Lateralization of brain function in cognitive music processing of chord versus rhythm

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Introduction

Pitch, rhythm, chord, and melody are the basic components of music. Former brain functional studies on music cognition included the proficiency effects [1], the imagined instrumental performance [2], and the relationship between music and motor or frontal cortical activations [3]. Different hemispheric dominance of primary auditory cortex in cognitive processing of melody and rhythm has also been shown [4]. In this study, we used an interlaced fMRI paradigm design to suppress the auditory activation signals, such that music cognitive functions could be better perceived. Specifically, we investigated the difference in brain functions between chord distinguishing and rhythm recognition.

Material and Method

Seven amateurs (four males, three females, 22 ± 1.41 yr) with past music training in instrument performance and capable of chord and rhythm distinguishing were recruited. The chord distinguishing stimuli consisted of three-note C-major chords played sequentially, plus discordant ones composed of three neighboring semitones interleaved in random order. The rhythm distinguishing stimuli included a mixture of triplet, syncopation, and dotted notes played at a tempo of 120 beats per minute. The block design of the paradigm was shown in Fig.1, where a rhythm test period (64 sec) was inserted during the rhythm distinguishing task to ensure the volunteers concentrating on the stimulation (through vocal communication). All subjects were asked to perform both the chord and rhythm tasks. Image acquisitions were performed on a 3T system (Philips Achieva), using T2*-weighted EPI (TE=35ms) with scanning interval of 8 seconds. The number of time frames was 96 in rhythm session and 64 in chord session, each containing 12 slices for whole-brain coverage at a voxel size 3x3x7 (mm^3). High-resolution whole-brain EPI with voxel size 2x2x2 (mm^3) was collected for inter-subject coregistration and normalization. Data analysis was performed using spm2, with the 8 images during the rhythm test period removed to avoid confounding interference. The final image number included for both analyses was hence 64.

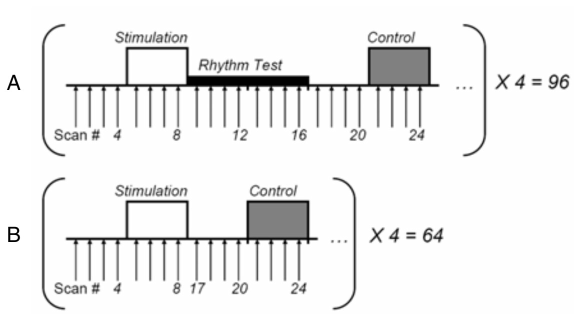

Fig 1. The paradigm used for the distinguishing of rhythm (A) and chord (B). The stimulation and control conditions represent recognition processing and passive listening, respectively.

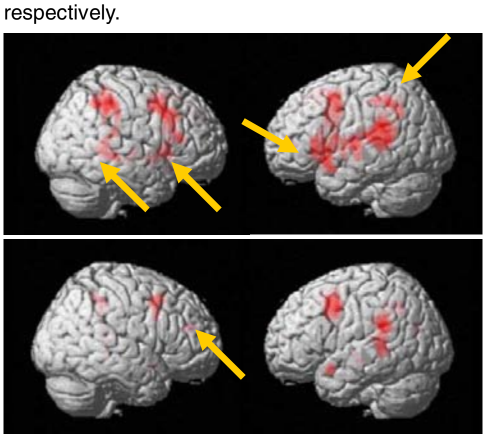

Fig 2. The activation sites of chord distinguishing (top row) and rhythm recognition (bottom row). Analysis was done by spm2 with corrected p<0.01 and extent threshold =10 voxels. The different activation regions between two tasks were pointed by arrows (see texts).

Results

The activation regions of the two tasks were shown in Fig.2. The Brodmann's area (BA) 6 was activated in both tasks with left-side dominance, with activation level in chord distinguishing substantially higher than in rhythm recognition. BA40 activation was also found in both tasks, with similar tendency in lateralization and activation level. BA38, 22, and 9 were only activated on left side in rhythm test, but bilaterally activated in chord distinguishing. As a side note, for BA9, the activation was constrained only near the middle frontal gyrus without extending to the superior frontal gyrus. Task-related difference was further found on BA44 and 45. BA44 was bilaterally activated only in chord distinguishing task, while slight activation was observed on the right side of BA45 in rhythm recognition task. BA41 and 42, believed to be the auditory receptive cortex and integration region, were activated on the left side in chord distinguishing task.

Discussion and Conclusion

The recognition of chord and rhythm were functionally different because of their unique properties: A chord contains information in pitch and harmony, while rhythm consists of variations and combinations in tempo. It was believed that cognitive processing of chord distinguishing was generally more difficult and complex than rhythm recognition. Our fMRI results showing larger activation regions in chord distinguishing than that of rhythm recognition seemed to support the general perspective. The behavior of left dominance suggested that the left hemisphere of brain may have close association with music processing. In particular, BA6 and 40 seemed to be functionally important in cognitive music processing of both chord and rhythm. Activations in BA44 (chord) and 45 (rhythm), covering approximately the Broca's area in charge of motor coordination for speech and language processing [5], suggested that both chord and rhythm were embedded in subjects with training in music performance as specific forms of language symbols. Finally, we believe that the activations of BA41 and 42 in chord distinguishing implied auditory integration, because activations due to auditory receiving should have been suppressed in the interlaced design, as evidence in the rhythm task.

In conclusion, common lateralization propensity between rhythm and chord stimulation was found in our subjects, with the activation regions of chord distinguishing substantially larger than rhythm stimulation. Results from our study would help a better understanding of the cognitive process involved in the key elements in music. The interlaced design of fMRI is an effective technique toward cognitive investigations of music processing in the brain.

References

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