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Common Components in Perception and Imagery of Music: an EEG study

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ABSTRACT

Background and Aims

Mental imagery has been a subject of investigation for a considerable time. Recent investigations suggest that there is overlap in the electrical brain activations for imagination and perception of music (Schaefer et al., 2009, 2011a; Vlek et al., 2011). The current work is a new analysis of four datasets that investigate imagination of music, aiming to clarify the common processes in perception and imagination of music for stimuli of varying complexity. These studies, using electroencephalography (EEG), look at various aspects of music, namely rhythmic accents, monophonic melodies, more complex rhythms or natural music stimuli. By decomposing the event-related EEG data, widely differing datasets may be investigated using the same analysis method. We first used Principal Component Analysis (PCA), and expanded on this method using PARAFAC tensor decomposition, which allows to add the task into the decomposition, but does not make assumptions of independence or orthogonality, and calculate the relative strengths of the identified components for each task.

Method

Four experiments were analysed, each containing a perception and an imagery condition for auditory material of varying musical complexity. The Imagined Accents were three different actual or imagined accent patterns on a running metronome, whereas Imagined Melodies used four isochronous, monophone simple melodies. The Imagined Rhythm stimuli consisted of five different rhythmic phrases and for Imagined Natural Music, two well-known phrases were used (start of Tchaikowski's Nutcracker March, and the opening phrase of 'Day Tripper' by the Beatles). Details on the participants, experimental procedure and stimuli can be found in Vlek et al (2011), Schaefer et al (2009), Desain (2004), and Schaefer et al (2011b) respectively. As each experiment was carried out under different conditions, the preprocessed event-related potentials were used. The preprocessing procedures can be found in the aforementioned papers. For both decomposition methods, the number of relevant components was estimated through a 9-fold crossvalidation procedure.

Results

Although the experimental set-ups varied considerably, decomposition of the event-related potential (ERP) over both tasks (imagery and perception) with PCA shows that similar component distributions are found to explain most of the variance in each dataset. All datasets show a fronto-central and a more parietal component as the largest sources of variance (explaining 76% to 93% with 3-4 components), fitting with projections of the areas reported to be sources of the N1/P2 complex, and some additional temporally and laterally distributed components. Using the tensor decomposition, somewhat less of the variance is (61-89%), and the fronto-central and parietal components are the only distributions that are found here, indicating them to be the most relevant between the tasks. This shows the main PCA components to be further decomposable into parts that load fully on to either the perception or imagery task, or both, with differing time-courses, thus adding more detail to the first set of results. Both components are shown to have multiple parts that are differentially active during perception and imagination.

Conclusions

Using four different experiments, common components are found between perception and imagination of auditory materials of varying musical complexity. Given the differing nature of the hardware set-ups as as well as the stimulus material, the decomposed activation patterns are strikingly similar, and shared components can be found for different levels of the stimulus.

As the fronto-central distribution is also reported as the projection of the N1/P2 ERP complex, itself a composite response, it is likely that multiple areas contributing to this well-known response are active for both perception and imagination of auditory material. Considering the stimulus differences, exploratory interpretations suggest that frontal activation is more specific to rhythmic processing whereas pitch structure appears to be more centrally projected, for both perception and imagination.

The tensor decomposition is shown to be a promising tool, offering an opportunity of identifying subprocesses in the brain that are not independent, in concurrence with the concept of the brain as a causally dense system.

Keywords

Music Imagery, EEG, PCA, PARAFAC

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