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The influence of music and music therapy on pain-induced neuronal oscillations measured by magnetencephalography

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ABSTRACT

Modern forms of music therapy are clinically established for various therapeutic or rehabilitative goals, especially in the treatment of chronic pain. However, little is known about the neuronal mechanisms that underlie pain modulation by music. Therefore, we attempted to characterize the effects of music therapy on pain perception by comparing the effects of 2 different therapeutic concepts, referred to as receptive and entrainment methods, on cortical activity recorded by magnetencephalography in combination with laser heat pain. Listening to preferred music within the receptive method yielded a significant reduction of pain ratings associated with a significant power reduction of delta-band activity in the cingulate gyrus, which suggests that participants displaced their focus of attention away from the pain stimulus. On the other hand, listening to self-composed "pain music" and "healing music" within the entrainment method exerted major effects on gamma-band activity in primary and secondary somatosensory cortices. Pain music, in contrast to healing music, increased pain ratings in parallel with an increase in gamma-band activity in somatosensory brain structures. In conclusion, our data suggest that the 2 music therapy approaches operationalized in this study seem to modulate pain perception through at least 2 different mechanisms, involving changes of activity in the delta and gamma bands at different stages of the pain processing system.

1. Introduction

Pain is an unpleasant feeling that can be influenced by various psychological and contextual factors. Different methods in psychotherapy target emotional modulations to promote pain relief or strengthen the capacity to cope with pain. An interesting approach is the integration of music. The use of music for healing has been known throughout the history of medicine in many cultures. The oldest testimonies can be dated back to the fourth millennium BC in the Egyptian culture [24], but the best-known report might be found in the Old Testament about King Saul's convalescence from depression with the help of David playing the harp. Further sources from the Greek, Roman, Arabian, and shamanistic healing procedures document music as therapy for various therapeutic or rehabilitative goals [9,29]. Notably, different music styles or harmonic patterns are capable of generating quite different mood states [18], depending on individual experiences with music, memories, and personal preferences for certain music styles. Music is considered to recruit neural circuits similar to those previously associated with emotional states [3]. Despite numerous clinical reports of benefits of music in management of different pain conditions [5,7,26,27], the underlying neuronal mechanisms are widely unknown. Neuroimaging studies have revealed anatomical pathways involved in the modulation of pain by distraction or higher-order cognitive processes, the latter involving phenomena such as placebo-induced analgesia [2], perceived control over pain [35], or religious beliefs [36].

In this study we used repetitive painful laser stimuli that reliably activate pain-relevant brain structures as revealed by both electroencephalography (EEG) and magnetencephalography (MEG) [21]. The design of our study aimed to conceptualize important features of 2 different concepts of music therapy within an experimental pain paradigm. First, the so-called receptive music therapy [31] uses preferred music to promote associations of well-being opposing the pain. Second, we used a method referred to as entrainment [8], which involves active participation of patients in composing and performing music together with a

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therapist. Pain reduction in the receptive method is assumed to be primarily mediated by distraction. In contrast, within the entrainment method, the use of self-composed music with opposing valences of pain and healing music requires an intense interaction between music therapist and participant on promoting the capability of actively controlling the pain. Distraction, which we assume to mainly inhibit pain by the receptive approach, has been found to reduce the amplitude of late laser-evoked potential (LEP) components generated in the cingulate cortex [19]. We hypothesize that laser-evoked activity in the delta band that mainly contributes to the late LEP component should correlate with pain under the influence of the receptive method. No study thus far has examined the effects of active coping on pain-evoked potentials or MEG fields. However, it is conceivable that the clear difference of attentional engagement away or toward the pain between the 2 approaches of music therapy might influence pain perception differently and accordingly differ with respect to neuronal oscillations within the described pain matrix.

2. Materials and methods

2.1. Participants

Before the start of the experiment, the protocol was approved by the local ethics review board. Twenty right-handed participants (10 female, age 27.2 ± 4 years) were involved in this study after they provided written informed consent. All participants were tested for the absence of normal hearing and were free to terminate the experiment at any time. Additionally all participants were interviewed for musicality, whether they regularly listen to music or play any instrument. Only 1 participant played an instrument professionally.

2.2. Music therapy

The entrainment music therapy method involves a defined procedure consisting of 4 phases: (1) an extensive pain interview with indication for treatment and formulation of the therapeutic contract; (2) the composition of a so-called "pain music" and "healing music" with the help of a variable set of instruments that are provided; (3) the application phase, in which the therapist plays the individually composed music for the patient; and (4) the reflective discussion of the previous phases. For further information on the procedure and an explanatory approach see Metzner [20].

In our experiment, the pain and healing music were individually composed specifically for the experimental laser pain, which was applied to the participants before the composition procedure (see also experimental protocol). During the composition procedure, the participants composed their pain music and healing music together with the music therapist in a specially designed music therapy room, which was equipped with different instruments such as flutes, guitar, piano, cello, and various percussion instruments. Either the participants picked the instruments by themselves or the music therapist chose the instruments according to the sound the participants had in mind reflecting the laser pain or healing music. Then these sounds and musical pieces were played together and composed with the music therapist separately for the pain music and the healing music. When the music met the participants expectations as pain music and healing music, the composition was digitally recorded for the main MEG experiment. For the receptive music therapy, subjects were asked before the experiment to provide their favourite music, which usually induces well being, on CD or an MP3 stick.

2.3. Music stimuli

The digitized music was cut into 1-min epochs and normalized for overall spectral power; to avoid systematic differences in physical properties of music, we applied a normalization procedure. The intensities of the sounds were adjusted by equalizing the root mean square power across all sound files. To avoid onset and offset clicking transients, the sound files were windowed with a linear 10-ms rise and fall time. An ANOVA of the Fast Fourier transformed music did not show any differences in volume or spectral power in different frequency bands across the resulting normalized epochs. In a nonstatistic descriptive manner, the music varied between the participants and between individual pain and healing music. In general, the pain music can be best described as comprising sharp high-pitch sounds, whereas the healing music consisted of warm and calming motifs (see Supplementary Audio Files online). During the experiment, the music was presented at 60 dB using a custom-built MEG-compatible auditory earphone device (Stax SRM-212 Driver Unit and Stax SR-003 electrostatic transducers, Stax Limited, Miyoshi (Saitama Prefecture), Japan), which was connected via plastic tubes to the participants' ear. For control conditions, healing and pain music of 1 other participant as well as a no music condition were presented during the experiment. Hence, each participant was exposed to his or her own healing music, his or her own pain music, his or her own preferred music, alien pain music, alien healing music, and no music during the experiment (Fig. 1).

2.4. Physiological data and reaction times

Before the MEG experiment, the influence of music was tested for different arousal and attention parameters. Heart rate, skin conductance, body temperature, and breathing rate were acquired during listening to the 5 different music conditions using a Biopac MP35 device (Biopac Systems, Inc., Goleta, CA). Furthermore, a reaction time task was performed while listening to the music. The participant had to fixate a cross and press a button as fast as possible when the fixation cross changed to a cycle symbol. Visual stimuli and music were controlled and presented on the computer screen using Presentation software (Neurobehavioral Systems, Albany, CA).

2.5. Pain stimuli

We delivered brief infrared laser stimuli of 1-ms duration and a beam diameter of 5 mm to the dorsum of the left hand using a thulium laser (wavelength 2 μm, StarMedTec, Starnberg, Germany). Individual pain thresholds were determined using 3 series of increasing and decreasing stimuli. Beginning at 160 mJ, we used a step size of 20 mJ. The procedure of determining individual pain threshold was important to make the test participants familiar with the laser stimuli and instruct them to clearly distinguish between nonpainful and painful laser stimuli. Pain was defined as a light pin prick or burning sensation. During the experiment, 2 different intensities were used that were clearly in the painful range of all participants, a laser energy of 450 mJ for the low pain stimuli and 600 mJ for the high pain stimuli. Studies examining the effects of analgesic drugs on pain-evoked potentials proved the use of 2 different stimulus intensity within a randomized series to minimize habituation effects [4]. The participants rated the laser pain stimulus intensity and unpleasantness by filling up the x and y scale of a coordinate system using a joystick with their right hand (Fig. 1). Thus, the participants were able to rate sensory discriminative and affective motivational components of pain within 1 joystick move. The individual rating was displayed online on a screen using a square within the coordinate system, which changed size and colour depending on the strength of the intensity rating (labeled as painful, from pale red to dark red) and the unpleasantness rating (labeled as unpleasant, from pale blue to dark blue). Hence, a maximal unpleasant and painful pain rating was displayed with a violet square of maximal size (Fig. 1C).