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Music-induced changes in functional cerebral asymmetries

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ABSTRACT

After decades of research, it remains unclear whether emotion lateralization occurs because one hemisphere is dominant for processing the emotional content of the stimuli, or whether emotional stimuli activate lateralised networks associated with the subjective emotional experience. By using emotion-induction procedures, we investigated the effect of listening to happy and sad music on three well-established lateralization tasks. In a prestudy, Mozart's piano sonata (K. 448) and Beethoven's Moonlight Sonata were rated as the most happy and sad excerpts, respectively. Participants listened to either one emotional excerpt, or sat in silence before completing an emotional chimeric faces task (Experiment 1), visual line bisection task (Experiment 2) and a dichotic listening task (Experiment 3 and 4). Listening to happy music resulted in a reduced right hemispheric bias in facial emotion recognition (Experiment 1) and visuospatial attention (Experiment 2) and increased left hemispheric bias in language lateralization (Experiments 3 and 4). Although Experiments 1–3 revealed an increased positive emotional state after listening to happy music, mediation analyses revealed that the effect on hemispheric asymmetries was not mediated by music-induced emotional changes. The direct effect of music listening on lateralization was investigated in Experiment 4 in which tempo of the happy excerpt was manipulated by controlling for other acoustic features. However, the results of Experiment 4 made it rather unlikely that tempo is the critical cue accounting for the effects. We conclude that listening to music can affect functional cerebral asymmetries in well-established emotional and cognitive laterality tasks, independent of music-induced changes in the emotion state.

1. Introduction

The precise way the left and the right cerebral hemispheres contribute to emotion processing remains unclear. While some evidence suggests that emotion processing relies entirely on the right cerebral hemisphere (Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Borod et al., 1998), other studies suggest a left hemispheric contribution for processing emotions of positive valence (Jansari, Rodway, & Goncalves, 2011; Stafford & Brandaro, 2010) and/or approach motivation (Alves, Aznar-Casanova, & Fukusima, 2009). The right hemisphere hypothesis originated from clinical observations of patients after unilateral lesions of the right cerebral hemisphere and postulates that the right hemisphere is superior for the expression and perception of emotion, regardless of emotional valance (Borod et al., 1998). The valence model of emotion lateralization was based on another set of lesion studies, suggesting that damage to the left frontal lobe was more likely to elicit negative/depressive emotional states. In contrast, patients who developed positive/manic emotional states were more likely to suffer from right hemispheric lesions, sparing the left (for a review see Davidson, 1995; Silberman & Weingartner, 1986).

To investigate emotion lateralization in healthy participants, the majority of studies focused on emotion perception, where participants have to identify the emotional content of auditory or visual stimuli, such as emotional facial expressions, emotional prosody and emotional words. For example, Van Strien and Morpurgo (1992) showed that the central presentation of threatening words, as compared to non-threatening words, can reduce the typical left hemispheric advantage in a verbal task that required participants to report strings of letters presented to either the left visual field (LVF) or the right visual field (RVF), corresponding to the right and left hemispheres, respectively. The authors concluded that negative emotion induction can selectively activate right hemisphere processes. Ferry and Nicholls (1997) tried to replicate this finding by examining the effects of positive and negative emotions on a lateralized gap detection task. For each trial, participants in this study saw an emotive word in the middle of the screen

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followed by a target (a square) presented to either LVF or RVF. Participants were required to indicate whether the square contained a gap in its outer edge or not. In contrast to Van Strien and Morpurgo (1992), this study did not show any evidence of RVF or LVF facilitation after presentation of positive or negative emotive stimuli, respectively. Therefore, it can be questioned whether the presentation of emotive words is sufficient to induce mood changes on a trial-by-trial basis.

The hemispheric substrates of perceiving emotional information are likely to be different from those involved in the subjective emotional experience (Davidson, 1995). Therefore, studies have investigated emotional lateralization by directly manipulating participants' current emotional state. Although several different emotion induction techniques have shown their effectiveness and validity, especially for inducing negative emotions (see Westermann, Spies, Stahl, & Hesse, 1996, for a comprehensive review and meta-analysis), only a small proportion of laterality studies have used mood-induction procedures. For example, Gadea, Gomez, Gonzalez-Bono, Espert, and Salvador (2005) investigated the effect of negative emotions on perceptual asymmetries by using the Velten procedure (Velten, 1968), which consisted of 60 self-referent statements gradually progressing from emotionally neutral to depressed. Perceptual asymmetries in this study were measured by a consonant–vowel dichotic listening task. In line with an increase in negative mood as measured by the PANAS mood scale (Watson, Clark, & Tellegen, 1988), together with a 15% increase in cortisol levels, the results revealed the right ear advantage (REA) typically found in this task, and indicative a left dominant language lateralization, to be significantly reduced. As concluded by Gadea et al. (2005), the results were compatible with Kinsbourne's (1970) attentional-activation model suggesting that negative mood induction activated the right hemisphere, subsequently facilitating the reporting of verbal stimuli presented to the left ear, thereby reducing the REA.

The current paper focuses on using music to induce emotional states. Music listening has been shown to effectively induce negative and positive emotions (Gerrards-Hesse, Spies, & Hesse, 1994; Westermann et al., 1996; Västfjäll, 2002; Juslin & Laukka, 2004; Lundqvist, Carlsson, Hilmersson, & Juslin, 2009). Critically, initial research was concerned with whether listeners simply perceived and processed the emotional content of musical stimuli, or whether listeners experienced changes in subjective emotional states in response to music (Juslin & Laukka, 2004). Lundqvist et al. (2009) yielded support for the latter notion. Participants listened to popular music with either a sad or happy expression, and it was found that happy music generated greater self-reported happiness, less sadness, more zygomatic facial muscle activity, greater skin conductance and lower finger temperature in contrast to sad music.

The effect of music on emotional states and its underlying functional brain activity has also been investigated using electrophysiological and neuroimaging techniques. For example, using electroencephalography (EEG), Schmidt and Trainor (2001) observed that asymmetry in frontal EEG activity differentiated the valence of musical emotions. Specifically, greater relative left frontal EEG activity was found after listening to joyful and happy musical excerpts, whereas greater relative right frontal EEG activity was found after listening to fearful and sad music. Although frontal EEG asymmetry did not differentiate the variation in the intensity of emotions between the musical excerpts, it was found that the overall frontal EEG activity decreased from fear to joy to happy to sad excerpts. Similarly, Altenmüller, Schürmann, Lim, and Parlitz (2002) investigated neural activation that accompanied participants' emotional response to positively and negatively valenced music stimuli from a range of genres (e.g., Jazz, Pop, classical music). Although Altenmüller et al. found a widespread bilateral fronto-temporal activation during music listening, this study found a strong lateralization when participants' emotional valence attributions of the perceived music were taken into account. Specifically, positive emotional attributions (e.g. "I like the music very much") were accompanied by an increase in left-temporal activation, whereas negative attributions (e.g. "I do not like the music at all") revealed more bilateral activation with preponderance of the right fronto-temporal cortex. "Although emotional valence attributions cannot simply be taken as *emotions* itself, the judgements are closely linked to the emotions felt during listening" (Altenmüller et al., 2002, p. 2249). Therefore, the results suggest that it was the participants' emotion experience rather than the emotional valence portrayed in music that was associated with lateralized brain activation.

In this context it is important to note that emotional experience and the emotional valence portrayed in music are not necessarily the same. In fact, many individuals enjoy listening to sad music (e.g., Vuoskoski, Thompson, McIlwain, & Eerola, 2011). Also, given that their findings were marginally affected by music genre, Altenmüller et al. (2002) further concluded that the actual auditory brain activation was more determined by their affective emotional valence than by acoustical fine structure.

Another study combined functional magnetic resonance imaging (fMRI) and EEG with subjective measures of emotional reactions during passive listening to pleasant and unpleasant music masterpieces (Flores-Gutierrez et al., 2007). Similar to Altenmüller et al. (2002), the authors revealed a left-lateralised network including primary auditory cortex, posterior temporal, parietal and prefrontal regions when participants reported pleasant feelings. Conversely, a right-lateralised network including right fronto-polar and paralimbic regions was found when participants reported unpleasant states. Taken together, emotion induction studies that look at lateralization after music listening partly support the valence hypothesis of emotion experience, suggesting that the frontal regions of each hemisphere contribute asymmetrically to the experience of emotion (Heilman, 1997): positive emotions, induced by listening pleasant music, are related to a relative increase of activation in the left frontal lobe, and negative emotions, induced by listening to unpleasant music, are related especially to an increase in right frontal lobe activation.

The aim of the present study was to elaborate whether the effect of listening to happy and sad music on lateralization in an emotional and non-emotional/attention task is mediated by the music-induced emotion. In line with a previous study that revealed Mozart's piano sonata (K. 448) to be able to induce happy emotions (Thompson, Schellenberg, & Husain, 2001), listeners in our prestudy rated Mozart's piano sonata (as used in the original *Mozart-effect* studies, Rauscher, Shaw, & Ky, 1993, 1995), and Beethoven's Op. 27, No. 2 (*Moonlight Sonata*) as expressing happiness and sadness, respectively. Four experiments were performed in which we investigated the effects of music listening, and corresponding changes in mood, on three well established laterality tasks: (i) an emotional chimeric faces task, originally developed by Levy, Heller, Banich, and Burton (1983) (Experiment 1), (ii) a lateralized spatial attention task (visual line bisection; e.g., Hausmann, Ergun, Yazgan, & Gunturkun, 2002; Hausmann, Corballis, & Fabri, 2003a; Hausmann, Waldie, Allison, & Corballis, 2003b) (Experiment 2), and (iii) a verbal consonant–vowel dichotic listening task (Hugdahl, 1995, 2003) (Experiments 3 and 4). With reference to the valence hypothesis, it was hypothesised that listening to the happy excerpt will increase participants' positive emotions, thereby increasing left frontal activation, and consequently diminishing the right hemispheric bias typically reported for the emotional chimeric faces (Experiment 1) and visual line bisection task (Experiment 2). In line with this prediction, we predicted that listening to the happy excerpt increases the typical REA,