fMRI Study to Investigate Spatial Correlates of Music Listening and Spatial-Temporal Processing

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Purpose

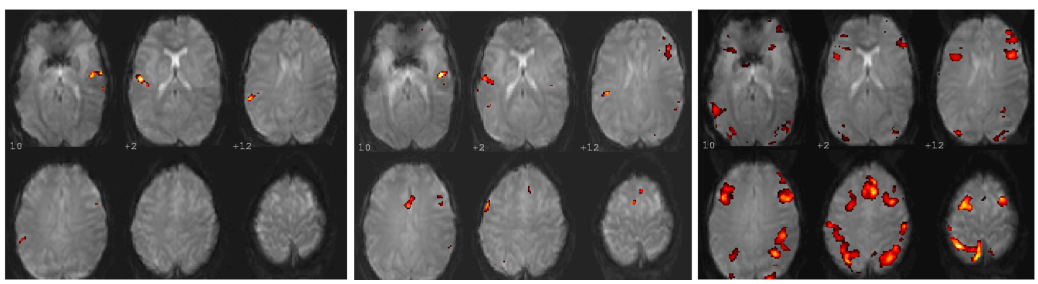
It is predicted that exposure to music might excite and enhance the cortical firing patterns used in spatial-temporal reasoning [*Leng X & Shaw GL (1991) Concepts Neurosci. 2, 229*]. This has been supported by behavioral experiments demonstrating the Mozart effect -a causal short-term enhancement of spatial-temporal reasoning following exposure to the Mozart Sonata (K.448) [*Rauscher FH, et al, (1993) Nature 365, 611; (1995) Neurosci Lett 185, 44*]. An EEG coherence study of the Mozart effect revealed the presence of right frontal and left temporo-parietal coherent activity induced by listening to the Mozart sonata (not seen with control stimuli) and carrying over to the spatial-temporal task [*Sarnthein J, et al, (1997) Neurol Res 19,107*]. In our previous study, we have conducted fMRI experiments, examining the cortical activity that occurred in subjects during exposure to the Mozart Sonata as compared to control (piano and Beethoven's Fur Elise) music [*Bodner M, et al, Neurol Res, October, 2001. 23 (7): 683-690*]. In that study, subjects showed increased cortical activity in prefrontal, frontal, parietal and occipital cortices in addition to temporal lobes while listening to Mozart's sonata. In this present study, we added spatial-temporal processing (STP) tasks in our experiments to study cortical regions that are common to both (STP) and listening to Mozart's sonata. In similar fMRI studies of music, Uftring et al (*Proc. ISMRM 2002, p 1468*) reported activation in the frontal and parietal lobes in addition to auditory cortex when an emotionally arousing music selected by the subject was played. Brooks et al (*Proc. ISMRM 2002, p 1501*) showed that in mental object rotation tasks trained musicians showed activity in Broca's area (BA 44) orbitofrontal area (BA 11), parietal lobule and premotor areas, which were not seen in non-musicians. Several other studies were published that suggest visuo-spatial processing areas may share common neural substrates with musical ability (*Hassler M. (1992) Psychoneuroendocrino, 17, 55, Johnson J., (1998), Neurol. Res. 20, 666*). Therefore, our goal is to investigate these common neural sites that are recruited in visuo-spatial information processing and certain music pieces.

Methods

Two healthy female volunteers were scanned using a 3T Magnex magnet interfaced with a Philips/Marconi console. Before each study, subjects signed a written consent that was approved by the IRB. Both subjects had no prior musical training. For data acquisition, 2D EPI sequence was used with TR=3s, TE=31ms. 5 mm thick, 17 and 23 contiguous axial slices were collected from the two subjects, respectively. This covered the entire cortex (in subject 1, cerebellum was not included due to limited linearity of the head gradient coil). Native in plane matrix size was 94*64 with a FOV of 240mm. Auditory stimuli was delivered by a Pentium PC that is connected to an audio amplifier that drives a pneumatic earphone transducer (www.etymotic.com). The headset used in the study attenuates external noise by 25 dB (Newmatic Sound Systems). Each subject listened to two music pieces, Mozart's sonata and Beethoven's Fur Elise. Four fMRI sessions were performed with each subject on two separate days. On the first day, they listened to one of the music pieces followed by the STP session. In this part, different paper-fold-and-cut tasks are displayed on an LCD screen placed inside the magnet and subjects were asked to mentally unfold them. On the second day, the experiment was repeated with the other music followed by another sequence of paper folding tasks. Each music session started with 30 s of baseline, followed by 4 repetitions of the music for 108s each, and with 30s baseline (silence) periods in between and at the end. Therefore, each music session lasted 9min, 42s. For STP tasks, 4 different puzzles were projected for 30s each, followed by a 30s baseline where a blank screen was displayed. This lasted 4.5 minutes. The application of stimuli was synchronized to the data acquisition by a TTL pulse generated by the scanner.

Results

Prior to statistical analysis, the images were realigned for motion compensation. Then, they were analyzed by General Linear Model that is implemented by SPM2 software [*Friston, K.J. et al, Human Brain Mapping,(1994) 1, 153-171.*]. Activation maps were generated for voxels that survive a corrected p threshold of 0.05. In both subjects, it is observed that Beethoven's Fur Elise activated only regions in the auditory cortex. On the other hand, both subjects showed increased activity in the prefrontal cortex, and also in the occipital lobe while listening to Mozart's sonata. Fig. 1 illustrates data from the 2nd subject. We also generated maps of brain activity that are common to both listening to Mozart's sonata and performing STP. This was done by masking maps of STP results with those of Mozart sessions (p=0.0001, uncorrected for Mozart activation map and p=0.05, corrected for STP map). Fig. 2 illustrates axial slices with sites of neuronal activity common to both tasks overlaid in hot colors for both of the subjects. The two subjects' data were spatially normalized and then entered into a fixed effects analysis to generate the maps shown in Fig.2.



(a) (b) (c)

Fig.1 maps showing sites of activity with (a) Beethoven's music; (b) Mozart's sonata, (c) Spatial-temporal task

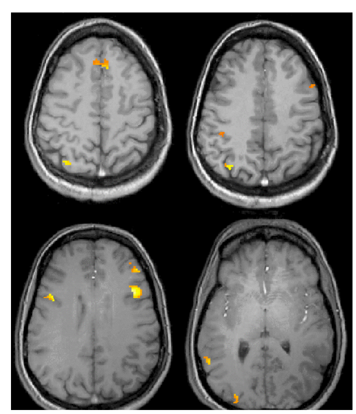


Fig.2. Sites of activity common to both STP and listening to Mozart's sonata

Discussion

In this preliminary study, we have shown that listening to the Mozart Sonata resulted in activation of specific regions in prefrontal, frontal and occipital cortices (in addition to auditory cortex), which was in accord with our earlier fMRI study, in which we studied 7 volunteers. Since we did not observe prefrontal activation for Beethoven's popular piano music, it is expected that this activation was not due to anticipations from either knowing the piece, some general expectation because the piece was classical, or some type of general build-up or afterdischarge of activity. These results demonstrate that Mozart's sonata activated cortical regions involved in higher order cognitive processes that were not seen in control music (in our previous study, we had tested two different control music, both of which activated only auditory cortices). Although a complete overlap of Mozart related activation with areas recruited in solving STP puzzles was not observed, the areas commonly activated in Mozart listening and STP included dorsolateral prefrontal cortex (Brodmann areas 9,46) which is known to be critical in temporal and spatial organization and supporting the cognitive processes of working memory and motor set that allow the brain to bridge time between percepts and action. Common areas also include occipital lobe (Bordmann areas 18 and 19), which process visual information, including "mental imagery". Although we studied only two subjects for this particular experiment in which we included STP tasks, we obtained consistent results from both data sets. Moreover, similar activation patterns were observed in our earlier fMRI study. We focused our current work on collecting more data from a larger pool of subjects and seeking other music pieces from other composers, which might yield patterns of activity in areas involved in higher order processing of information.