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Differences between musicians and non-musicians in neuro-affective processing of sadness and fear expressed in music

Mona Park[a,b,e,1], Evgeny Gutyrchik[a,b,e,*,1], Yan Bao[f,g,b,e], Yuliya Zaytseva[a,b,e], Petra Carl[a,b], Lorenz Welker[b,d], Ernst Pöppel[a,b,e,f], Maximilian Reiser[c], Janusch Blautzik[c], Thomas Meindl[c]

[a] Institute of Medical Psychology, Ludwig Maximilian University, Goethestr. 31, 80336 Munich, Germany
[b] Human Science Center, Ludwig Maximilian University, Goethestr. 31, 80336 Munich, Germany
[c] Institute of Clinical Radiology, Ludwig Maximilian University, Goethestr. 31, 80336 Munich, Germany
[d] Institute of Musicology, Ludwig Maximilian University, Goethestr. 31, 80336 Munich, Germany
[e] Parmenides Center for Art and Science, Kirchplatz 1, 82049 Pullach, Germany
[f] Department of Psychology, Peking University, 100871 Beijing, China
[g] Key Laboratory of Machine Perception (MoE), Peking University, 100871 Beijing, China

HIGHLIGHTS

- Musicians rate "negative" emotions expressed in music as more arousing.
- For sadness, musicians show higher activation in the right prefrontal cortex.
- For fear, musicians show higher activation in the right parietal cortex.
- No specific modulations were observed in response to happiness.

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ABSTRACT

Music is known to convey and evoke emotional states. Musical training has been argued to lead to changes in neural architecture and enhanced processing of emotions. It is not clear, however, whether musical training is also associated with changes in behavioral and neural responses to musically conveyed discrete emotions. Using functional magnetic resonance imaging, we investigated the responses to three musically conveyed emotions (happiness, sadness, fear) in a group of musicians and a group of non-musicians. We find that musicians rate sadness and fear as significantly more arousing than non-musicians, and that musical training is associated with specific neural activations: In response to sadness expressed in music, musicians show activation increases in the right *prefrontal* cortex, specifically in the superior and middle frontal gyri. In response to fear, musicians show activation increases in the right *parietal* cortex, specifically in the supramarginal and inferior parietal gyri. No specific activations were observed in response to happiness. Our results highlight the strong association between musical training and altered processing of "negative" emotions on both the behavioral and on the neural level.

1. Introduction

Using music in research on emotions has become increasingly popular and numerous neuro-imaging studies have been investigating the neural correlates of musically conveyed emotions. Similar to the brain structures involved in the processing of emotion in other domains [1], distinct neural networks have been associated with the processing of musically conveyed emotions including the amygdala, the hippocampus and other areas of the limbic system, the parahippocampal gyrus, the orbitofrontal and cingulate cortex, other paralimbic structures as well as the insula (for an overview see [2]).

The processing of musically conveyed emotions is assumed to be influenced by a number of factors: musical features, performative and contextual aspects; but also listener specific characteristics such as personality traits, musical talent or musical expertise have been proposed to mediate music emotion processing [3,4]. Trained

* Corresponding author at: Human Science Center, LMU Munich, Goethestr. 31, 80336 Munich, Germany. Tel.: +49 89 2180 75 626; fax: +49 89 2180 75 615.
E-mail address: evgeny.gutyrchik@med.uni-muenchen.de (E. Gutyrchik).
[1] These authors contributed equally.

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musicians have been shown to exhibit more refined cognitive skills (see [5] for an overview), and seem to also be more competent in the processing of emotion. Musicians are trained to comprehend emotional content and to express emotion through music by making use of musical features including tempo, harmony, or intensity [6]. Musicians also show increased proficiency in perceiving emotions specifically related to music, e.g. in pitch processing [7] and in the perception of emotional expressions in musical performance [8]. Furthermore, musicians are assumed to show stronger emotional response to music [9] and apparently experience more musically induced chills [10].

How are these differences in the experience and processing of emotions in music between musicians and non-musicians represented on the neural level? Anatomically, musicians' brains have been shown to differ significantly from non-musicians' brains in structure and functions [11] and the musician's brain is regarded as a "model of neuroplasticity" (e.g. [12]). Gaser and Schlaug [13] assume that these differences are structural adaptations due to continual rehearsal and extended skill acquisition which consequently lead to altered neural activation in music processing. Schmithorst and Holland [14] found that musicians and non-musicians recruit distinctly different neural networks, including visual association areas and the inferior parietal lobules for processing of musical harmony – a key feature determining the affective quality of a musical piece. However, no study has as of yet explicitly investigated differences between musicians and non-musicians in the neural processing of musically conveyed discrete emotions. In order to gain understanding of these potential differences, we used functional magnetic resonance imaging (fMRI) to scan a group of musicians and a group of non-musicians while listening to musical excerpts validated to convey happiness, sadness, and fear. To also assess differences on the behavioral level, participants rated each excerpt on the affective dimensions valence (pleasantness, varying from negative to positive) and arousal (psychological and physiological activation, varying from low to high) outside of the scanner. We expected to find differences between musicians and non-musicians in the processing of music expressing happiness, sadness and fear on the behavioral and on the neural level. We expected differences in behavioral ratings to reflect musicians' improved competence in processing of musical emotions and we assumed to find differences between musicians and non-musicians in brain activation in neural networks involved in musical emotion processing.

2. Material and methods

2.1. Participants

24 young healthy volunteers, 12 musicians (7 female, mean age = 20.25, SD = 1.76 years) and 12 non-musicians (7 female, mean age = 19.00, SD = 0.60 years) participated in the study. All participants were right-handed, with no report of neurological or psychiatric illness, head trauma or psychoactive substance abuse and had no contraindications for MRI (e.g. pacemaker implant, pregnancy). In the group of non-musicians no participant had any previous formal musical training. In the group of musicians, all participants had previous formal music training (mean years of training = 13.83, SD = 2.58 years) in a variety of musical instruments (stringed instruments: 29%, accordion: 24%, piano: 35%, flute 12%). Musicians did not differ from non-musicians in general intelligence, independent t-test: t (22) = −0.65, $p > .05$, health, $t(21) = 1.88$, $p > .05$, or in mood before, Mann–Whitney U test: $z = 1.17$, $p > .05$, or after the experiment, $z = -0.06$, $p > .05$. The study was performed in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and was approved by the ethics committee of the Medical Faculty of the University of Munich. All participants signed an informed consent.

2.2. Material

A set of 24 musical excerpts composed and validated to express the basic emotions happiness, sadness and fear [15] was used as in Park et al. [4]. As an intermediary condition, we used pieces validated to convey a calm state. All excerpts are composed in pseudo-romantic or pseudo-classical style with computer generated piano timbre. "Happy" excerpts are composed in major mode with an intermediate to fast *tempo*, in medium to high pitch. "Sad" excerpts are written in minor mode at an average slow *tempo*. "Scary" excerpts are set in minor mode, *tempo* varies widely and some have irregular rhythms or are dissonant (for further details on the compositions refer to [15]). The emotional excerpts have been found to be clearly distinguishable with regard to the dimensions of valence and arousal. "Happy" excerpts are perceived as arousing and pleasant, "scary" excerpts as arousing and unpleasant, and "sad" pieces are perceived as pleasant and low in arousal [15]. The original compositions by Vieillard et al. [15] vary between 12 and 14 s. To provide comparable and relatively long duration times, two original compositions of a given emotional quality were combined to last about 21 s each.

2.3. Experimental procedure

As described in Park et al. [4], participants listened to the musical stimuli binaurally via pneumatic, noise attenuating and non-magnetic headphones during scanning. Sound level was individually adjusted to be comfortable. Light was dimmed to suppress further visual stimulation in the scanner. Participants listened passively to the musical excerpts and were asked to keep their eyes closed during the experiment. During each of three measurement sessions (runs) three emotional qualities (happiness, sadness, fear) and an intermediary condition (calm) were presented twice (two different compositions per run) resulting in six iterations of each condition over all three runs. The musical stimuli were presented under computer control in a pseudo-randomized order. To control for order effects, two versions of stimuli sequences were created and participants were randomly assigned to either one of them. Each stimulation-interval was followed by a pause. After scanning, participants listened to the same set of excerpts again and rated each excerpt on the affective dimensions valence (feeling pleasant to unpleasant) and arousal (feeling activated, from high to low) using the self-assessment manikin, a five-point pictorial, non-verbal affective rating system [16]. Participants were instructed to indicate how they felt when listening to each excerpt by marking a picture on each dimension that would best reflect their feelings to the excerpt.

2.4. Image acquisition and fMRI data analyses

MRI was performed using a 3 T whole body system (Magnetom VISION, Siemens, Erlangen, Germany) at the University Hospital of LMU Munich. The scanner was equipped with a standard TIM head coil and the participant's head was securely but comfortably fastened by a foam cushions in order to minimize head movements. For acquiring the blood oxygen level dependent (BOLD) functional images, an T2*-weighted Echo-Planar Imaging (EPI) sequence was used with the following parameters: repetition time (TR) = 3000 ms, echo time (TE) = 30 ms, flip angle (FA) = 80°, number of slices = 28, slice thickness = 4 mm, inter-slice gap = 0.4 mm, interleaved acquisition, field of view (FOV) = 192 mm × 192 mm, matrix = 64 × 64, in-plane resolution = 3 mm × 3 mm. Functional images were obtained in axial orientation, covering the whole