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Modulation of the startle reflex by pleasant and unpleasant music

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ABSTRACT

The issue of emotional feelings to music is the object of a classic debate in music psychology. Emotivists argue that emotions are really felt in response to music, whereas cognitivists believe that music is only representative of emotions. Psychophysiological recordings of emotional feelings to music might help to resolve the debate, but past studies have failed to show clear and consistent differences between musical excerpts of different emotional valence. Here, we compared the effects of pleasant and unpleasant musical excerpts on the startle eye blink reflex and associated body markers (such as the corrugator and zygomatic activity, skin conductance level and heart rate). The startle eye blink amplitude was larger and its latency was shorter during unpleasant compared with pleasant music, suggesting that the defensive emotional system was indeed modulated by music. Corrugator activity was also enhanced during unpleasant music, whereas skin conductance level was higher for pleasant excerpts. The startle reflex was the response that contributed the most in distinguishing pleasant and unpleasant music. Taken together, these results provide strong evidence that emotions were felt in response to music, supporting the emotivist stance.

1. Introduction

The emotional power of music remains a mystery. Unlike most emotional inducers, music is not a sentient being nor does it seem to have any obvious adaptive value (Pinker, 1997). Yet, most people affirm that they feel strong emotions when they listen to music (Sloboda and O'Neill, 2001). This paradox led many music scholars to believe that music is only iconic or representative of emotion, a position coined as 'cognitivist' by Kivy (1990). Opponents to this view, known as 'emotivists', feel that the cognitivist position does not render justice to the direct and unmediated fashion in which emotions are experienced by listeners (Davies, 2001). Although the debate is at a theoretical level, its resolution has practical implications for interpreting music effects. Indeed, if music is only representative of emotion, its therapeutic value could be seriously questioned. Studies measuring physiological, endocrine and brain responses to music as indices of emotional reactivity have supported the emotivist view, but the nature of these emotional responses and their resemblance with emotions induced by other stimuli is unclear.

1.1. Autonomic nervous system responses

In order to show that people not only recognize but feel emotions in response to music, emotional reactions should be measured by techniques that are independent of voluntary subject control, such as psychophysiological measures. Following this line of research, Krumhansl (1997) compared the autonomic responses elicited by different musical emotions and found that sad, happy, and fearful music could be differentiated by their autonomic activation patterns: Sad music was most strongly associated with changes in heart rate, blood pressure, skin conductance and skin temperature, fearful music was mostly associated with changes in the rate and amplitude of blood flow, and happy music principally produced changes in respiratory activity and showed the highest skin conductance level (SCL). However, subsequent studies have failed to replicate many of these findings. Khalfa et al. (2002) found that skin conductance responses (SCR) were highest during the listening of fearful music, Baumgartner et al. (2006) observed increased SCL during sad and fearful music compared to happy music, and Nater et al. (2006) found higher SCL during the listening of unpleasant compared to pleasant music. Moreover, Nater et al. (2006) found higher heart rates during unpleasant compared to pleasant music, whereas Sammler et al. (2007), Witvliet and Vrana (2007), and Krumhansl (1997) found the opposite. Therefore, there are inconsistent findings of the intensity and direction of these autonomic responses between studies.

Such inconsistencies across psychophysiological emotion studies are relatively common (Cacioppo et al., 2000), and the outcomes may be related to some context-bound patterns of actions that allow the same emotion to be associated with a wide range of behavior and varying patterns of somatovisceral activation (Lang et al., 1990). However, it should be noted that some psychophysiological measures appear more reliable than others. For example, respiration rate appears to be consistently higher during happy and fearful music than during

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sad music (Baumgartner et al., 2006; Etzel et al., 2006; Krumhansl, 1997; Nyklicek et al., 1997), although this effect may reflect differences in arousal that differentiate happiness and fear from sadness, and not musical emotions *per se* (Nyklicek et al., 1997). Indeed, cognitive theories of emotion have criticised the use of autonomic measures as indexes of felt emotions due to the non-specific nature of arousal (Schacter and Singer, 1962). For example, high arousal characterizes both fear and happiness. Moreover, in music, arousal is known to be mainly driven by its tempo (Gomez and Danuser, 2007). The fact that respiration rate has been linked to tempo through what appears to be a general entrainment mechanism further contributes to discredit respiration rate as a clear index of musical emotions (Etzel et al., 2006). Although tempo is one of the main determinants of musical emotions, musical emotions depend on many other factors than simple tempo perception (Peretz et al., 1998). Thus, until the context-bound patterns of action that affect the autonomic responses to musical emotions understood and controlled, more specific measures of emotional reactions to music are needed to convince the sceptical cognitivist that music effectively induces emotions in the listener.

1.2. Hormonal responses

Neuroendocrine and hormonal responses constitute yet another type of involuntary response that can be linked to emotional feelings. Contrary to physiological responses, some hormones can be more readily associated with positive or negative emotion (Barak, 2006), such as cortisol with stress and negative emotions, or immunoglobin A (S-IgA) with relaxation and positive emotions (Watanuki and Kim, 2005). A few studies have found that listening to relaxing and pleasant music was associated with lower levels of cortisol (Khalfa et al., 2003; Miluk-Kolasa et al., 1994), lower plasmatic levels of β-endorphins (McKinney et al., 1997) and higher mu-opiate receptor expression (Stefano et al., 2004). However, those studies only compared music with a silent control condition. Therefore, the observed effect may be attributed to non-emotional aspects of the musical condition, such as distraction. Indeed, when two musical conditions are compared, no differences were found between music inducing positive or negative moods on levels of cortisol (Clark et al., 2001), nor between up- or down-lifting musical excerpts on levels of S-Iga, dopamine, norepinephrenine, epinephrine or number of lymphocites (Hirokawa and Ohira, 2003), suggesting that the differences previously observed were mainly related to non-specific aspects of the task. One exception is the study by Gerra et al. (1998), who observed higher levels of β-endorphins, adrenocorticotropic hormone (ACTH), cortisol, norepinephrine and growth hormone in youngsters listening to techno-music compared to classical music. However, these changes in neuroendocrine responses appeared to be mainly linked to the high arousal induced by the techno-music, combined with the novelty-seeking temperament of the participants. Neuroendocrine responses, although promising, appear to have the same limitations as autonomic responses.

1.3. Brain imaging

Brain imaging techniques provide yet another way to measure emotional reactions objectively. Studies using such techniques have shown that pleasant emotional reactions to music activate regions previously known to be involved in approach-related behaviors, such as the prefrontal cortex (Blood and Zatorre, 2001; Blood et al., 1999; Koelsch et al., 2006; Menon and Levitin, 2005), periacqueductal gray matter (Blood and Zatorre, 2001), and the nucleus accumbens (Blood and Zatorre, 2001; Menon and Levitin, 2005). Negative emotions in contrast activate regions involved in withdrawal-related behavior, such as the parahippocampal gyrus (Blood et al., 1999) and amygdala (Koelsch et al., 2006). Although these observations are fairly consistent with activations observed with other emotional inducers, brain activations alone do not allow for the distinction between processes involved in emotional perception and emotional feeling. Physiological changes that affect the body and its responses are necessary to demonstrate the induction of emotional feelings.

1.4. Present study

Although these studies demonstrate that some emotions are felt in response to music, the results do not definitely refute the cognitivist viewpoint, as many psychophysiological responses are inconsistent, and the responses that appear to induce the most stable responses (e.g., respiration rate or hormonal responses) may be influenced by other confounding factors, such as arousal or distraction. Finally, brain imaging techniques cannot solely discriminate emotional feelings from other aspects of emotional processing.

In order to demonstrate the induction of emotional feelings, involuntary changes that affect the body and emotional processing have to be observed in response to musical excerpts conveying different emotions. In this context, the startle reflex is a good candidate measure, as it has been extensively and successfully used to probe emotional reactions. It is an automatic defensive reaction to surprising stimuli and can be measured by the magnitude of the eye blink triggered by a loud white noise. As a response of the defensive emotional system, it is frequently used to test the efficacy of anxiolytic drugs (Winslow et al., 2007) or to explore emotional reactivity in affective disorders (Grillon and Baas, 2003). In normal individuals, it is typically enhanced by negative emotions and diminished by positive ones, using pictures (Lang et al., 1998), films (Kaviani et al., 2004), or sounds (Bradley and Lang, 2000) to induce emotions. The present study applied an affective startle modulation paradigm to musical stimuli and compared the effects of pleasant and unpleasant musical excerpts on the acoustic startle blink reflex. If emotions are induced during music listening, then the startle reflex should be larger and of shorter latency during unpleasant music compared to pleasant music.

Moreover, in order to measure music effects on emotional reactions, heart rate and skin conductance responses were also obtained along with facial expressions by assessing electromyographic (EMG) activity of the *zygomaticus major* (smiling) and the *corrugator supercilii* (frowning). Previous studies have shown that the activity of these muscles discriminated well between pleasant and unpleasant emotions elicited by pictures (Lang et al., 1998). Thus, it was expected that zygomatic activity would be higher during pleasant music, and corrugator activity to be more noticeable during unpleasant music (Witvliet and Vrana, 2007).

2. Methods

2.1. Participants

Sixteen participants (9F, 7M), aged between 20 and 40 years (M=25.1±9.3 years) took part in this study. None were musicians, all reported fewer than five years of musical training, and none claimed any regular practice of a musical instrument.

2.2. Musical excerpts

The musical excerpts used in this study were adapted from a prior study on pain modulation (Roy et al., 2008). Three 100 s excerpts of pleasant music and three 100 s excerpts of unpleasant music were selected from a pool of 30 musical excerpts. Each of the 30 excerpts had been previously evaluated by 20 independent participants on the dimensions of valence (on a 0='pleasant' and 9='unpleasant') and arousal (with 0='relaxing' and 9='stimulating'). Three highly pleasant and three highly unpleasant excerpts were selected. Since unpleasant excerpts were always judged to be arousing, all excerpts were selected in the high range of arousal. Pleasant excerpts were judged to be more