotional stimuli) for several minutes in order to reliably alter mood and arousal levels. A prolonged exposure time is used because brief clips of

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music, though potentially interpretable as carrying an emotional message, lack the capacity to generate an actual change in affective states (Balch & Lewis, 1996; Blaney, 1986; Carmichael & Hairston Atchinson, 1997; Durand & Mapstone, 1998; Gerrards-Hesse, Spies, & Hesse, 1994; Martin & Metha, 1997; Nava, Landau, Brody, Linder, & Schächinger, 2004; Niedenthal & Setterlund, 1994; Philippot, 1993).

Several definitions of emotion exist in the literature. Schimmack and Grob (2000) operationalized the concept of emotion using three core elements: valence (pleasant-unpleasant), energy arousal (awake-tired), and tension arousal (tense-relaxed). This operationalization, which we also adopt, combines Thayer's (1978a, 1978b) multidimensional model of affect with Russell's (1980) circumplex model of affect (valence and arousal). In Thayer's model, affect involves two factors: energetic arousal (energy versus boredom) and tension arousal (tension versus calm). In the circumplex model, affective states are described as points in a two-dimensional space composed of arousal (low or high) and valence (unpleasant or pleasant). For example, happiness is described as a feeling of excitement (high arousal) combined with positive affect (positive valence). With only one dimension of arousal, however, the circumplex model cannot easily differentiate states such as sadness and fear, which often are comparable in valence and energy but differ in the degree of tension experienced. More generally, distinguishing between energy arousal and tension arousal reflects evidence that these dimensions are judged differently (Ilie & Thompson, 2006) and are associated with distinct neural systems (Gold, MacLeod, Deary, & Frier, 1995; Schimmack, 1999; Schimmack & Grob, 2000; Schimmack & Reisenzein, 2002; Tucker & Williamson, 1984).

Researchers have emphasized the need to distinguish between *perceived* and *felt* emotion (Gabrielsson, 2002; Schubert, 2007; Zentner et al., 2008). Gabrielsson reviewed a range of studies on the perception and induction of emotion with music and concluded that perceived and felt emotion need not be aligned with one another. Schubert (2007) defined the differences that may occur between perceived and felt emotion as the "gap across emotion loci" or GAEL, and argued that such gaps are relevant to musical preferences. Specifically, as GAEL increases, preference for music often decreases, presumably because listeners value the alignment of emotional intentions and experience. Zentner et al. (2008) found that emotional responses to different genres of music differed between perceived and felt emotion. Among the emotional labels used in their investigation (e.g., affectionate, melancholic, calm, joyful, sensual), negative ones were most often associated with perceived but not felt emotions. In contrast, labels such as "tender longing" and "amazement" were associated with both perceived and felt emotions.

The current investigation offers another opportunity to examine the relation between perceived and felt emotion. Ilie and Thompson (2006) compared emotion perception in music and speech, whereas the current investigation compared emotional *experience* in these domains. By comparing the two investigations, it was possible to elucidate the relation between *perceived* and *felt* emotion.

Our hypothesis is that acoustic attributes are connected to emotional experience in the same way in music and speech. We tested this hypothesis in two ways. First, we assessed the *feeling* or *experiential* quality of emotion after participants were exposed to music or speech that varied in rate, pitch height, and intensity. Second, we examined cognitive changes that are known to be correlated with affective states: changes in speed of processing, and changes in creative problem solving. We selected these cognitive changes for consideration based on two lines of evidence.

First, for the past 30 years, a body of evidence by Isen and colleagues indicates that positive mood enables individuals to think more creatively and perform better on creative problem solving tasks (Isen, 2000; Isen, 1984; Isen & Christianson, 1999; Isen, Daubman, & Nowicki, 1987; Isen & Means, 1983). Performance on categorization, complex decision making, creative problem solving, and heuristics tasks is better following manipulations that induce a positive mood (e.g., receiving a chocolate bar, playing a happy tune) compared to manipulations that represent a neutral mood (Isen & Daubman, 1984; Isen, Niedenthal, & Cantor, 1992; Kahn & Isen, 1993). On the other hand, sad moods have been found to decrease creative performance (O'Hanlon, 1981).

Second, changes in arousal influence reaction times during routine tasks. One of the most well-known and influential models to depict the influence of arousal on cognitive performance was that of Yerkes and Dodson (1908). According to their model, performance is poor following low or high levels of arousal, and optimal at intermediate levels. A large body of literature supports this view (Berlyne, 1967; Doerr & Hokansn, 1965; Fiske & Maddi, 1961; Sarason, 1980; Solomon & Corbit, 1974). In a 1972 review, Duffy found that the monotonic association between arousal and reaction time on routine tasks was, however, more robust than the curvilinear relationship Yerkes and Dodson (1908) proposed. This seeming contradiction could be the result of several factors, including attention contributions and the inability to induce high levels of arousal in the laboratory (Duffy, 1972).

Regardless, it is clear that changes in optimal levels of arousal are facilitative of shorter reaction times on routine task performance. Based on these previous findings, increased arousal induced by music or speech should facilitate performance on speed of processing tasks but not on creativity tasks; conversely, positive states induced by music or speech should facilitate performance on creativity tasks but not on speed of processing tasks (Duffy, 1972; Isen et al., 1987).

We predicted that manipulations of rate, pitch height, and intensity would have both experiential and cognitive consequences. Experiential effects should be observed for all three dimensions of emotion: valence, energetic arousal, and tension arousal. Based on evidence suggesting links between positive valence and creativity (Isen et al., 1987) and between arousal and routine task performance (Duffy, 1972), cognitive effects should be observed on measures of speed of processing and creativity. The nature of this causal chain—from *stimulus manipulation* to *affective experience* to *cognitive change*—was explored by mediation analyses. We predicted that there would be reliable effects of our stimulus manipulations on cognitive measures, but that these effects would be dependent on changes in affective states. Because no previous studies have directly compared the effects of such manipulations for music and speech, we were unsure whether similar effects would be observed in the two domains.

Experiment 1

Method

PARTICIPANTS

Sixty-four University of Toronto at Mississauga undergraduate students (36 females and 28 males), ranging in age from 17 to 32 years, participated in the study. Students were recruited from introductory psychology classes and received partial course credit for their participation. They had an average of 2.73 years of formal music lessons (SD = 3.14 years; range = 0 to 13 years). None of the participants showed evidence of clinical depression based on an initial administration of the Beck Depression Inventory, short form (Beck & Beck, 1972).

MATERIALS

The stimuli consisted of a musical piece by Mozart—Serenade In D Major, K. 320 'Posthorn': III. Concertante: Andante grazioso (7:18). Brief excerpts of these stimuli were used in Ilie and Thompson (2006). The musical piece was taken from Mozart: "Posthorn" Serenade; Marches K. 335 Nos. 1 & 2; Divertimento K. 251 "Nannerl Septet" (1993; SONY release) CD recording and was edited using *Pro Tools software* (version 5.0.1). The average amplitude of the music was 86 dB (SD = 5.29 dB) based on audiometric measurements taken at the headphones, and the average pitch was 178 Hz (SD = 72 Hz) as determined by Praat (Boersma & Weenink, 2004). The rate of the music was 120 bpm as determined by ProTools' *Identify Beat* command. Using ProTools (Digidesign, version 5.0.1), eight versions of the musical excerpt were created by manipulating intensity (loud = 80% normalization, average dB value for loud excerpt: 82 linear dB SPL, soft = 5% normalization, mean dB value for soft excerpt: 60.30 linear dB SPL), rate (fast and slow versions were 1.12 and 0.89 times the rate of the original samples respectively, or 134.4 bpm and 106.9 bpm), and pitch height (high = two semitones up, 193.2 Hz mean pitch for high-pitch excerpts; low = two semitones down, 156.6 Hz mean pitch for low-pitch excerpts). The manipulations yielded eight presentations (2 pitches × 2 tempi × 2 intensities).

Rate manipulations were based on pitch manipulations. That is, we used manipulations of rate that would result in pitch shifts of two semitones higher or lower than the original recordings if accomplished by analogue manipulation (as in speeding up or slowing down a tape recorder). Ilie and Thompson (2006) also conducted pilot testing to ensure that excerpts of the music stimuli sounded natural given that uniform manipulations of rate, pitch height, and intensity may not occur in normal music. Participants assessed whether the manipulated excerpts could be encountered under daily listening contexts and were representative of music samples one might encounter in every day music experiences. That analysis revealed no significant reduction in the degree to which manipulated excerpts sounded natural and intelligible.

DEPENDENT MEASURES

Experiential measures. Emotional experience was measured using subjective ratings for each pole of the three-dimensional model of emotion: valence (pleasant and unpleasant), energy arousal (energetic and boring), and tension arousal (tense and calm), resulting in 6 unipolar scores for each participant. Subjective ratings were used instead of physiological measures because they are simple to administer and yield reliable data (Dermer & Berscheid, 1972; McNair, Lorr, & Droppleman, 1992; Schimmack & Grob, 2000; Schimmack & Reisenzein, 2002), whereas physiological measures cannot differentiate effects on valence and arousal and tend to yield highly variable data (Krumhansl, 1997; Thayer, 1970).

The three-dimensional model of affect assumes approximate bipolarity of valence, energy arousal, and tension arousal (Schimmack & Grob, 2000; Schimmack & Reisenzein, 2002). However, to allow for the possibility that opposing qualities for each dimension of emotion are independent of each other (e.g., a stimulus might be experienced as both energetic and boring), the response format was a unipolar intensity scale ("0" = "not at all" to "4" = "extremely"). For example, a rating of "0" on the pleasant scale indicated that the participant was not feeling any pleasantness at the time of testing, and a rating of "4" indicated that the participant was feeling extremely pleasant.

Preliminary analyses, corroborated by analyses reported by Ilie and Thompson (2006), indicated that the six rating scales could be reduced to three bipolar scales. To obtain bipolar indicators of each dimension, ratings on the lower pole items were subtracted from ratings on the higher pole items and transposed to a scale from 1–9, with ratings of 5 indicating equivalent ratings on the lower and higher pole, and ratings above or below 5 indicating greater weighting on the high or low poles respectively. For example, a rating of 3 on pleasantness and a rating of 2 on unpleasantness gave a score of 6 (3–2+5).

Speed of processing. Speed of processing was measured by two "routine" tasks adapted from Isen, Berg, and Chen (1993). At the outset of each task, a one-page document (8" x 11") was displayed in the center of the computer screen. The page consisted of 408 Wingdings geometric characters (17 columns x 24 rows). As soon as the page appeared, participants were required to point and click with a computer mouse on a specific type of character as quickly as possible (a teardrop in task 1 or an arrowhead in task 2). The target character appeared 58 times on the page, and participants had to click on all 58 targets in order to complete the task. Any target character that was successfully clicked was emboldened. Participants were informed that once all 58 targets had been identified a new screen with the message "Thank you for participating" would be displayed, signaling completion of the task. Success on the task was measured by the time taken to complete the task.

Creativity. Creativity was assessed using two tasks: Dunker's (1945) candle problem and Maier's (1931) two-string problem. Creativity was measured according to the proportion of individuals who successfully identified the solution to the assigned problem. Dunker's (1945) candle task has high internal validity (.95), high reliability (.81), and has been used extensively as a measure of creativity (Isen, 2000; Vosburg, 1998). In this task, the participant is given a candle, a box of tacks, and a book of matches, and is asked to attach the candle to the wall in such a way that it will burn without dripping wax on the floor. To solve the problem, the person can empty the box of tacks, tack the box to the wall, and use the box as a platform for the candle. Thus, the person must use one of the items (the box) in an unconventional way—a classic criterion of creativity (Dunker, 1945; Koestler, 1964; Weirtheimer, 1959). A number of studies have shown that participants experiencing positive affect perform better than controls on this task (Isen, 1984, 1987, 2000, 2002; Isen et al., 1987; Isen, Johnson, Mertz, & Robinson, 1985; Isen & Means, 1983; Isen et al., 1992; Kahn & Isen, 1993; Murray, Sujan, Hirt, & Sujan, 1990).

In Maier's (1931) two-string problem, the participant is required to tie together two strings that are hanging from the ceiling. Neither string is long enough for the participant to hold onto while stretching to grasp the other one. A chair and a pair of scissors are available. To solve the problem the participant must tie the scissors to one string and use it as a pendulum to grab the second string while holding on to the first string. Thus, in order to solve the problem the participant must use the scissors in an unconventional way. Like Dunker's candle task, Maier's two-string task is considered reliable and valid (Adamson & Taylor, 1954; Battersby, Teuber, & Bender, 1953; Birch & Rabinowitz, 1951; Cofer, 1951; Gick & Holyoak, 1980; Judson, Cofer, & GeHand, 1956).

Procedure. The experiment was created and administered using *Experiment Creator*, a software application that is available from the second author's website. Eight participants were assigned to each of 8 conditions (2 pitch height × 2 rate × 2 intensity). They were randomly assigned to one of the two exemplars of each cognitive task (Maier's two strings or Dunker's candle task for the creativity task; and identifying teardrops or arrowheads for the speed of processing task). They were seated in a sound-attenuated booth, given a demonstration of the task, and asked whether they were familiar with the tasks or music. Familiarity with the tasks was assessed at the end of the experiment when participants were asked to rate their familiarity with the music and each of the two cognitive tasks on a scale rating from "0" ("I was not familiar with it prior to this experiment") to "5" ("I was very familiar with it prior to this experiment"). No familiarity with the tasks or music was indicated.

Excerpts were presented through Sennheiser HD headphones. After listening to music for seven minutes, participants rated their emotional experience using the full range of the six unipolar emotion rating scales. They then completed the cognitive tasks: the speed of processing task was completed on computer and the creativity task was completed in an adjacent room. Order of presentation was counterbalanced. Participants then completed a demographics questionnaire and were debriefed.

Results and Discussion

EXPERIENTIAL EFFECTS

The six unipolar scales were first converted to three bipolar scales, as described above, and subjected to

TABLE 1. Mean Ratings of Experienced Valence, Energy Arousal, and Tension Arousal After Seven Minutes Exposure to Music.

Pitch	Rate	Intensity	Valence	Energy	Tension
High	Fast	Loud	5.00	4.88	3.88
			2.00	*1.89*	*1.96*
		Soft	6.13	4.25	1.38
			1.36	*2.05*	*1.60*
	Slow	Loud	5.13	4.38	3.13
			2.03	*2.20*	*2.48*
		Soft	7.13	2.87	2.38
			0.99	*1.96*	*1.30*
Low	Fast	Loud	5.25	4.75	5.25
			2.38	*1.98*	*2.71*
		Soft	4.38	5.25	3.00
			2.39	*1.91*	*2.51*
	Slow	Loud	5.25	4.13	2.13
			1.83	*2.17*	*2.23*
		Soft	4.63	3.75	1.63
			1.69	*0.89*	*1.51*

TABLE 2. ANOVA for Ratings of Valence, Energy Arousal, and Tension Arousal After Seven Minutes Exposure to Music.

Source	*df*s	*F*	partial η^2	*p*
Between-subjects		Valence Ratings		
Pitch Height	1, 56	4.22	.07	< .05
Pitch Height × Intensity	1, 56	6.01	.10	< .05
		Energy Arousal		
Rate	1, 56	4.34	.07	< .05
		Tension Arousal		
Rate	1, 56	4.12	.07	< .05
Intensity	1, 56	8.20	.13	< .05
Pitch × Rate	1, 56	5.14	.08	< .05

analysis. Table 1 displays the means and standard deviations following exposure to music for each bipolar rating scale: valence, energy, and tension. Table 2 displays the between-subjects results of the ANOVA for valence, energy arousal, and tension arousal ratings. Analyses confirmed that manipulations of stimulus properties led to reliable changes in emotional experience.

Valence. For valence ratings, there was a main effect of Pitch Height and a significant interaction for Pitch Height and Intensity, $p < .05$ (for F and df values, see Table 2). Mean ratings of felt valence after exposure to high-pitch music ($M = 5.84$, $SD = 1.80$) were significantly higher than mean ratings of felt valence after exposure to low-pitch music ($M = 4.88$, $SD = 2.03$). Follow-up analyses for the two levels of pitch at each level of intensity (Bonferroni's correction) revealed a main effect of Pitch Height for soft, $F(1, 56) = 10.15$, $p < .01$, but not loud music, *n.s.* Listeners in the soft music condition reported feeling more pleasant (high valence) after high-pitch music ($M = 6.63$, $SD = 1.26$) than after low-pitch music ($M = 4.50$, $SD = 2.00$). In the loud condition, valence ratings were no different after high-pitch music ($M = 5.06$, $SD = 1.95$) or low-pitch music ($M = 5.25$, $SD = 2.05$). There were no other significant differences.

Energy arousal. For energy arousal there was a main effect of Rate, $p < .05$. Ratings of energy were higher after fast music ($M = 4.78$, $SD = 1.90$) than after slow music ($M = 3.78$, $SD = 1.88$). No other effects were significant.

Tension arousal. For tension arousal, there was a main effect of Rate, $p < .05$, with higher ratings of tension after fast music ($M = 3.38$, $SD = 2.56$) than after slow music ($M = 2.31$, $SD = 1.93$). There was also a main effect of Intensity, $p < .05$, with higher ratings of tension after loud music ($M = 3.60$, $SD = 2.53$) than after soft music ($M = 2.09$, $SD = 1.82$). There was also a significant interaction between Pitch Height and Rate, $p < .05$. Follow-up analyses for the two levels of rate at each level of pitch (Bonferroni's correction) revealed a main effect of rate for low-pitch music, $F(1, 56) = 9.23$, $p < .01$, but not high-pitch music, *n.s.* For low-pitch music, the experience of tension was greater following fast music ($M = 4.13$, $SD = 2.78$) than following slow music ($M = 1.88$, $SD = 1.88$). For high-pitch music, the experience of tension was not affected by the rate of the music, whether fast ($M = 2.63$, $SD = 2.16$) or slow ($M = 2.75$, $SD = 1.95$). No other effects were significant.

COGNITIVE EFFECTS

Order of presentation had no effect on the dependent variables and was dropped from further analyses. Table 3 displays mean scores on the speed of processing and creativity tasks following manipulations of Rate, Pitch Height, and Intensity. Table 4 displays the between-subjects results of the ANOVA for the speed of processing and creativity tasks. As predicted, stimulus manipulations reliably affected performance on cognitive tasks.

Speed of processing. We conducted a between-subjects ANOVA with speed of processing as the dependent variable and Intensity (loud or soft), Rate (fast or slow), Pitch Height (high or low) and a dummy variable representing the two types of tasks as independent variables.[1] Results revealed a main effect of Rate, $p < .05$, and a significant interaction between Pitch Height and Rate, $p < .01$. The mean completion time was longer (slower speed of processing) after exposure to slow

[1]For speed of processing, one case was identified as a univariate outlier (371 s) in the high-pitch, fast rate, loud condition $z = +3.22$ ($p < .001$, two tailed test) and was replaced with the value of the mean for the high-pitch, fast rate (collapsed over loudness) group (199.46).

TABLE 3. Mean Scores on Speed of Processing (Seconds to Complete) and Creativity Tasks (Proportion Correct) after Seven Minutes Exposure to Music.

Pitch	Rate	Intensity	Speed of processing	Creativity
High	Fast	Loud	199.13	.63
			20.74	*.52*
		Soft	191.50	.63
			29.95	*.52*
	Slow	Loud	167.13	.75
			52.31	*.46*
		Soft	218.63	.88
			56.33	*.35*
Low	Fast	Loud	165.38	.63
			29.99	*.52*
		Soft	187.63	.38
			37.36	*.52*
	Slow	Loud	232.13	.50
			48.63	*.53*
		Soft	233.88	.25
			43.44	*.46*

TABLE 4. ANOVA for Speed of Processing and Creativity.

Source	*df*s	*F*	partial η^2	*p*
Between-subjects		Speed of processing		
Rate	1, 56	6.78	.11	< .05
Pitch Height × Rate	1, 56	8.07	.13	< .01
		Creativity		
Pitch Height	1, 56	5.30	.09	< .05

music ($M = 212.94$, $SD = 55.25$) than after exposure to fast music ($M = 195.32$, SD $= 25.20$). Follow-up analyses for the two levels of rate at each level of pitch (Bonferroni's correction) revealed a main effect of rate for low-pitch music, $F(1, 30) = 16.02$, $p < .001$, partial $\eta^2 = .35$, but not high-pitch music, *n.s.* For low-pitch music, completion times were shorter (faster speed of processing) after fast music ($M = 176.50$, $SD = 34.69$) than after slow music ($M = 233.00$, $SD = 44.55$). For high-pitch music, completion times were not affected by rate, whether fast ($M = 195.34$, $SD = 25.20$) or slow ($M = 192.88$, $SD = 58.86$). Task type did not have a significant effect on the dependent variable and was therefore dropped from further analyses.

We next examined the possibility that experiential effects mediated the above cognitive effects, using the steps outlined by Baron and Kenny (1986). However, although the results above satisfy steps 1 (relationship between independent and outcome variables) and 2 (relationship between independent and mediator variables) of a mediation analysis (Tables 2 & 4), the remaining conditions required to demonstrate mediation were not met (i.e., steps 3 and 4). A correlation analysis revealed no reliable relationships between speed or processing and valence, $r(62) = .09$, $p > .05$, energy arousal, $r(62) = -.19$, $p > .05$, or tension arousal, $r(62) = -.13$, $p > .05$. Moreover, we were unable to demonstrate that the proposed mediators (valence, energy, and tension) affect the outcome variable (speed of processing) when the independent variables are statistically controlled. Thus, either our manipulations directly affected speed of processing, or our experiment lacked sufficient power to demonstrate mediation, or another variable that was unmonitored in our investigation mediated the effect.

Creativity. Preliminary analyses revealed no effects or interactions related to the two different types of creativity tasks used. Therefore, this variable was dropped from further analyses. Although creativity scores are dichotomous, the data meet criteria for conducting ANOVA (see Lunney, 1970). ANOVA with Creativity scores as the dependent variable (proportion correct) and Intensity (loud or soft), Rate (fast or slow), and Pitch Height (high or low) as independent variables revealed a main effect of Pitch Height, $p < .05$. Participants who listened to high-pitch music were more successful at solving creativity tasks ($M = 0.72$, $SD = 0.46$) than participants who listened to low-pitch music ($M = 0.44$, $SD = 0.50$). There were no other significant effects.

We next assessed the possibility that experiential effects mediated the relationship between pitch height and creativity. The above results satisfy Step 1 of mediation analysis as outlined by Baron and Kenny (1986): a significant relationship exists between pitch height and creativity (Table 4). The effects reported in the previous section satisfy Step 2 of mediation analysis: significant relationships were observed between the stimulus manipulations and the experiential variables (Table 2). Because creativity scores were categorical (0 or 1), steps 3 and 4 were evaluated through hierarchical logistic regression analysis, for which all assumptions were found to be tenable. A test of the full model with the three affective measures and pitch height, rate, and intensity against a constant-only model was statistically reliable, $\chi^2(6, N = 64) = 14.66$, $p < .05$, indicating that the six predictors, as a set, reliably distinguished between success and failure to solve the creativity tasks. The variance accounted for is moderate, with Nagelkerker $R^2 = .28$. Prediction of successfully completing the creativity task (76%) was better than the prediction for failure to successfully complete the creativity task (56%), for an overall success rate of 67%. According to the Wald criterion, only valence reliably predicted creativity performance, $z = 5.85$, $p < .01$ (Step 3), whereas the effect of pitch height on creativity performance was no longer evident (step 4). This result implies that the effect of pitch height on creativity was fully mediated by emotional valence.

No significant effects of listener's gender or years of music training were observed. This null result may reflect the small number of participants within each condition. Future investigations should include the assessment of these important individual difference variables as they have the potential to inform us of the range of variables contributing to the observed effects.

Experiment 2

The results of Experiment 1 confirmed that seven minutes exposure to music leads to changes in mood, arousal, and performance on cognitive tasks (see also Husain, Thompson, & Schellenberg, 2002; Thompson, Schellenberg, & Husain, 2001). They also extend the findings of Ilie and Thompson (2006) by demonstrating that manipulations of basic stimulus attributes not only influence *perceptual* appraisals of emotion; they induce *experiential* and *cognitive* changes following seven minutes exposure to music. Experiment 2 was conducted to evaluate whether similar experiential and cognitive effects can be induced by spoken materials.

Method

PARTICIPANTS

One hundred and twenty-eight University of Toronto at Mississauga undergraduate students (71 females and 57 males), ranging in age from 17 to 32 years, participated in the study. Students were recruited from introductory psychology classes and received partial course credit for their participation. They had an average of 2.80 years of formal music lessons (SD = 3.81 years; range = 0 to 16 years). None of the participants showed evidence of clinical depression based on an initial administration of the Beck Depression Inventory, short form (Beck & Beck, 1972). Some individuals participated in both experiments. Those individuals completed different cognitive tasks in the two experiments, however, and their participation in the two experiments was separated by at least one week. For example, those who completed Maier's two strings problem in Experiment 1 were administered Dunker's candle task in Experiment 2, and vice versa.

MATERIALS

The stimuli consisted of two speech excerpts (one female and one male speaker). Brief excerpts of these stimuli were also used in Ilie and Thompson (2006). The speech excerpts were spoken by two students (1 female, 1 male) majoring in theatre and drama at the University of Toronto. The actors read a descriptive text about sea turtles, and were recorded using a Tascam 244 mixer, a compressor limiter dB × 163, and a unidirectional dynamic microphone ATM 63 (25 ohms). The recordings were then processed using *Pro Tools software* (version 5.0.1). The average amplitude of the female speech was 71 dB (SD = 1.97 dB) and 72 dB (SD = 2.09 dB) for the male speech, based on audiometric measurements taken at the headphones. The average pitch of speech samples was 127 Hz for the male speaker (SD = 33 Hz) and 206 Hz for the female speaker (SD = 47 Hz) as determined by Praat (Boersma & Weenink, 2004). The average speaking rate was 149 words per minute (about 2.5 words per second, 3.41 syllables per second).

Manipulations of speech were identical to manipulations of music in Experiment 1. ProTools was used to create eight versions of each recording by manipulating intensity (loud = 80% normalization, mean dB value for loud excerpts: 81.01 linear dB SPL; soft = 5% normalization, mean dB value for soft excerpts: 54.1 dB linear SPL), rate (fast and slow versions were 1.12 and 0.89 times the rate of the original samples, respectively, or 188 and 118 words per minute), and pitch height (two semitones up or down from the original recording: mean fundamental frequency for the high-pitch version = 187.05 Hz; mean fundamental frequency for the low-pitch version = 145.02 Hz). The manipulations yielded sixteen presentations (2 pitches × 2 tempi × 2 intensities × 2 speakers). Each presentation was seven minutes in length, the same length of stimuli as employed in Experiment 1.

In Ilie and Thompson (2006), pilot testing for excerpts of the stimuli used here was conducted to ensure that speech stimuli sounded natural. That analysis revealed no significant reduction in the degree to which manipulated excerpts sounded natural and intelligible. These results address the remote possibility that emotional or cognitive effects of our manipulations were mediated by a cognitive appraisal of speech stimuli as unnatural or artificial.

DEPENDENT MEASURES

The experiential and cognitive measures were identical to those used in Experiment 1.

PROCEDURE

The procedure was identical to that described for Experiment 1.

Results and Discussion

EXPERIENTIAL EFFECTS

The six unipolar scales were converted to three bipolar scales and subjected to analysis. Tables 5a-b display the means and standard deviations following exposure to

TABLE 5. Mean Ratings of Experienced Valence, Energy Arousal, and Tension Arousal After Seven Minutes Exposure.

Pitch	Rate	Intensity	Valence	Energy	Tension
		Panel A (Female speech)			
High	Fast	Loud	5.13	6.13	5.88
			1.96	*1.25*	*1.73*
		Soft	5.63	6.38	4.63
			2.00	*0.92*	*2.07*
	Slow	Loud	5.50	2.25	2.88
			1.77	*1.28*	*2.75*
		Soft	5.25	3.38	2.50
			2.31	*1.51*	*2.51*
Low	Fast	Loud	4.25	3.00	3.13
			1.67	*1.20*	*2.53*
		Soft	3.75	2.88	2.25
			1.91	*1.36*	*2.38*
	Slow	Loud	2.38	2.00	4.25
			2.00	*1.60*	*2.92*
		Soft	2.88	1.38	1.88
			1.89	*1.41*	*2.23*
		Panel B (Male speech)			
High	Fast	Loud	5.13	2.88	4.63
			1.64	*2.42*	*1.51*
		Soft	5.88	3.63	3.13
			1.36	*2.42*	*2.42*
	Slow	Loud	4.37	2.50	3.25
			2.13	*2.00*	*2.38*
		Soft	4.50	1.88	3.00
			2.07	*2.03*	*2.33*
Low	Fast	Loud	4.00	3.63	3.25
			2.51	*1.85*	*2.43*
		Soft	4.13	1.50	4.00
			1.81	*1.31*	*1.93*
	Slow	Loud	3.75	0.88	2.75
			2.43	*1.36*	*2.60*
		Soft	3.25	1.25	2.13
			2.31	*1.39*	*1.55*

TABLE 6. ANOVA for Ratings of Valence, Energy Arousal, Tension Arousal and Speaker's Sex After Seven Minutes Exposure to Music.

Source	*df*s	*F*	partial η^2	*p*
Between-subjects		Valence		
Pitch Height	1, 112	20.96	.16	< .001
Rate	1, 112	4.47	.04	< .05
		Energy Arousal		
Speaker's Sex	1, 112	13.63	.11	< .001
Pitch Height	1, 112	33.13	.23	< .001
Rate	1, 112	43.89	.28	< .001
		Tension Arousal		
Rate	1, 112	6.43	.05	< .05
Intensity	1, 112	3.99	.03	< .05
Speaker's Sex × Rate	1, 112	4.306	.04	< .05

male and female speech for each of the bipolar rating scales: valence, energy, and tension. Table 6 displays the between-subjects results of the ANOVA for valence, energy arousal, tension arousal ratings, and speaker's sex. As observed for music, manipulations of spoken materials led to reliable changes in feelings of emotion.

Valence. An ANOVA with Intensity (loud or soft), Rate (fast or slow), Pitch Height (high or low), and Speaker's Sex as independent variables revealed a main effect of Pitch Height, $p < .001$, and a main effect of Rate, $p < .05$ (for *F* and *df* values, see Table 6). Mean ratings of felt valence after exposure to high-pitch speech ($M = 5.17$, $SD = 1.99$) were significantly higher than mean ratings of felt valence after exposure to low-pitch speech ($M = 3.55$, $SD = 2.06$). Mean ratings of felt valence after exposure to fast speech ($M = 4.73$, $SD = 1.93$) were significantly higher than mean ratings of felt valence after exposure to slow speech ($M = 3.98$, $SD = 2.26$). All other effects and interactions were *n.s.*

Energy arousal. An ANOVA with energy arousal as the dependent variable revealed a main effect of Speakers' Sex, a main effect of Pitch Height, and a main effect of Rate, $p < .001$. Ratings of felt energy were higher after listening to female speech ($M = 3.42$, $SD = 2.15$) than after listening to male speech ($M = 2.36$, $SD = 2.11$); after listening to high-pitch speech ($M = 3.72$, $SD = 2.35$) than after listening to low-pitch speech ($M = 2.06$, $SD = 1.65$); and after listening to fast speech ($M = 3.84$, $SD = 2.23$) than after listening to slow speech ($M = 1.94$, $SD = 1.68$). No other effects were significant.

Tension arousal. An ANOVA with tension arousal as the dependent variable revealed a main effect of Rate, $p < .05$, with higher ratings of tension associated with fast speech ($M = 3.86$, $SD = 2.30$) than slow speech ($M = 2.83$, $SD = 2.40$). There was also a main effect of Intensity, $p < .05$, with higher ratings of tension associated with loud speech ($M = 3.75$, $SD = 2.48$) than soft speech ($M = 2.94$, $SD = 2.26$). There was also an interaction between Speaker's Sex, Pitch Height, and Rate, $p < .05$. Follow-up analyses (Bonferroni's correction) revealed that for female speech, ratings of tension were similar for the low-pitch slow speech ($M = 3.06$, $SD = 2.79$) and low-pitch fast speech ($M = 2.69$, $SD = 2.41$) conditions. Ratings of tension did not change significantly for participants who heard the high-pitch slow speech ($M = 2.69$, $SD = 2.55$) stimuli, but did increase significantly for participants who heard the high-pitch and fast speech ($M = 5.25$, $SD = 1.95$). For male speech, however, tension ratings were significantly higher for low-pitch fast speech ($M = 3.88$, $SD = 2.09$)

TABLE 7. Mean Scores on Speed of Processing (Panel A) and Creativity (Panel B) Tasks After Seven Minutes Exposure to Female and Male Speech.

Pitch	Rate	Intensity	Female speech	Male speech
		Panel A (Speed of processing)		
High	Fast	Loud	165.38	159.38
			35.60	*17.86*
		Soft	155.75	244.50
			48.44	*54.38*
	Slow	Loud	225.50	221.13
			37.60	*64.13*
		Soft	199.75	236.25
			57.82	*49.87*
Low	Fast	Loud	192.00	192.75
			50.64	*48.15*
		Soft	221.38	232.88
			64.16	*43.66*
	Slow	Loud	217.13	264.75
			63.32	*74.46*
		Soft	261.00	248.63
			75.55	*65.09*
		Panel B (Creativity)		
High	Fast	Loud	.50	.38
			.53	*.52*
		Soft	.75	.50
			.46	*.53*
	Slow	Loud	.63	.38
			.52	*.52*
		Soft	.75	.63
			.46	*.52*
Low	Fast	Loud	.38	.25
			.52	*.46*
		Soft	.63	.38
			.52	*.52*
	Slow	Loud	.37	.38
			.52	*.52*
		Soft	.50	.38
			.53	*.52*

compared with low-pitch slow speech ($M = 2.44$, $SD = 2.09$). There were no differences in ratings between high-pitch fast speech and high-pitch slow speech. No other effects were significant.

Cognitive Effects

Tables 7a-b display means and standard deviations of manipulations of Rate, Pitch Height, and Intensity on speed of processing and creativity tasks. Table 8 displays the between-subjects results of the ANOVA for the speed of processing and creativity tasks. As predicted, stimulus manipulations reliably affected performance on cognitive tasks. Order of presentation had no effect on the dependent variables and was dropped from further analyses.

TABLE 8. ANOVA for Ratings of Speed of Processing Responses After Seven Minutes Exposure to Female and Male Speech.

Source	*df*s	*F*	partial η^2	*p*
Between-subjects		Speed of processing		
Speaker's Sex	1, 112	4.33	.04	< .05
Pitch Height	1, 112	8.17	.07	< .01
Rate	1, 112	15.82	.12	< .001
Intensity	1, 112	4.32	.04	< .05
Speakers' Sex × Pitch Height × Intensity	1, 112	5.62	.02	< .05

Speed of processing. Preliminary analysis revealed no effects related to the type of speed of processing task so this variable was dropped from further analyses. An ANOVA with speed of processing as the dependent variable revealed a main effect of Speaker's Sex, $p < .05$, a main effect of Pitch Height, $p < .01$, a main effect of Rate, $p < .001$, a main effect of Intensity, $p < .05$, and an interaction between Speaker's Sex, Pitch Height, and Intensity, $p < .05$ (For *F* and *df* values, see Table 8). Completion times were shorter after exposure to female ($M = 204.73$, $SD = 61.55$) than male speech ($M = 225.03$, $SD = 60.65$); high-pitch speech ($M = 200.95$, $SD = 56.52$) than low-pitch speech ($M = 228.81$, $SD = 63.93$); fast speech ($M = 195.50$, $SD = 55.03$) than slow speech ($M = 234.27$, $SD = 62.32$); and loud speech ($M = 204.75$, $SD = 58.80$) than soft speech ($M = 225.02$, $SD = 63.33$). For female speech, completion times were similar after listeners heard the high-pitch loud ($M = 195.44$, $SD = 47.06$) or soft female speech ($M = 177.75$, $SD = 56.32$). Listeners who heard the low-pitch soft speech ($M = 204.56$, $SD = 56.88$) displayed significantly longer completion times (performed slower) than listeners who heard the low-pitch loud speech ($M = 177.75$, $SD = 56.32$). For male speech, however, the effect was reversed. Completion times were similar after listeners heard the low-pitch soft ($M = 240.75$, $SD = 54.15$) or loud speech ($M = 228.75$, $SD = 71.08$). Listeners who heard the high-pitch soft speech ($M = 240.38$, $SD = 50.58$) displayed significantly longer completion times than listeners who heard the high-pitch loud speech ($M = 190.25$, $SD = 55.54$). No other effects were significant.

We next assessed the possibility that experiential effects mediated the above effects for speed of processing. In view of the main effect and interaction involving Speaker's Sex, separate mediation analyses were conducted for female and male speakers. Conducting separate analyses addresses the possibility, implied by the significant effects of speaker sex, that there are differences in the experiential and cognitive consequences of listening to female and male speech. Tables 9a and 9b displays the ANOVA and regression analysis for variables predicting speed of processing for female and male speech, respectively.

Female speech. Step 1 of the mediation analysis confirmed that manipulations of female speech (stimulus variables) were significantly related to speed of processing. An ANOVA with speed of processing as the dependent variable revealed a main effect of Pitch Height, $p < .05$, and a main effect of Rate, $F(1, 56) = 9.21$, $p < .01$, partial $\eta^2 = 0.14$. Completion times were shorter after exposure to high-pitch speech ($M = 186.59$, $SD = 51.84$) than after exposure to low-pitch speech ($M = 222.88$, $SD = 65.83$). Completion times were also shorter after exposure to fast speech ($M = 183.63$, $SD = 54.75$) than slow speech ($M = 225.84$, $SD = 61.50$). No other effects were significant.

Step 2 confirmed that stimulus variables also were related to the potential mediator variables: valence, energy arousal, and tension arousal. An ANOVA with valence as the dependent variable revealed a main effect of Pitch Height, $p < .001$. An ANOVA with energy as dependent variable revealed a main effect of Pitch Height, $p < .001$, a main effect of Rate, $p < .001$, and an interaction between Pitch Height and Rate, $p < .01$. An ANOVA with tension as dependent variable revealed a main effect of Intensity, $p < .05$, and a Pitch by Rate interaction, $p < .05$. These results confirm that manipulations of female speech were significantly related to the mediator variables.

Step 3 confirmed that the mediator variables remain significant predictors of speed of processing when stimulus manipulations are statistically controlled. Regression analysis with speed of processing as the criterion variable and mediator (valence, energy arousal, and tension arousal) and stimulus variables (pitch height, rate, intensity, pitch height by rate interaction) as predictors revealed an $R^2 = .34$, intercept = 255.23, $F(7, 56) = 4.19$, $p < .01$. Valence ($sr^2 = .01$, $\beta = -.15$) and tension arousal ($sr^2 = .02$, $\beta = -.15$) were not statistically significant contributors. However, Energy arousal ($sr^2 = .07$; $\beta = -.46$) contributed significantly to the model, suggesting that the effect of the stimulus manipulations on speed of processing was mediated by energy arousal. Step 4 implied full mediation: although stimulus manipulations were significantly associated with speed of processing when considered on their own (Step 1), none were significant predictors when emotional (mediator) variables were included in the model.

Male speech. Step 1 of the mediation analysis confirmed that stimulus manipulations were related to speed of processing. An ANOVA confirmed a main effect of Rate, $p < .05$, a main effect of Intensity, $p < .05$, and a significant

TABLE 9. Mediation Analysis on Speed of Processing Responses Using Baron & Kenny's (1986) Model.

Panel A (Female speech)

Source	*df*s	*F*	partial η^2	*p*
Step 1.	Between-subjects ANOVA: speed of processing			
Pitch Height	1, 56	6.80	.11	< .05
Rate	1, 56	9.21	.14	< .01
Step 2.	Between-subjects ANOVA: valence			
Pitch Height	1, 56	7.98	.24	< .001
	Between-subjects ANOVA: energy arousal			
Pitch Height	1, 56	44.61	.44	< .001
Rate	1, 56	49.78	.47	< .001
Pitch Height × Rate	1, 56	10.84	.16	< .01
	Between-subjects ANOVA: tension			
Intensity	1, 56	4.08	.07	< .05
Pitch Height × Rate	1, 56	5.92	.10	< .05

Variable	*B*	*SE B*	*β*	*p*
Step 3.				
Valence	−4.13	3.77	−.15	.277
Energy Arousal	−13.24	−.15	−.46	**.016**
Tension Arousal	−3.54	3.05	−.15	.251
Step 4.				
Pitch Height	2.75	9.39	.05	.771
Rate	−2.24	9.00	−.04	.809
Intensity	−3.74	6.90	−.06	.590
Pitch Height × Rate	3.50	7.46	.06	.641

Panel B (Male speech)

Source	*df*s	*F*	partial η^2	*p*
Step 1.	Between-subjects ANOVA: speed of processing			
Rate	1, 56	6.68	.11	< .05
Intensity	1, 56	5.17	.11	< .05
Rate × Intensity	1, 56	65.34	.09	< .05
Step 2.	Between-subjects ANOVA: valence			
Pitch Height	1, 56	5.42	.09	< .05
Rate	1, 56	9.77	.15	< .01
Pitch Height × Rate	1, 56	4.25	.07	< .05

Variable	*B*	*SE B*	*β*	*p*
Step 3.				
Valence	−8.56	3.71	−.30	**.025**
Energy Arousal	2.95	4.12	.10	.477
Tension Arousal	−7.17	3.51	-.26	**.046**
Step 4.				
Pitch Height	−4.57	7.11	−.08	.523
Rate	−12.87	7.25	−.21	.082
Intensity	−16.04	6.86	−.27	**.023**
Pitch Height × Rate	4.61	6.89	−.31	.488
Rate × Intensity	−18.48	6.61	.08	**.046**

interaction between Rate and Intensity, $p < .05$. Completion times were shorter after loud and slow male speech ($M = 228.69$, $SD = 56.05$) than after soft and slow male speech ($M = 256.69$, $SD = 68.07$). Completion times were similar for listeners who heard the loud fast male speech ($M = 201.93$, $SD = 58.83$) and soft fast male speech ($M = 212.81$, $SD = 48.99$). No other effects were significant.

Step 2 confirmed that stimulus manipulations were related to potential mediator variables (valence, energy, tension). An ANOVA with valence as the dependent variable revealed a main effect of Pitch Height, $p < .05$. An ANOVA with energy arousal as the dependent variable revealed a main effect of Pitch Height, $p < .05$, a main effect of Rate, $p < .01$, and a significant interaction between Pitch Height and Rate, $p < .05$. An ANOVA with tension arousal as the dependent variable revealed no significant effects.

Step 3 confirmed that the mediator variables are related to speed of processing even when stimulus variables are statistically controlled. Regression analysis with speed of processing as the criterion variable and the mediator (valence, energy, arousal) and stimulus variables (pitch, rate, intensity, rate by intensity and pitch by rate interactions) as predictors revealed an $R^2 = .34$, intercept = 278.96, $F(8, 55) = 3.56$, $p = .002$. Valence ($sr^2 = .06$; $\beta = -.30$), Tension ($sr^2 = .05$; $\beta = -.26$), Intensity ($sr^2 = .07$, $\beta = -.27$), and Rate by Intensity Interaction ($sr^2 = .09$; $\beta = -.31$) significantly contributed to the model. Although these results support partial mediation by affective variables, Step 4 failed to support full mediation in that stimulus variables (Intensity; Rate $\times$ Intensity) remained significant predictors in the model.

Creativity tasks. Preliminary analysis revealed no effects related to the type of creativity task administered, so this variable was dropped from further analyses. An ANOVA with Intensity (loud or soft), Rate (fast or slow), Pitch Height (high or low), and Speaker's Sex as independent variables and creativity scores as the dependent variable revealed no statistically significant effects. Although this null result would appear to obviate the need for mediation analysis (in that there is no reliable effect to begin with), Kenny, Kashy, and Bolger (1998) and others maintain that further analyses may nonetheless be informative in such circumstances. Specifically, they argue that a reliable relationship between the stimulus variables and the mediator (Step 2), combined with a reliable relationship between the mediator and the outcome variable when stimulus variables are controlled (Step 3), is sufficient to demonstrate mediation. We therefore proceeded to examine whether there were significant relationships between the stimulus variables and the mediator variables, and between the mediator variables and the outcome variables (controlling for stimulus variables).

The previous section established that there is a significant relationship between the stimulus variables and our experiential measures (Step 2). The goal of Step 3 was to confirm that experiential measures were significantly related to creativity scores when stimulus variables are controlled. Because creativity scores were categorical (0 or 1), this analysis was accomplished using hierarchical logistic regression analysis. The analysis confirmed that creativity was significantly predicted by experiential variables once stimulus variables are controlled. A test of the full model against a constant-only model was statistically reliable, $\chi^2(7, N = 128) = 27.54$, $p < .001$, indicating that all of the predictors, as a set, reliably differentiated success and failure to solve the creativity tasks. The variance in creativity scores accounted for is moderate, with Nagelkerker $R^2 = .26$. Prediction of successfully completing the creativity task, 69%, was similar with the prediction for failure to successfully complete the creativity task, 71%, for an overall success rate of 70%. According to the Wald criterion, however, only valence, $z = 10.58$, $p < .01$, reliably predicted creativity performance. The results suggest that stimulus manipulations influenced the valence of emotional experiences, which in turn influenced performance on creativity tasks. However, the absence of a reliable effect of stimulus manipulations on creativity scores underscores the need for further research on the nature of this mediation.

As in Experiment 1, no significant effects of listener's gender or years of music training were observed. However, our investigation was not optimally designed to evaluate these variables and further research on their relevance is warranted.

General Discussion

Manipulations of rate, pitch height, and intensity in music and speech influenced experiences of valence, energy arousal, and tension arousal. The manipulations also influenced two types of cognitive functioning: speed of processing and creative problem solving. On balance, the analyses suggest that cognitive effects were partially mediated by the experiential variables. To our knowledge, this is the first examination of emotion induction involving identical manipulations of auditory features in music and speech. The results indicate that rate, pitch height, and intensity have overlapping experiential and cognitive consequences in the two domains, supporting the idea that music and speech are linked to emotion through a common acoustic code that is processed by shared neural circuitry (Ilie & Thompson, 2006; Juslin & Laukka, 2003; Koelsch, Schroger, & Gunter, 2002; Maess, Koelsch, Gunter & Friederici, 2001; Patel, 2003, 2008; Patel & Daniele, 2003; Patel, Peretz, Tramo, & Labreque, 1998; Tillman, Janata, & Bharucha, 2003). The renowned link between music and emotion may arise from a general mechanism that connects auditory attributes such as intensity, rate, and pitch height with core dimensions of emotion, regardless of whether those attributes occur in music, speech, or environmental sounds.

Effects of manipulations on energy arousal and tension arousal were not always the same, confirming the need to distinguish between these two types of arousal (Ilie & Thompson, 2006; Robbins, 1997; Schimmack & Reisenzein, 2002). For example, manipulations of intensity influenced experiences of tension arousal, but not energy arousal. This distinction—which also was evident in our 2006 perceptual investigation—has important implications for theories of music that attach significance to arousal and related constructs (Huron, 2006; Juslin & Sloboda, 2001; Juslin & Västfjäll, 2008; Meyer, 1956). Acknowledging three dimensions of emotional experience provides a more complete description of the emotional states that are induced by music and speech.

It is notable that all of the significant main effects observed for music also were observed for speech, but two effects observed for speech were not evident for music. Convergent effects in the two domains include the effect of intensity on tension arousal, the effect of rate on energy arousal and tension arousal, and the effect of pitch height on the valence of experience. There also was convergence when significant effects were not observed. Intensity manipulations had no effect on valence or energy arousal for both music and speech, and pitch height manipulations had no effect on tension arousal for either domain.[2]

There were two notable differences in the experiential effects of our manipulations for music and speech. First, rate manipulations influenced the experience of valence after exposure to speech, but not music. Second, pitch height manipulations influenced energy arousal after exposure to speech, but not after exposure to music. Such differences may reflect divergent attentional strategies or cultural display rules for the two domains. For example, the unique effect of pitch height for speech stimuli may reflect the fact that heightened energy in speakers is generally manifested in an increased fundamental frequency of the speaking voice, whereas increased energy in music would not result in an increase in the average pitch of composed music from the Western cannon.

For both music and speech, experienced energy arousal was higher for fast stimuli than for slow stimuli. For speech, however, energy arousal also was influenced by pitch and by the sex of the speaker. Across conditions, high-pitch or female speech was judged as more energetic than low-pitch or male speech. It is possible that speech that is high-pitched and spoken by a female may have special significance because of its association with infant-directed speech (IDS) or *motherese* (Drach, Kobashigawa, Pfuderer, & Slobin, 1969). This form of speech may be experienced as more energetic because of its special biological function (Pegg, Werker, & McLeod, 1992). Infant-directed speech has been observed in a variety of cultures and is associated with several perceptual benefits (Fernald, 1992; Grieser & Kuhl, 1988; Ruke-Dravina, 1977; Shute & Wheldall, 1989). For example, it attracts infants' attention by making speech more interesting (Snow, 1972), it facilitates language-learning tasks (Fernald & Mazzie, 1991; Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996), it makes it easier for infants to segregate speech from background noise (Colombo, Frick, Ryther, Coldren, & Mitchell, 1995), and it helps to maintain emotional ties between parents and infants (Werker & McLeod, 1989).

Intensity had no effect on valence or energy arousal in either experiment. This finding must be reconciled with previous research on speech showing that happiness (a positively-valenced emotion) is associated with medium to high vocal intensity, and sadness is associated with low vocal intensity levels (Juslin & Laukka, 2003). There are three possible explanations for this discrepancy. First, our investigation did not focus on discrete emotions but evaluated core dimensions of emotion. Effects of intensity on valence may be observable at the level of discrete emotions but not at the level of underlying affective dimensions. Second, seven minutes exposure to high intensity stimuli may lead to loudness adaptation, eliminating potential effects of intensity on emotional experience. The latter explanation cannot explain the effects of intensity on tension, however. Third, the link between intensity and positive valence may be *perceptual* in nature, and may not predict the experience of emotion following seven minutes exposure.

The latter explanation is consistent with results reported by Ilie and Thompson (2006). In that study—which involved shorter excerpts of the same materials used here—changes in intensity influenced the perception of all three dimensions of emotion: valence, tension, and energy. A comparison of the results of the two studies implies that perceptions of emotion based on exposure to brief excerpts of speech or music do not always predict the emotional experiences that result following extended exposure to speech or music.

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[2]Between-subjects analyses combining Experiments 1 and 2 are available upon request. However, as the two experiments involved partial overlap of participants, observations are not independent and results of this analysis should be interpreted with caution.

TABLE 10. Comparison of the Experiential Effects of Seven Minutes Exposure to Music and Speech with the Perceptual Effects Reported by Ilie & Thompson (2006).

Stimulus properties			Valence	Energy Arousal	Tense Arousal
		Experiential effects			
Intensity	Loud	Music	/	/	+
	Soft		/	/	–
	Loud	Speech	/	/	+
	Soft		/	/	–
		Perceptual effects			
Intensity	*Loud*	*Music*	–	+	+
	Soft		+	–	–
	Loud	*Speech*	–	+	+
	Soft		+	–	–
		Experiential effects			
Rate	Fast	Music	/	+	+
	Slow		/	–	–
	Fast	Speech	+	+	+
	Slow		-	–	–
		Perceptual effects			
Rate	*Fast*	*Music*	/	+	+
	Slow		/	–	–
	Fast	*Speech*	–	+	/
	Slow		+	-	/
		Experiential effects			
Pitch Height	High	Music	+	/	/
	Low		–	/	/
	High	Speech	+	+	/
	Low		–	–	/
		Perceptual effects			
Pitch Height	*High*	*Music*	–	/	+
	Low		+	/	–
	High	*Speech*	+	+	/
	Low		–	–	/

Note. "+" indicates significantly higher ratings on the affect dimension represented, "–" indicates lower ratings on the affect dimension represented, "/" indicates no significant difference.

The convergence of the effects of intensity manipulations in Experiments 1 and 2 suggest that intensity acts as a domain-general signal of emotion possibly because intensity is a basic biological signal with deep evolutionary roots. As such, the appraisal of intensity may occur automatically and unconsciously at lower levels of the central nervous system (Scherer & Zentner, 2001).

Table 10 summarizes the significant main effects associated with our manipulations and indicates the direction of these effects. The experiential effects observed in the current study are listed first. The perceptual effects observed by Ilie and Thompson (2006) for shorter excerpts of the same stimuli are listed in italics.

On the whole, the results are consistent with the possibility that music and speech prosody share a common underlying code for the communication and induction of emotion, but that they also draw upon selected domain-specific emotional signals. The notion of a shared emotional code accounts for the overlap in the main effects observed for music and speech. However, results for music and speech were not identical. Given such differences, it seems reasonable to infer that emotion induction occurs partially through domain-specific processes. Such processes may arise through learned associations between emotion and music and between emotion and speech prosody.

For example, listeners may allocate greater attentional resources to salient aesthetic properties of music, whereas they may attend primarily to auditory attributes of speech that concern its verbal content. In other words, different levels of attention may be directed to auditory qualities in the two domains, giving rise to selected differences in the experiential consequences of stimulus manipulations. Associations that are specific to each domain, such as the association between high-pitch speech and motherese, may further allow for differences in the emotional consequences of manipulating auditory attributes in music and speech.

A number of interactive effects of the stimulus manipulations also lacked convergence between domains. Two interactive effects were observed following exposure to music. First, there was a significant interaction between pitch and intensity for valence of experience: pitch height influenced the valence of experience for soft but not loud music. Second, there was a significant interaction between pitch and rate for both tension-arousal and speed of processing: rate influenced these measures for low-pitch music but not high-pitch music. Following exposure to speech, there were two triple interactions: one between Speaker's Sex, Pitch Height, and Rate for tension-arousal, and another between Speaker's Sex, Pitch Height, and Intensity for speed of processing. None of these interactive effects were predicted and it would be premature to provide interpretations of the effects before they are corroborated in independent research. Nonetheless, they illustrate some of the subtle ways in which stimulus attributes of music and speech diverge in their potential to influence emotional experience and cognitive function.

Some of the differences in the experiential and cognitive consequences of listening to music and speech may reflect pre-existing differences in intensity, rate, and pitch height between our music and speech samples. Music and speech stimuli used in our investigations were selected so as to be natural and were not equated on any auditory attributes prior to the manipulations. Indeed, it is not possible to match stimuli on these attributes without rendering them unnatural. For example, the rate of natural speech is rarely the same as the natural rate of music. Normalization procedures matched music and spoken stimuli for peak levels in intensity, but such matching necessarily left other measures of intensity unmatched, such as the mean, mode, median, and lowest levels. For example, there was a slight dB difference between the music and speech stimuli (4 dBs in our 2006 experiment; 6 dBs in the current investigation). These inevitable differences in intensity (and other attributes) between samples may partially account for differences between domains. Although the full implications of such pre-existing differences in attributes are unclear, our own belief is that divergent effects in the two domains likely arose from a combination of differences in attentional strategies, learned associations, and basic auditory attributes.

COMPARISON OF PERCEIVED AND FELT EMOTION

The current investigation also allowed us to address Gabrielsson's (2002) model of the possible relationships between perceived and felt emotion based on brief and seven minutes exposures to manipulations of rate, pitch height, and intensity. Intensity manipulations had similar effects for tension arousal after brief (Ilie & Thompson, 2006) and seven minutes exposure (current investigation) to music and speech, illustrating a positive relation between perceived and felt emotion. However, the same manipulation had dissimilar effects for valence and energy arousal. Our manipulations influenced perceptual judgments of valence and energy following brief excerpts but had no significant effect on experiences of these attributes following more prolonged exposure. This difference may suggest a reduced threshold for perceptual effects than for experiential effects.

Rate manipulations had similar effects for energy arousal after brief (Ilie & Thompson, 2006) and seven minutes exposure (current investigation) to music and speech, and similar effects for tension arousal for music, again indicating a positive relationship between perceived and felt emotion. For speech, however, the effects of rate manipulations on perceived valence were opposite to the effects of rate manipulations on experienced valence. Specifically, slow speech was *perceived* as more pleasant than fast speech, but after seven minutes exposure listeners *felt* more pleasant after hearing fast speech than slow speech. In short, there is no guarantee that the perception of emotion following brief exposure to spoken stimuli will converge with the emotions that are actually experienced following seven minutes exposure to those same stimuli.

For speech, pitch height manipulations had similar perceptual and experiential effects, indicating a positive relationship between perceived and felt emotion. For music, manipulations of pitch height yielded no systematic relationship between perceived and felt emotion for tension arousal, and a negative relationship between perceived and felt emotion for valence. In short, we observed multiple relationships between perceived and felt emotion, as described by Gabrielsson (2002). It is possible that more extreme manipulations of the three auditory parameters might have resulted in consistently positive relationships between perceived and felt emotion, but the goal of our investigation was to examine manipulations that are within the range of what occurs naturally.

Although we believe that Gabrielsson's (2002) perceived versus felt conceptualization of affect is most suited for interpreting the current data and Ilie & Thompson's (2006) previous results, we also acknowledge that it is possible to interpret these data within other theoretical frameworks. The model described next extends Gabrielsson's conceptualization and suggests ways of further testing the link between perceived and felt affect.

OVERVIEW AND OUTLINE OF A MODEL

The results of the investigation, considered with other data on links between music and emotion, suggest a framework for understanding the perception and induction of emotional states following auditory input, illustrated in Figure 1. The model incorporates existing understandings of the emotional code that is shared by music and speech, along with features derived from the current data in a diagram that summarizes how auditory cues combine to induce emotional states. It describes the combination of cues shared between music and speech needed to convey and induce specific emotional states.

The input level of the framework includes three auditory domains: music, speech prosody, and environmental sounds. The second level distinguishes this input into shared and domain-specific properties, acknowledging that some of the building blocks for the auditory communication of emotion are shared between domains, while others are domain-specific. Speech specific properties include learned conventions such as the use of a rising final pitch to indicate irony. However, speech also contains attributes that communicate emotions in common with music, such as intensity, tempo, and overall pitch height. The third level of the framework is the perceptual level. Perceived emotion may occur by means of a cognitive appraisal of domain-specific and shared auditory properties. Both speech-specific properties and shared acoustic properties may be consciously evaluated (appraisal), while some shared acoustic properties (e.g., intensity) may be processed in the absence of conscious awareness.

Processing may terminate at the perceptual level or it may continue to the fourth level where exposure to auditory stimuli gives rise to a genuine experience of emotion.

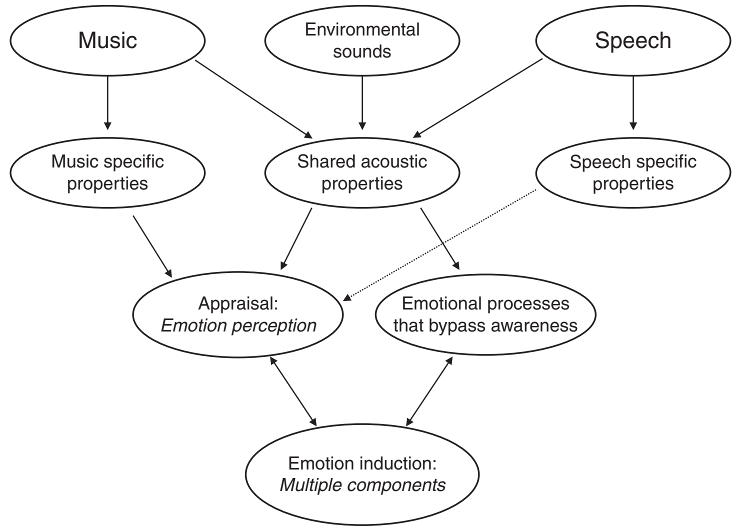

FIGURE 1. A framework for understanding the communication and induction of emotion by auditory channels.

In the latter case, appraisal processes combine with unconscious emotional processing to induce an emotional experience. Emotional states entail changes in multiple subsystems, including experiential and cognitive changes, as illustrated by the current investigation, along with physiological changes and motor expressions (Grandjean & Scherer, 2008). Emotion induction is partially driven by the output from a perceptual appraisal, but is also influenced by direct connections with brain areas that bypass awareness. Whereas the perceptual level receives input from both shared and domain-specific features, processes that bypass awareness only receive input from basic auditory signals of emotion.

An assumption of the framework is that emotional states can influence the perception of emotion through feedback mechanisms. That is, although perceptual evaluation generally occurs through a cognitive appraisal of domain-specific and shared auditory features, once an emotion is induced, this state may influence perceptual judgments through feedback (e.g., if the music makes us feel sad, we may use this as information to judge the music to be sad) (Schwarz & Clore, 1983). Repeated exposure to auditory stimuli may result in strong feedback from emotional states to perceptual judgments, gradually nurturing increased alignment between appraisal and experience.

The current results, together with those reported by Ilie and Thompson (2006), illustrate that some auditory attributes have similar emotional functions in music and speech. Shared processing between domains is cognitively and theoretically economical: principles of emotional processing in one domain can be applied to other auditory domains without the need for additional neural resources. Shared cues, however, are supplemented by domain-specific cues that also shape our perceptions and experiences of emotion. Cues that are common across auditory domains are likely to be developmentally stable and resistant to processes of enculturation. In contrast, domain-specific cues are susceptible to processes of enculturation, and act to refine and fractionate emotional communication systems in different domains. Following arguments by Thompson and Balkwill (2010), processes of enculturation not only enhance the differentiation of emotional communication in different domains; they act to differentiate emotional communication systems *across cultures*. That is, a developmental process of fractionation permits the emergence of domain-specific and culture-specific systems of emotional coding, whereas emotional cues that are shared across domains exert their influence throughout the lifespan.

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