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Emotional Responses to Music: Experience, Expression, and Physiology

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Abstract

A crucial issue in research on music and emotion is whether music evokes genuine emotional responses in listeners (the emotivist position) or whether listeners merely perceive emotions expressed by the music (the cognitivist position). To investigate this issue, we measured self-reported emotion, facial muscle activity, and autonomic activity in 32 participants while they listened to popular music composed with either a happy or a sad emotional expression. Results revealed a coherent manifestation in the experiential, expressive, and physiological components of the emotional response system, which supports the emotivist position. Happy music generated more zygomatic facial muscle activity, greater skin conductance, lower finger temperature, more happiness, and less sadness than sad music. The finding that the emotion induced in the listener was the same as the emotion expressed in the music is consistent with the notion that music may induce emotions through a process of emotional contagion.

Keywords: Music, emotion, emotional experience, facial expression, electromyography, autonomic activity, gender differences, emotional contagion.

Introduction

One of most commonly cited reasons for listening to music is that music induces strong emotions (Juslin & Laukka, 2004). Yet, although experimental researchers often use music as a means of mood induction (Västfjäll, 2002; Westerman, Spies, Stahl, & Hesse, 1996), music has rarely been the subject of mainstream research on emotions. One reason for this puzzling state of affairs could be that emotion researchers assume that emotions have evolved because they solved adaptive problems. That is, emotions prepared the individual to deal with situations that were significant for reproduction and survival (Cosmides & Tooby, 2000; Darwin, 1872/1998). Unlike most other stimuli that evoke emotions, such as encounters with dangerous animals, threats, or facial expressions, music has no obvious, intrinsic survival value. Some authors have therefore suggested that music cannot induce the 'garden variety' of emotions, such as happiness and sadness (Kivy, 1990; Scherer, 2003). However, in view of the finding that listeners report experiencing such emotions while listening to music (Gabrielsson, 2001; Juslin & Laukka, 2004; Sloboda, 1992; Wells & Hakanen, 1991), further research is needed to determine whether such responses may indeed occur.

Components of Emotion and Their Measurement

In gathering, analyzing and classifying 92 definitions and 9 skeptical statements about the concept of emotion, Kleinginna and Kleinginna (1981) conclude that there is little consistency among definitions of emotions and that many of them are vague. Despite this lack of consensus on a precise definition of emotions (Ekman & Davidson, 1994), many researchers today agree that emotional responses are manifested in three components: experience, expression, and physiology (Buck, 1994; Ekman, 1993; Izard, 1977, Lang, 1995; Levenson, 1994; Leventhal 1984; Plutchik, 1993). That is, emotions give rise

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to affective *experiences* such as feelings of happiness, sadness, pleasure, and displeasure; activate widespread *physiological* adjustments to the evoking conditions; and lead to *expressive* behaviors that are often, but not always, goal directed and adaptive.

There are two dominant models on how emotions are organized: the discrete emotions model, which postulates that there is a small number of distinguishable primary or basic emotions (Buck, 1988; Ekman, 1992*;* Izard, 1971, 1972, 1991; Tomkins, 1984), where each emotion is activated and regulated through different mechanisms and processes (Izard, 1993; LeDoux, 1996), and the dimensional model, which from a semantic perspective suggests that emotions are best described by a set of underlying dimensions of emotion that are bipolar and consist of valence (pleasantness–unpleasantness) and arousal or activation (Green & Salovey, 1999; Russell, 1980; Russell & Carroll, 1999*;* Watson & Tellegen, 1985, 1999).

Emotional experience

Subjective experience, or feeling, has been seen as an essential element of the emotional system as far back as the third century BC and Aristotle. The reason for its importance, Scherer (2003) argues, is that it integrates all components and serves as the basis for the conscious representation and regulation of emotions. Consequently, the most straightforward approach to measuring emotions has been through self-report. Self-reports may involve forced-choice formats, rating scales, or free phenomenological description. Self-report measures based on adjective lists, such as the Differential Emotions Scale (Izard, Dougherty, Bloxom, & Kotch, 1974), have been found to be reliable in differentiating among emotions induced through imagery (Boyle, 1984), film segments (Philippot, 1993), and facial expressions (Lundqvist & Dimberg, 1995). Similarly, studies of music have reported emotion differentiation in self-report measures (for a review, see Juslin & Sloboda, 2001).

There are, however, a number of methodological problems with self-reports. One is that participants may answer according to what they feel is the expected, socially most acceptable response. This can be dealt with by using cover stories that divert the participants from the true nature of experimental hypotheses (Aronson, Ellsworth, Carlsmith, & Gonzales, 1990; Judd, Smith, & Kidder, 1991; Smith, 2000). Another problem is that listeners may find it difficult to discriminate felt emotions from the emotions perceived in the music (Kivy, 1990; Meyer, 1956). Clear instructions on whether the listeners should focus on perceived or induced emotions could help to alleviate this problem (Scherer & Zentner, 2001).

Facial expression

The face plays a prominent role in human expression of emotions (Darwin, 1872/1998; Ekman, 1999), and distinct facial expressions are formed by the contraction of specific facial muscles (Hjortsjö, 1970). Electromyographic (EMG) measurements over the facial muscle regions HAVE been found to differentiate the valence of affective reactions (Cacioppo, Petty, Losch, & Kim, 1986). For instance, activity over the muscle regions of *zygomaticus major* (used when smiling) and *corrugator supercilii* (used when frowning) can reliably indicate the degree of valence of emotional imagery (Fridlund, Schwartz, & Fowler, 1984; Schwartz, Fair, Salt, Mandel, & Klerman, 1976), facial expressions (Dimberg, 1982; Lundqvist, 1995; Lundqvist & Dimberg, 1995), vocal expressions (Hietanen, Surakka, & Linnankoski, 1998), and auditory stimuli in general (Bradley & Lang, 2000; Dimberg, 1990; Jäncke, Vogt, Musial, Lutz, & Kalveram, 1996). Moreover, facial EMG has been used in selected studies of music listening (Kallinen, 2004; Witvliet & Vrana, 1996; Witvliet, Vrana, & Webb-Talmadge, 1998). Consistent with the findings from studies of non-musical stimuli, these studies found increased zygomatic activity to positively valenced music, and increased corrugator activity to negatively valenced music.

Autonomic activity

One of the primary functions of the autonomic nervous system (ANS) is to provide the body the support to deal with behavioral demands, such as increased heart rate in response to perceived danger. Similarly, a primary purpose of emotion is to respond to behavioral demands that may require mobilization for action. Therefore, some researchers have argued that at least some emotions should reflect specific autonomic activity (e.g., Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990). However, the extent to which different emotions involve different patterns of ANS activity is a controversial issue. Previous reviews of autonomic responses to non-musical stimulation, such as film excerpts, imagery, or facial activation, have revealed relatively few cases where autonomic indices such as heart rate, skin conductance, and finger temperature were able to clearly discriminate among emotions (Cacioppo, Klein, Berntson, & Hatfield, 1993).

Measurements of autonomic activity in music listeners have for over a hundred years been an attractive way to non-obtrusively explore how the mind processes music (Bartlett, 1996). During this period, most studies have focused on arousal rather than valence. Bartlett (1996) found in his review of more than 130 studies that, generally, percussive, fast tempo, highly rhythmic, and loud dynamic music was found to evoke increases in heart rate and muscle tension and thus regarded as high arousing music, whereas melodic, slow tempo, legato style, and soft dynamic music was found to evoke decreases in heart rate and muscle tension, as well as increases in skin temperature and skin resistance (i.e., decreased skin conductance), and thus regarded as low arousing music.

Few physiological studies have investigated the *valence* dimension of musically induced emotions. Krumhansl (1997) reported that fearful and happy music induced higher heart rate than sad music, which has been demonstrated in other studies (e.g., Nyklíček, Thayer, & Van Doornen, 1997; Pignatiello, Camp, Elder, & Rasar, 1989). Furthermore, happy music evoked greater skin conductance than fearful music, which, in turn, evoked greater skin conductance than sad music. Moreover, happy music induced higher skin temperature than sad and fearful music. This is consistent with the results reported by McFarland and coworkers (McFarland, 1985; McFarland & Kadish, 1991; McFarland & Kennison, 1989) who found that music with positive valence induced increased temperature, while music with negative valence induced decreased temperature. Decreased finger temperature is a result of vasomotor constriction due to increased activity in the sympathetic branch of the autonomic system. Elevated activity in the sympathetic nervous system is common in response to a negative event.

Response Coherence

As shown above, much research has been devoted to each of the emotion components, but although many researchers regard response coherence (or 'response synchronization'), i.e., that an emotional reaction leads to a corresponding response in all components, as an important defining characteristic of emotions (e.g., Scherer & Zentner, 2001), few studies have demonstrated coherence among them (e.g., Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Hence, the extent to which coherence exists has been the matter of some debate (Lang, 1988; Russell, 2003). It has been argued that the three components of emotion do not necessarily correspond (Izard, 1992, Lang, Levin, Miller & Kozak, 1983). Absence of any one component is not usually seen as offering sufficient grounds for concluding that an emotion has not occurred. For example, there are situations in which emotions are experienced; yet no facial expressions are displayed (Ekman, 1972). Similarly, there are times when avoidance behaviors occur independently of any corresponding subjective feeling (LeDoux, 1996). In addition, some people may have a predominance of an experience-arousal link, others a predominance of an experience-expression link (Pennebaker & Roberts, 1992), and both individual and situational characteristics may influence the extent to which the components match. Other problems are to find the adequate measures of emotional responding within the three response systems and to take into account varying lags among the measures of emotional responding, which may limit the indices of coherence, especially if the responses involved are short-lived. Some researchers argue that each component has its own particular determinants and that no single component is more fundamental to or representative of emotional responses than any other component (Frijda, Ortonay, Sonnemans, & Clore, 1992).

Nevertheless, the validity of conclusions about the occurrence of an emotion clearly increases when responses from all three components are measured, and when several measures of each component are used (Ekman, 1977). Previous studies of music have found modest evidence of coherence among different components (e.g., Krumhansl, 1997; Vaitl, Vehrs, & Sternagel, 1993). Clearly, evidence of a coherent emotional response including several components would help to resolve the important issue of whether music can induce genuine emotions in listeners (the emotivist position), or whether listeners merely perceive emotions expressed by the music (the cognitivist position). Because merely perceiving an emotion in music does not require an emotional state in the listener that includes autonomic and expressive responses, only the emotivist position would predict a coherent response in listeners' experience, expression, and physiology (Scherer & Zentner, 2001).

The Present Study

The goal of this study was to investigate listeners' combined experiential, facial, and autonomic responses to music. The stimuli consisted of popular music with either happy or sad emotional expressions. Happiness and sadness are emotions that are easily expressed in music (Juslin & Laukka, 2003), and that also seem to be common responses to music (Juslin & Laukka, 2004). Thus, it was regarded as beneficial to use music with these expressions as stimuli.

Based on the three-component definition of emotion, the discrete emotions model, and previous emotion research, a number of *a priori* hypotheses were specified. It was predicted that happy music, compared to sad music, would induce:

1. more self-rated happiness
2. less self-rated sadness
3. no differences in self-rated anger, fear, surprise, or disgust.
4. more zygomatic muscle activity
5. less corrugator muscle activity
6. higher heart rate
7. greater skin conductance
8. higher finger temperature

Observations supporting the hypotheses would indicate an overall coherent response pattern and thus support the emotivist position.

In addition, we expected to find gender differences. Previous research has found that male and female listeners differ with regard to their perception of the emotional expression in music (Kamenetsky, Hill, & Trehub, 1997), their reasons for listening to music (North, Hargreaves, & O'Neill, 2000), their decoding accuracy in non-verbal communication (Fischer, Rodriguez Mosquera, van Vianen, & Manstead, 2004; Hall & Matsumoto, 2004), their facial responses to facial expressions (Dimberg & Lundqvist, 1990) and auditory stimuli (Dimberg, 1990), and their finger temperature response to musical stimuli (McFarland & Kadish, 1991). In line with these studies, we predicted that female participants would show more pronounced responses than male participants.

Method

Participants

Thirty-two university students, 16 men with a mean age of 23.3 (*SD* = 3.66) and 16 women with a mean age of 22.9 (*SD* = 5.43), took part in the experiment. They were musically untrained and participated on a voluntary basis.

Stimuli

The stimuli consisted of simple pop songs in a singer-songwriter style sung and performed on the acoustic guitar. Musical scores are given in the appendix. The music was composed especially for this study in order to eliminate confounding effects due to personal memories associated with the music (the 'Darling, they're playing our song' phenomenon; see Davies, 1978). The songs were performed with lyrics to maintain the representativeness of this style of music. One happy song and one sad song each were performed by a male and a female singer, yielding a total of four musical performances that were recorded onto a mini disc. The songs were performed with lyrics to maintain the representativeness of this style of music. Previous research has suggested that the music has a much larger impact on listeners' responses than the lyrics (Ali & Peynircioglu, 2006; Sousou, 1997) and that most listeners do not even know what the lyrics of pop songs are about (Konecni, 1984). Still, as a precaution, we decided to use lyrics in English that were neutral in character (no emotion words were allowed). The happy music lasted 140 seconds and the sad music 204 seconds and were played in full. For comparative reasons, only data obtained during the first 140 seconds of the sad music were used in the subsequent analyses. The happy music featured fast tempo, high sound level, and major mode, while the sad music featured slow tempo, low sound level, and minor mode. These characteristics have been associated with happy and sad expressions in previous research on emotional expression in music (for a review see, Juslin & Laukka, 2004). The tempo of the happy music was about twice that of the sad music. The sound level of the happy music was, in Root Mean Square (RMS) power, 3.6 dB higher for the happy (-22.1 dB) than for the sad music (-25.7 dB). Before the experiment the stimuli were rated by a group of students on the emotion expressed in the music. Hence, a face validity of the stimuli was established. These students did not participate in the experiment.

Apparatus

Bipolar *facial EMG* recordings were made from the left corrugator and zygomatic muscle regions, in accordance with Fridlund and Cacioppo's (1986) guidelines. Before attaching the 4 mm miniature surface Ag/AgCl electrodes filled with EMG gel, we cleansed the skin to reduce interelectrode impedance. All impedance was reduced to less than 10 kΩ (Fridlund & Cacioppo, 1986). The electrodes were connected to Contact Precision Instruments (CPI) bioamplifiers with low and high pass filters set at 1000 Hz and 10 Hz, respectively. Notch filters set at 50 Hz were used to diminish interference with the electric mains. The raw EMG signals were analyzed by means of rectifier/integrators, with the time constant set at .01 seconds. The EMG was measured in micro Volts (μV).

Heart rate was measured by attaching a photo-plethysmograph probe to the distal phalanx of the third finger on the left hand. A CPI finger pulse amplifier analyzed the signal and a CPI interval timer was used to produce interbeat interval data. The interbeat interval data were then transformed into heart rate data (bpm) (Papillo & Shapiro, 1990).

Skin conductance level was recorded by attaching two 8 mm Ag/AgCl electrodes filled with Med Associate skin conductance electrode paste to the middle phalanx of the first and second finger of the participant's left hand. The electrodes were connected to a CPI self-balancing skin conductance amplifier. The skin conductance was measured in micro Siemens (μS).

Finger temperature was measured by attaching a temperature probe to the palmar surface of the distal phalanx of the second finger of the left hand. The probe was insulated to diminish disturbances related to variability in room temperature. During the study, the room temperature was 22 °C ± 1 °C.

All output signals were digitized at 10 Hz per channel by a 12-bit CPI A/D converter and stored on disk. All measurement equipment was placed in an adjacent room to eliminate auditory interference and distraction.

Self-reported emotional experience was measured by an abbreviated Swedish version of the Differential Emotions Scale (DES; Izard, Dougherty, Bloxom, & Kotch, 1974). The ratings, which measured experience of *sadness*, *anger*, *fear*, *disgust*, *surprise*, *happiness*, and *interest*, were each represented by three items. *Sadness* was represented by (Swedish translation in brackets) sad (ledsen), downhearted (nedstämd), and blue (vemodig); *anger* by angry (arg), irritated (irriterad), and mad (ilsken); *fear* by fearful (ängslig), scared (skrämd), and afraid (rädd); *disgust* by disgusted (äcklad), turned off (känner avsky), and repulsed (känner motbjudande); *surprise* by surprised (förvånad), amazed (häpen), and astonished (överraskad); *happiness* by joyful (glad), happy (lycklig), and amused (upprymd); *interest* by interested (intresserad), concentrated (koncentrerad), and alert (uppmärksam).

The participants were asked to indicate the degree of emotional intensity on 100 mm visual analog scales that were labeled from "not at all", "slightly", "moderately", "rather strong", to "very strong". The scores of the three items that represented each emotion were totaled and could range from 0 to 300.

Procedure

The participants were tested individually in a soundproofed room, and listened to the music through headphones. The loudness was set at a comfortable level by the experimenters at the beginning of the study, but no measures of the actual dB-level at the headphones were made. When the participants arrived at the laboratory, they were informed that the aim of the experiment was to investigate physiological reactions to music. To draw attention away from their facial muscles, the participants were told that the electrodes attached to their face were used to index sweat gland activity. To mask the purpose of the DES questionnaire, which was to measure the effects of music on emotional experience, the participants were told that because different participants were tested at different times of the day, they might differ with regard to such things as tiredness and mood, and according to standardized experimental control procedures, they were therefore required to rate their emotions on multiple occasions (Lundqvist & Dimberg, 1995).

After receiving the instructions and having their electrodes attached, the participants completed the first DES questionnaire. Next, the four musical excerpts were played in a counterbalanced order. After each excerpt, a new DES questionnaire was completed. We preferred to collect self-reports in between the stimuli in order to minimize interference with ongoing measurement of facial and autonomic activity. Previous research has suggested that continuous and asynchronous response formats produce fairly similar results (e.g., Krumhansl, 1997; Schubert, 2001). Consequently, each participant completed the questionnaire a total of five times. After the experiment, the participants were briefed and interviewed regarding the instructions given at their arrival. None of the participants reported that they had been aware of the facial EMG or that the real purpose of the DES questionnaire had been to measure their emotional response to the music.

Design and Statistical Analyses

Before analysis, the EMG and ANS data were subdivided into time-blocks. Each time-block consisted of the mean activity during 5 seconds. The 5-second period immediately before the onset of each musical excerpt served as the pre-stimulus period. The data were scored as change scores between the pre-stimulus period and the time-blocks during music listening. Hence, both increasing and decreasing reactions were possible. There were 28 time-blocks per musical stimulus. For the DES ratings, changes in the scores between the ratings after each musical stimulus and the ratings before the musical presentation were calculated. Data were aggregated across both versions of the happy music and the sad music because no significant effect of singer was found.

The EMG and ANS data were analyzed using 2 × 2 × 28 split-plot factorial ANOVAs with gender of the listener (male/female) as between-subjects factor and music (happy/sad) and time-block (28) as within-subjects factors. The ANOVAs were subjected to Greenhouse-Geisser corrections (Greenhouse & Geisser, 1959). Emotional experience ratings were analyzed by 2 × 2 split plot factorial ANOVAs, with gender of the listener as between-subjects factor and music as within-subjects factor.

All statistical analyses were performed using SPSS for Windows, version 15.0 (SPSS, Chicago, IL), and *p*-values less than .05 were considered significant. Partial eta-squared (η_p^2) was calculated in order to estimate the degree of association (i.e., effect size) between the stimuli and the dependent variables. Cohen (1988) provides the following guidelines for interpreting the eta-squared value: .010 = small effect size; .059 = medium effect size; and .138 = large effect size.

Results

Emotional Experience

The results of the ANOVAs of the listeners' ratings of emotional experience, as shown in Table 1, revealed significant main effects of music on the sadness ratings and on the happiness ratings. No main or interaction effects were obtained for the other rating scales, or for any main or interaction effects including gender of the listener. Happy music induced more happiness than sad music, which, in turn, induced more sadness than happy music (see Table 2). The size of these effects were large, $\eta_p^2 = .273$ and $\eta_p^2 = .387$, respectively. The mean changes of intensity in rated happiness and sadness in absolute values were highly similar ($t(31) = .308$, $p = .76$).

Facial Expression

The overall ANOVA results for the facial EMG data (see Table 3) revealed significant main effects of music and time-block on the zygomatic activity readings. As shown in Figure 1, happy music evoked more zygomatic activity than sad music. Zygomatic activity initially increased in response to the music and then gradually decreased. A 95% confidence interval showed that the initial zygomatic increase was significant only for the happy music, while the decrease at the end of the music was significant only for the sad music. Although overall analyses of corrugator activity did not reveal any significant differences between happy and sad music, a 95% confidence interval was estimated for explorative purposes. As shown in Figure 2, both happy and sad music elicited an initial corrugator activity increase. This increase was significantly greater than zero for the sad music only. It is noteworthy that corrugator activity decreased toward the end of both the happy and the sad excerpts, but that the decrease was more pronounced for happy music. The partial eta-squared of the significant music and time-block effects of the zygomatic measures were medium to large ($\eta_p^2 = .128$ and $\eta_p^2 = .176$, respectively).

Autonomic Activity
The ANOVA results for ANS activity presented in Table 3 revealed significant main effects for music and time-block on both finger temperature and skin conductance level. No significant effects on heart rate were found. However, an analysis of the heart rate changes during the first 15 seconds of the music showed a significant quadratic (i.e., U-shaped) trend ($F_{\text{Quadratic}}$ (1, 28) = 19.41, $p < .0001$, $\eta_p^2 = .463$), confirming the initial deceleration-acceleration response pattern seen in Figure 3. As indicated by the ANOVA results in Table 3, and as also demonstrated in Figure 4, sad music induced a greater finger temperature change than happy music. The effect size was medium ($\eta_p^2 = .124$). Note also that both happy and sad music induced an initial decrease in finger temperature, followed by a large increase ($F_{\text{Quadratic}}$ (1, 30) = 13.00, $p < .001$, $\eta_p^2 = .302$). The initial decrease in temperature associated with happy music and the rebound increase for sad as well as happy music were significantly different from zero, as shown by the 95% confidence interval (Figure 4). Finally, happy music elicited significantly greater skin conductance levels than sad music (Figure 5). The effect size was large ($\eta_p^2 = .179$). Skin conductance levels decreased monotonically during listening (F_{Linear} (1, 30) = 50.93, $p < .0001$, $\eta_p^2 = .629$), and this trend was more pronounced for sad music.

Discussion

In this study, we investigated whether music is able to induce genuine emotions in listeners. As predicted, happy music, compared to sad music, generated more happiness (Hypothesis 1), less sadness (Hypothesis 2), no significant differences in any of the other four experience ratings (Hypothesis 3), more zygomatic activity (Hypothesis 4), greater skin conductance (Hypothesis 7) and lower finger temperature (Hypothesis 8). The relative magnitude of the effect of music on the emotional response system was in most cases large in terms of Cohen's (1988) guidelines, suggesting that music is a potent elicitor of emotions in listeners. However, contrary to our predictions, there were no differences in either corrugator activity or heart rate. Thus, in all but two of the measures, a difference in the predicted direction was observed. In none of the measures was there a difference in a direction opposite from that predicted. Consequently, the results indicate a coherent manifestation in the experiential, expressive, and physiological components of the emotional response system, which supports the emotivist position in the debate on musical emotions (Krumhansl, 1997; cf. Kivy, 1990). A second aim of the study was to investigate gender differences in emotional reactions to music. No gender differences were, however, found in any of the measures.

Emotional Experience
As predicted, happy music induced greater feelings of happiness, whereas sad music induced greater feelings of sadness. No differences were found in the other emotions measured. This is consistent with the differential emotions theory (e.g., Izard, 1977), because sad music induced the *specific* emotion of sadness, rather than a general negative emotional response also involving increases in anger, fear, and disgust. It should further be noted that the mean intensity changes in absolute values of the happiness ratings were highly similar to the intensity changes in the sadness ratings. This is important, because it eliminates overall differences in experiential intensity as a confounding factor for the observed differences in facial EMG and autonomic activity.

Facial Expression

The finding that happy music evoked greater zygomatic activity than sad music is consistent with previous studies of musical emotions (Kallinen, 2004; Witvliet & Vrana, 1996; Witvliet, Vrana, & Webb-Talmadge, 1998). This result, as well as results from previous studies of vocal (Hietanen, Surakka, & Linnankoski, 1998) and facial expression (Lundqvist & Dimberg, 1995), suggests that the activity over the zygomatic muscle region is a sensitive indicator of the experienced valence of emotional stimuli.

It was predicted that sad music would evoke greater corrugator muscle activity than happy music. No such difference was found. Instead, both happy and sad music induced a short burst of corrugator activity at the beginning of each musical excerpt. The corrugator activity was significantly greater than the pre-stimulus levels only in conjunction with sad music and only during the first 5 seconds after onset of the stimulus. This response pattern suggests a startle reaction, similar to that described by Witvliet and Vrana (1996) in connection with other musical stimuli. According to them, the magnitude of the startle is more pronounced in low rather than high arousal conditions. Since the corrugator responses to sad music in the present study were not at the same level as the self-reported sadness, it seems possible that the sad music used here lacked certain features necessary for the corrugator muscle to differentiate among happy and sad music. One possible explanation, based on the results of Witvliet and Vrana (1996), is that the arousal evoked by the music moderates emotional responses in facial muscles. Consequently, the slower tempo and lower sound level of the sad music may have induced a lower arousal level in the listeners and thus reduced the music's emotional impact to such an extent that it failed to induce corrugator increases. Further research using music evoking varying degrees of arousal and valence is needed to clarify this issue.

Autonomic Activity

As predicted, happy music evoked greater skin conductance levels than sad music. Contrary to predictions, happy music induced lower finger temperature than sad music. In previous studies that measured finger temperature responses to music, positively valenced music was found to induce a temperature increase, while negatively valenced music was found to induce a decrease (Krumhansl, 1997). McFarland (1985), who also reported on the level of arousal evoked by the music, suggested that negatively valenced, high arousing music induces a temperature decrease, while positively valenced, low arousing music induces a temperature increase. This result is consistent with studies of relaxation, showing that low arousing music induces a finger temperature increase (Guzzetta, 1989). Finger temperature changes attributed to the valence expressed in the music in earlier research may therefore in actual fact be an effect of the arousing level of the music. This would explain why the sad and low arousing music in this study was associated with high finger temperature, while the negative and high arousing music in previous studies was associated with low temperature.

We also predicted that happy music would induce higher heart rate than sad music, but found no such difference. However, a deceleration-acceleration pattern was observed at the beginning of each stimulus. This probably reflects an orienting response, revealing a shift in the participant's attention (e.g., Graham & Clifton, 1966; Sokolov & Cacioppo, 1997). The orienting response was similar in magnitude for both happy and sad music.

Theoretical Implications

The results of the present study support the emotivist perspective. However, a crucial question is what type of psychological process may give rise to the observed response patterns. Several mechanisms have been suggested to explain how music induces emotions: brain stem responses, evaluative conditioning, emotional contagion, mental imagery, episodic memory, and musical expectancy (Juslin & Västfjäll, 2006). This study was not designed to differentiate among theories of musical emotions, though some of the proposed mechanisms appear less likely in the present case. For example, the use of music composed especially for this study reduces the plausibility of an explanation in terms of associations or memories to a specific piece of music. It could be argued that the music was conventional, and that effects due to general associations with the musical genre therefore cannot be completely ruled out. However, what is particularly important about the present results is that the emotions evoked in the listeners were the same as those expressed by the music. This suggests that the emotional reactions to the music were somehow evoked by the emotional expression of the music. A growing body of research has shown that several aspects of musical structure may be used to convey different emotions to listeners, and that there are similarities between musically and vocally expressed emotions (e.g., Juslin & Laukka, 2003). Consequently, some authors have proposed that listeners may react emotionally to music through a process of emotional contagion (Juslin, 2001; Scherer & Zentner, 2001), similar to what has been found with regard to facial (Hatfield, Cacioppo, & Rapson, 1994; Lundqvist & Dimberg, 1995; Wild, Erb, & Bartels, 2001) and vocal (Hietanen et al., 1998) expression. That is, the listener perceives the emotion expressed in the music and then internally mimics the expression, which through afferent physiological feedback leads to induction of the same emotion (Dibben, 2004; Scherer & Zentner, 2001).

In conclusion, the present study provides support for genuine emotional responses to music, which is consistent with the emotivist position and with an explanation in terms of emotional contagion. Further research on emotional contagion with regard to music seems warranted, and would benefit from an approach that measures several emotion components both simultaneously and over time.

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Table 1
F-ratios for Listeners' Ratings of Emotional Experience to Happy and Sad Music

Source	*df*	Anger	Disgust	Fear	Happiness	Sadness	Surprise	Interest
Gender of listener (G)	1	<1	1.87	1.41	1.82	3.83	<1	1.48
swgr	30	(926.72)	(392.71)	(141.52)	(6561.92)	(1337.22)	(1951.35)	(8208.22)
Music (M)	1	2.99	<1	<1	11.28**	18.94***	<1	<1
M × G	1	<1	<1	<1	<1	<1	<1	<1
M × swgr	30	(229.31)	(77.80)	(99.11)	(529.75)	(261.09)	(299.49)	(797.68)

Note. swgr = subjects within groups.
**p* < .05. ***p* < .01. ****p* < .001.

Table 2
Means and Standard Deviations of Emotional Experience Ratings (0 – 300) to Happy and Sad Music

		Music	
Scale		Happy	Sad
Anger	*M*	16.3	9.8
	SD	28.7	17.2
Disgust	*M*	5.3	5.4
	SD	12.1	18.2
Fear	*M*	3.8	6.0
	SD	7.9	13.3
Happiness	*M*	115.3	96.0
	SD	59.1	61.4
Sadness	*M*	16.7	34.3
	SD	22.6	34.8
Surprise	*M*	24.4	22.3
	SD	34.6	31.6
Interest	*M*	131.1	125.0
	SD	68.7	66.2

Table 3

F-ratios for Listeners' Facial Electromyographic and Autonomic Activity to Happy and Sad Music

		Facial EMG activity		Autonomic activity			
Source	*df*	Corrugator	Zygomatic	SCL	FT	*df*[a] HR	HR
Gender of listener (G)	1	<1	<1	1.64	<1	1	<1
swgr	30	(689.90)	(379.09)	(5.04)	(1.32)	27	(1224.24)
Music (M)	1	<1	4.40*	6.53*	4.24*	1	<1
M × G	1	<1	1.10	<1	1.47	1	<1
M × swgr	30	(583.04)	(735.66)	(.67)	(1.39)	27	(748.06)
Time-block (T)	27	1.90	6.43***	40.40***	11.90***	27	1.196
T × G	27	<1	1.47	1.38	<1	27	<1
T × swgr	810	(12.00)	(10.87)	(.034)	(.033)	729	(14.29)
M × T	27	<1	<1	1.18	2.75	27	1.24
M × T × G	27	1.38	1.07	<1	1.43	27	<1
M × T × swgr	810	(11.65)	(8.21)	(.006)	(.019)	729	(10.49)

Note. swgr = subjects within groups; SCL = skin conductance level; FT = finger temperature; HR = heart rate.

[a] Three subjects were excluded due to finger plethysmograph malfunction.

*p < .05 and ***p < .001.

Figure captions

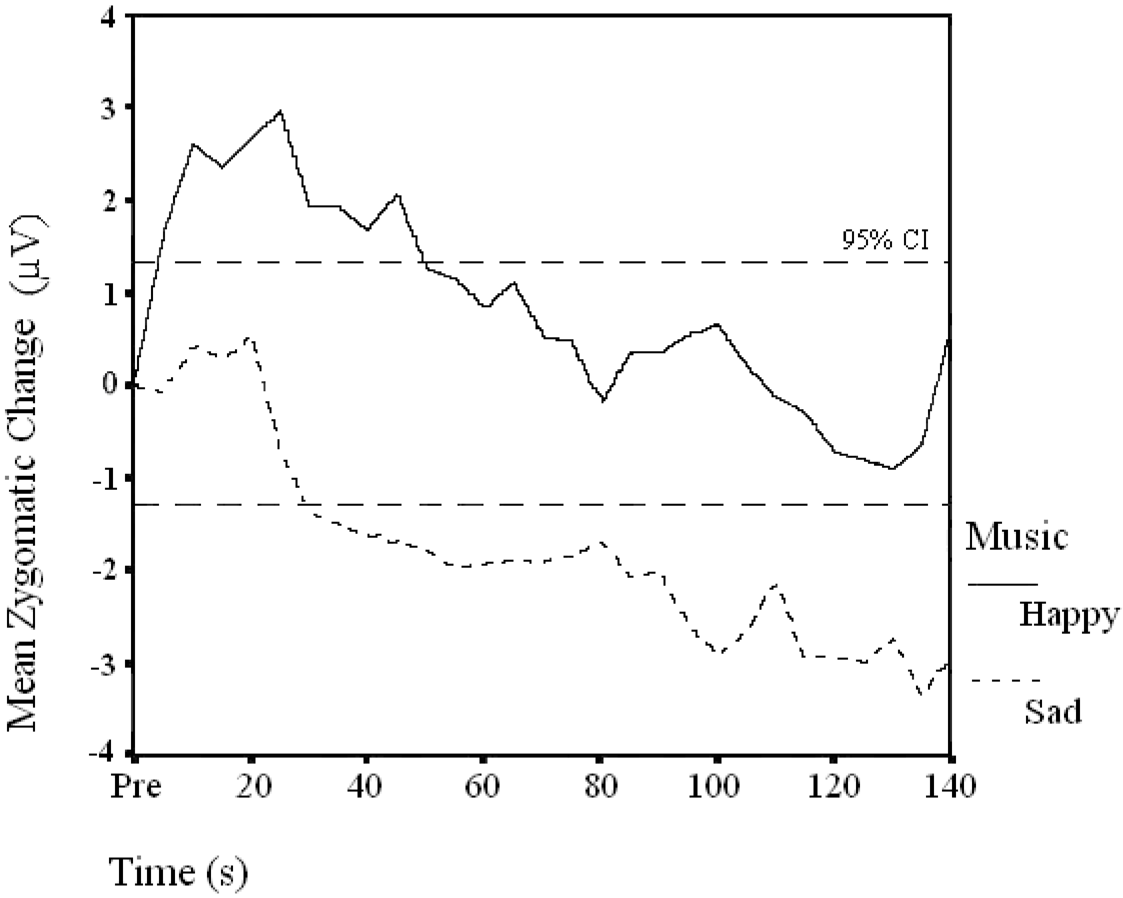


Figure 1. Mean zygomatic muscle region change in response to happy and sad music.

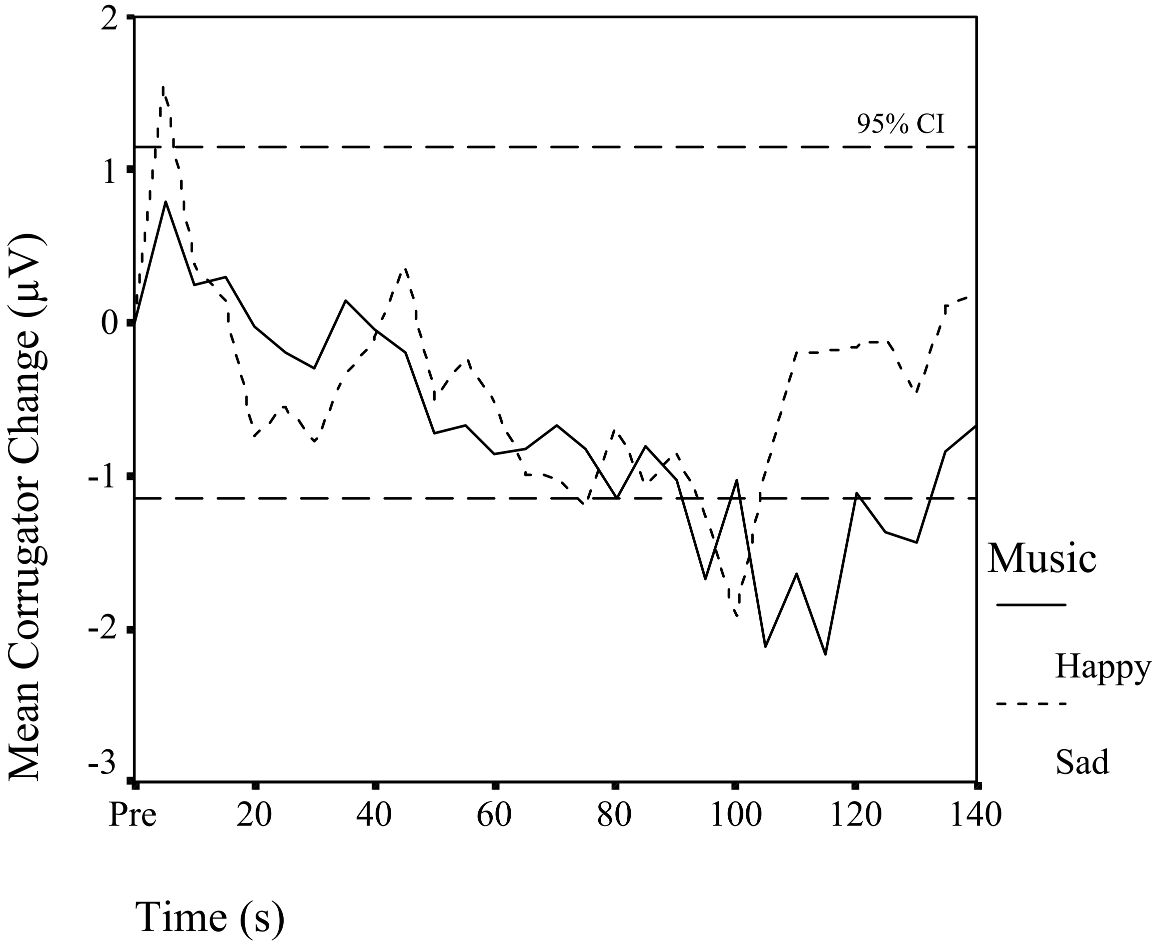


Figure 2. Mean corrugator muscle region change in response to happy and sad music.

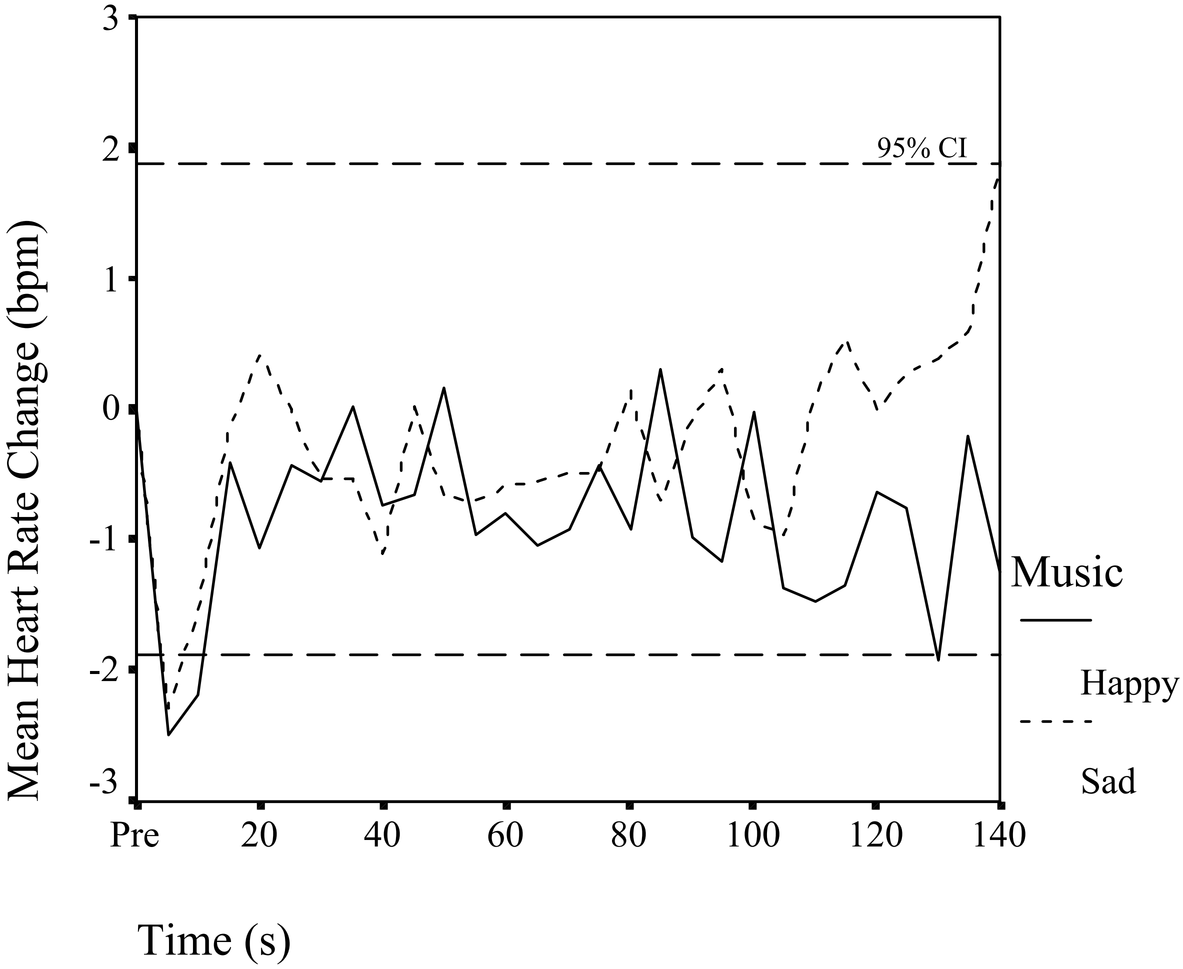


Figure 3. Mean heart rate change in response to happy and sad music.

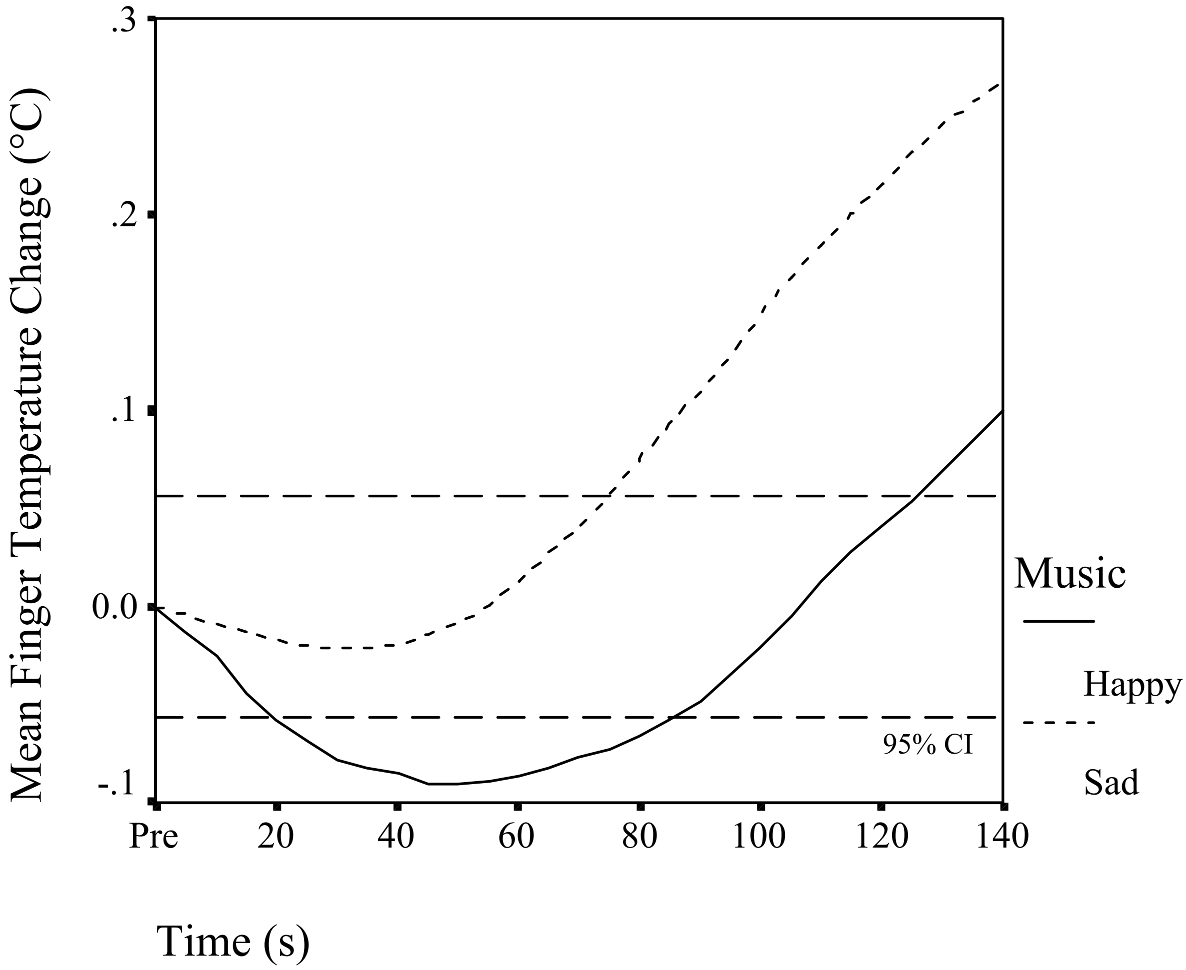


Figure 4. Mean finger temperature change in response to happy and sad music.

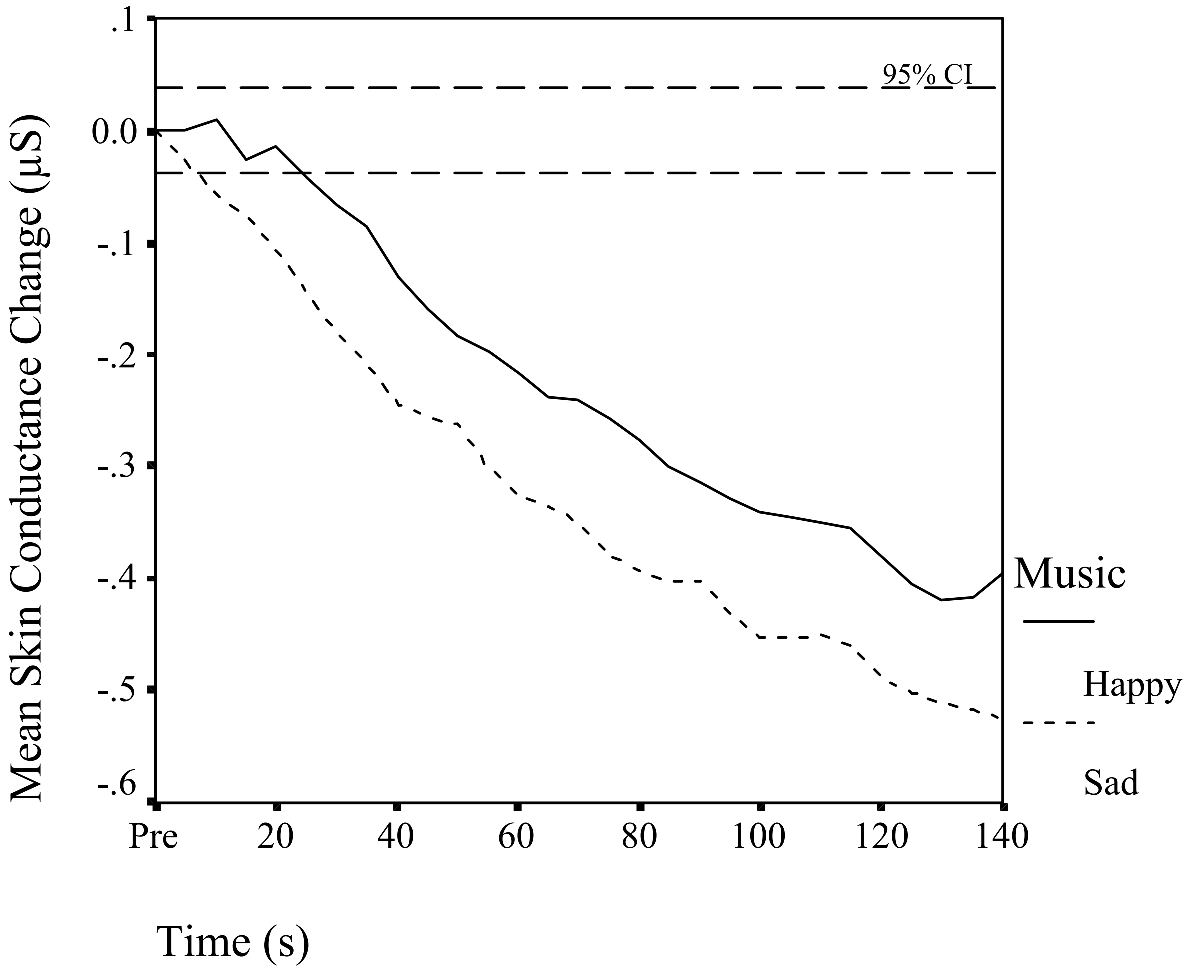


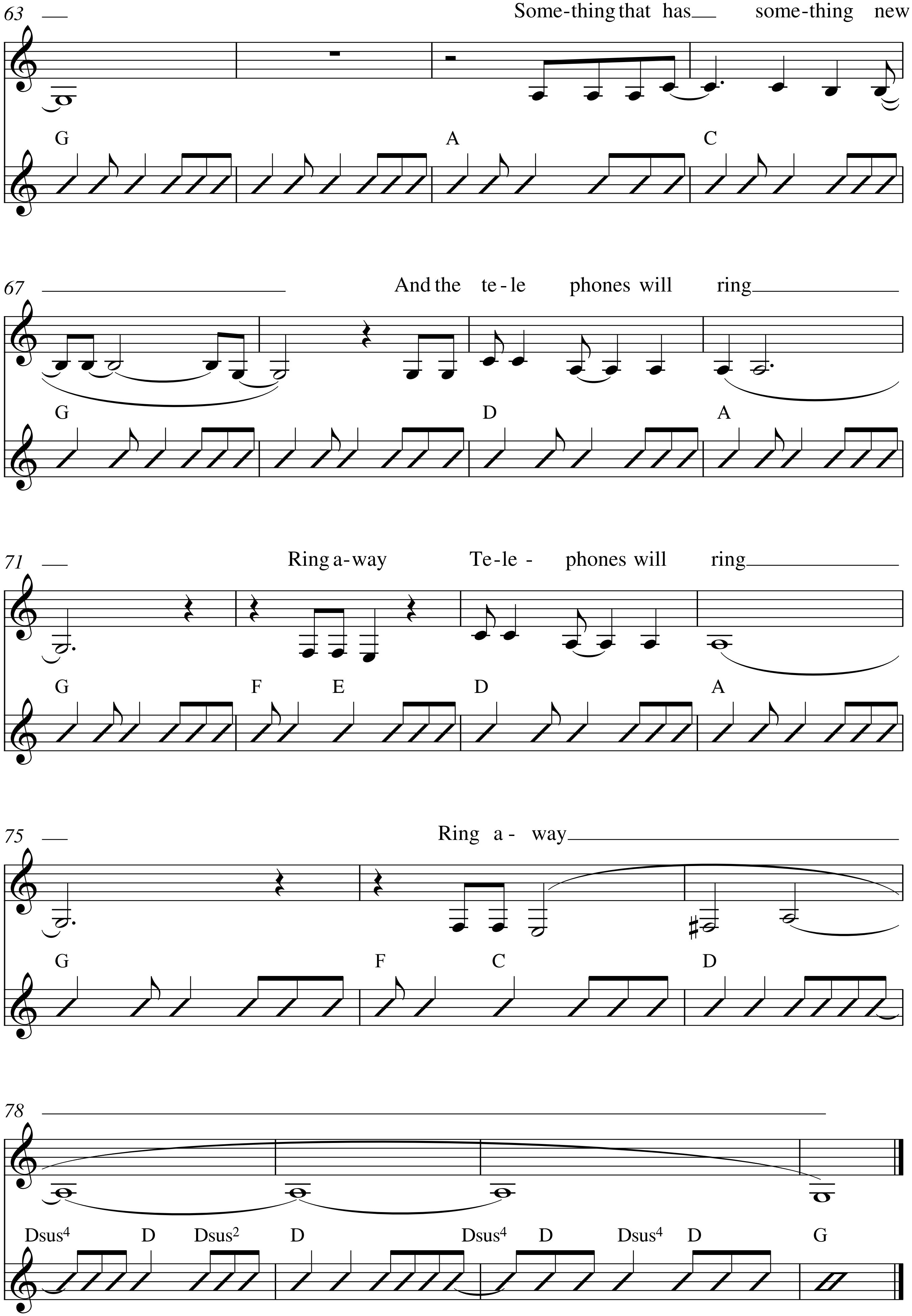
Figure 5. Mean skin conductance change in response to happy and sad music.

Happy Song


♩ = 150
Voice
Guitar
A C G A C
7
G A C
Time a - way From to - day
11
G A
To -mor-row will bring
14
C G D
you some-thing new
18
A G F E D A


23
Take me home_ to- day
G F C A C
27
A - way_ from the sun
G A C
31
You will ne - ver go this way
G A C
35
Come on bring_ a -
G A C
39
no-ther day_ And the te - le - phones will ring_
G D A


43
Ring a-way Te - le - phones will
G F E D A
47
ring Ring a- way
G F C D Dsus4 D Dsus2
51
Take me a- way from this place
D Dsus4 D Dsus2 A C
55
I will seek some-thing new
G A C
59
Some-thing for you and me
G A C


63
Some-thing that has some-thing new
G
A
C
67
And the te-le phones will ring
G
D
A
71
Ring a-way Te-le - phones will ring
G
F
E
D
A
75
Ring a - way
G
F
C
D
78
Dsus4
D
Dsus2
D
Dsus4
D
Dsus4
D
G

Sad Song

♩. = 48
Voice
Guitar
G5
Gm/B♭
7
Time a -
From to -
13
way
day
1.
2.
To -
18
mor - row will bring, bring you some-thing
G5
Em7
Gmaj7/B
24
new Don't look back on the
Cadd2no3
C6add2no3
G5
Em7


30
things
you once
knew
Gmaj7/B
Cadd2no3
C6add2no3
36
G5
Gm/B♭
42
Take
me
G5
48
home
A - way
Gm/B♭
G5
54
from the
sun
Gm/B♭


60
You will ne - ver see it this
G5 Em7 Gmaj7/B
66
way Come on and bring me a -
Cadd2no3 C6add2no3 G5 Em7
72
no - ther day
Gmaj7/B Cadd2no3 C6add2no3
78
G
83
B♭


88
We ei - ther buy or
G
B♭
93
we sell
Some - thing
G
98
new, some - thing old
B♭
103
Wipe off all the
G
Em
108
dust
This
Bm
C
G


113 time it's gon-na be
Em Bm
118 just
C G Em
123
Bm C
128 This time it's
G Em
132 gon - na be just
Bm C