Cortical Network Activated by Korean Traditional Opera (*Pansori*): A Functional MRI Study

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Abatract

The Pansori is a Korean traditional vocal music that has a unique story and melody which converts deep emotion into art. It has both verbal and emotional components, which can be coordinated by large-scale neural network. The purpose of this study is to illustrate the cortical network activated by a Korean traditional opera, *Pansori*, with different emotional valence using functional MRI (fMRI).

Nine right-handed volunteers participated. Their mean age was 25.3 and the mean modified Edinburgh score was +90.1. Activation tasks were designed for the subjects to passively listen to the two parts of *Pansories* with sad or hilarious emotional valence. White noise was introduced during the control periods. Imaging was conducted on a 1.5T Siemens Vision scanner. Single-shot echoplanar fMRI scans (TR/TE 3840/40 ms, flip angle 90, FOV 220, 64 x 64 matrix, 6 mm thickness) were acquired in 20 contiguous slices. Imaging data were motion-corrected, coregistered, normalized, and smoothed using SPM-96 software.

Bilateral posterior temporal regions were activated in both of *Pansori* tasks, but different asymmetry between the tasks was found. The *Pansori* with sad emotion showed more activation in the right superior temporal regions as well as the right inferior frontal and the orbitofrontal areas than in the left side. In the Pansori with hilarious emotion, there was a remarkable activation in the left hemisphere especially at the posterior temporal and the temporooccipital regions as well as in the left inferior and the prefrontal areas. After subtraction between two tasks, the sad *Pansori* showed more activation in the right temporoparietal and the orbitofrontal areas, in contrast, the one with hilarious emotion showed more activation in the left temporal and the prefrontal areas.

These results suggested that different hemispheric asymmetry and cortical areas are subserved for the processing of different emotional valences carried by the *Pansories*.

Key words: Pansori, Emotional valence, Functional MRI, Neural network

Introduction

Neuroimaging is increasingly being used to explore the cognitive aspects of brain activity. Sevaral technologies are currently available for brain activation studies, however, functional magnetic resonance imaging (fMRI) is gaining popularity because of its superior time resolution and finer spatial resolution (Le Bihan and Karni, 1995). The technique is non-invasive and it is possible to take repeated multiple scans in the same individual.

With the development of functional neuroimaging technique, it became possible to "observe" cognitive activity in the intact human brain and numerous studies were investigating the neural substrates of attention, perception, language, and memory in normal and brain-injured persons (Cabeza and Nyberg, 1997). Cortical language network and its left-ward asymmetry were defined by many researchers as well as the role of right hemisphere for the emotional prosody of human language (Petersen *et. al.*, 1988; Binder *et. al.*, 1995, 1996; Wildgruber *et. al.*, 1999; Buchanan *et. al.*, 1999).

However, imaging of the neural substrates of human emotion still remains one of the challenging areas and has started to have attention recently. Studies on fear (LaBar et. al., 1998) and emotional facial expression (Whalen et. al., 1998) demonstrated the activation of amygdala in associative emotional learning tasks and in nonconscious emotional process. Modulation of activities of amygdala to food stimuli under hungry state was also reported by the fMRI study (LaBar, 1999). Lane *et. al.*, (1997) explored the neural substrates of positive and negative emotional systems using PET. In their study, pleasant and unpleasant emotions were distinguished from neutral emotion by significant activation in the medial prefrontal cortex, thalamus, hypothalamus, and midbrain. The unpleasant one was distinguished from the neutral or pleasant emotion by activation of the bilteral occipito-temporal cortex, cerebellum, left parahippocampal gyrus, hippocampus, and amygdala, whereas the pleasant one was distinguished from the neutral but not unpleasant emotion by activation of the head of left caudate neucleus. Francis *et. al.*, (1999) reported in their fMRI study the activation of orbitofrontal cortex by the pleasant tactile stimuli in contrast to neutral stimuli.

However, it is still unclear which neural structures are integrated to subserve coordination of emotional experience as well as the role of different hemispheres for these emotional systems when the different emotional valences are given with the complex verbal and musical components such as an opera.

Pansori is a Korean traditional vocal music that has a unique story and melody which converts deep emotions of pain and sorrow into art. It consists of verbal, musical, and emotional components, which are supposed to be coordinated by large-scale neural network. In this study, we use fMRI to illustrate the cortical network activated by a Korean traditional opera, *Pansori*, with different emotional valence using functional MRI (fMRI).

Subjects and Methods

Subjects

Nine right-handed volunteers participated. Their mean age was 25.3 and the mean modified Edinburgh score was +90.1. None of the subjects reported the history of psychiatric or neurologic illness. All subjects provided informed consent to volunteer in this study.

Activation tasks

Activation tasks were designed for the subjects to passively listen to the parts of two *Pansories,* one is sad and the other hilarious. The former was selected from *"Simchung-ga"* and is about separation of a father and his only daughter due to their poverty. The latter one was selected from *"Heungboo-ga"* and is about teasing the ill-natured and greedy behavior of Nolboo, Heungboo's older brother. Both parts of *Pansories* were sung with appropriate empathy by a very famous *Pansori* singer, So-Hee Kim. During the control *i.e.* resting periods, white noise was introduced. The data of the subjects who reported to have experienced the designated emotional valence of each *Pansori* task were included in the group analysis.

Imaging parameters and data analysis

Imaging was conducted on a 1.5T Siemens Vision scanner equipped with whole-body gradients and a head coil. The *Pansori* tasks were edited using a CoolPro software and displayed by a computer. Auditory stimuli were delivered into the subject's ears in the scanner room through plastic tubes and earphones. Single-shot echoplanar fMRI scans (TR/TE = 3840/40 ms, flip angle = 90, FOV = 220, matrix = 64 x 64, slice thickness = 6 mm) were acquired in 20 contiguous slices parallel to the anterior commissure-posterior commissure line. Each functional run consists of 84 images with two alternating rest-task pairs (Figure 1). T1-weighted anatomical images were acquired using a FLASH sequence.

FMRI data were analysed using SPM96 software (Wellcome Department of Cognitive Neurology, London, UK). All functional images were realigned to the image taken proximate to the anatomical image using affine transformation built into SPM96. The realigned scans were coregistered to the subjects anatomic scan and then normalized to SPM96's template image. The functional data were smoothed with a 10-mm isotrophic Gaussian kernel prior to statistical analysis. Statistical contrast were set up using the general linear model implemented in SPM96 to calculate voxelwise signal differences between the conditions of interest. Activation was considered significant if uncorrected p-value is less than 0.001.

Results

The bilateral posterior temporal regions were activated while listening to both parts of *Pansories* tasks. However, the hemispheric asymmetry was different between two tasks. *Pansori* with sad emotion showed activation mainly at the superior temporal lobes and extended to the middle temporal lobe posteriorly in both temporal regions. But activation was more extensive in the right temporal lobe than the left side. In right side, the inferior frontal and the orbitofrontal areas were also activated, whereas some activation was seen in the middle frontal lobe in the left side (Fig. 2-A). In the *Pansori* with hilarious emotion, there was also bilateral temporal activation which showed remarkable asymmetry between two hemispheres. Activation of left temporal lobe was extended from the superior to middle and inferior lobes and posteriorly to the temporoparietal and temporooccipital regions. There was much activation of the bilateral inferior and prefrontal areas in the left area (Fig. 2-B). The subtraction results shows that the *Pansori* with sad emotion showed more activation in the right orbitofrontal and temporoparietal areas (Fig. 3). In contrast, the one with hilarious emotion showed more activation in the left temporal and the inferior and prefrontal areas (Fig. 4).

Discussions and Conclusions

During decade, there has been dramatic advances in the technical aspect of fMRI and contribute to conduct many experiments to unveil the cognitive processes undergone within the living brain.

The results of this fMRI study on the *Pansories* showed that different hemispheric asymmetry subserved for the different emotional valence. Generally, the rightward asymmetry for the *Pansori* with sad (negative) emotion and leftward asymmetry with hilarious (positive) emotion was prominent, which supported the Gianotti's (1972) concept of different hemispheric role for the different emotional valence.

Wildergruber *et. al.*, (1999) reported the fMRI activation of the orbito-frontal aspect of inferior frontal cortex and the superior temporal gyri of the right hemisphere in the task for discrimination of affective prosody of given sentence. However, they could not find the areas differently activated according to the emotional valence. Buchanan *et. al.*, (1999) also reported significant activation of the right inferior frontal and inferior parietal lobe and the left cingulate cortex in the fMRI study detecting emotional prosody.

One remarkable thing in our study was a different hemispheric aymmetry especially in the temporal and frontal regions for the *Pansories* with different emotional valence. As mentioned above, a *Pansori* has three components in its contents; the verbal, musical, and emotional. By its characteristics the verbal and emotional components were stronger than musical one. The *Pansori* with hilarious emotion showed the remarkable leftward asymmetry of temporal lobe activation that was extended to the posterior temoproparietal and temporooccipital areas. This finding may suggest that the subjects used their linguistic-semantic processing system more in listening to the part of the hilarious *Pansory* than the sad one. When the extensive activation of the left middle and inferior frontal lobe is taken into consideration, the unique role of left hemisphere for mediating positive emotional valence contained in the hilarious *Pansori* can also be suggested.

On the other hand, the sad *Pansori* showed the rightward asymmetry in the temporal lobe activation as well as more activation in the right orbitofrontal areas than the hilarious one by subtraction. We can not exclude the possibility that more affective weight and melodic components were carried on the *Pansori* with sad emotion, which resulted in the activation of the right hemisphere. However, the role of the orbitofrontal areas in processing negative emotional stimuli should have an attention with the consideration of its massive connection with limbic structures. Although in the study of Francis *et. al.*, (1999) the orbitofrontal areas were activated in relation with positive tactile response, it is still not well known about the specific role of the orbitofrontal areas in mediating different emotional valence with various sensory modalities.

In this study, we could not obtain the results of activation in the amygdala, known to have a important role for emotional association (Irwin, 1996; Labar, 1998; Morris, 1999; Whalen, 1998; Zalla, 1999). The activity of amygdala is known as early habituated during emotional experience. Our study, which was designed by the blocks of the tasks lasting more than a minute, might miss the early activation of amygdala which was habituated later. Furthermore, we did not assess the relative arousal levels of two *Pansories,* which give the possibility that the arousal level of the emotions in this study nct be enough to get the amygdala activated.

Adoption of event-related fMRI technique and detailed rating of emotional valence, arousal, and musical components of a *Pansori* would be helpful for further delineation of neural networks and their roles in future.

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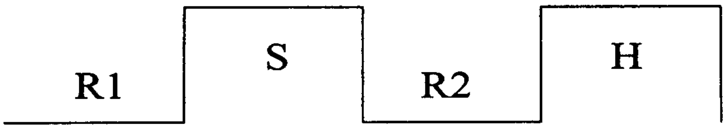

Figure 1. Diagram of the block design paradigm for *Pansori* activation study. R, rest period; S, *Pansori* with sad emotion, H, *Pansori* with hilarious emotion. Each task and rest period lasts 78.6 seconds.

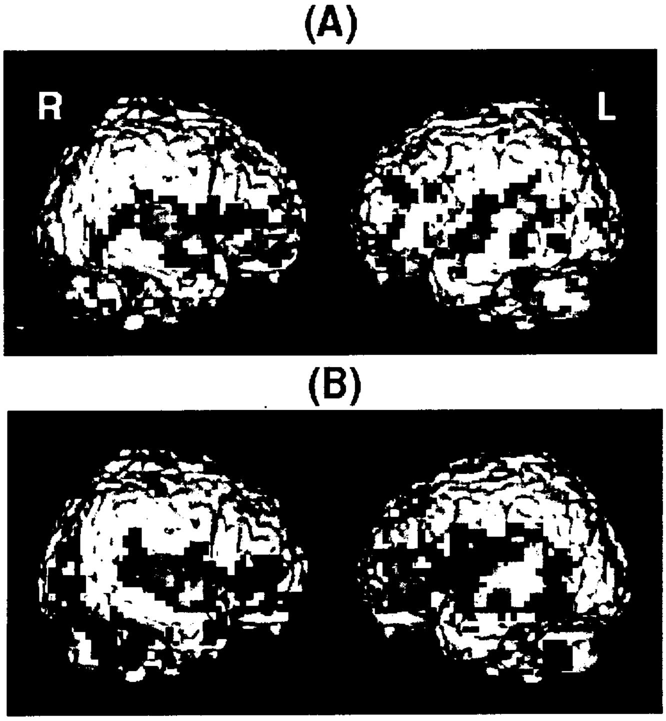

Figure 2. Activation areas of brain by two *Pansories* with sad (A) and hilarious (B) emotional valence. The left temporal and frontal regions of the hilarious *Pansori* were extensively activated.

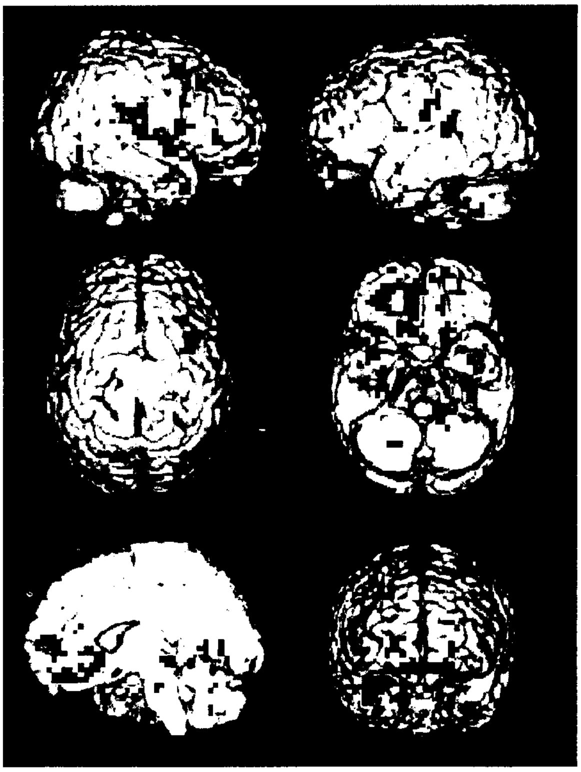

Figure 3. Brain areas more activated by the sad *Pansori* (subtraction of the hilarious from the sad one). The right orbitofrontal and temporoparietal areas were mainly activated.

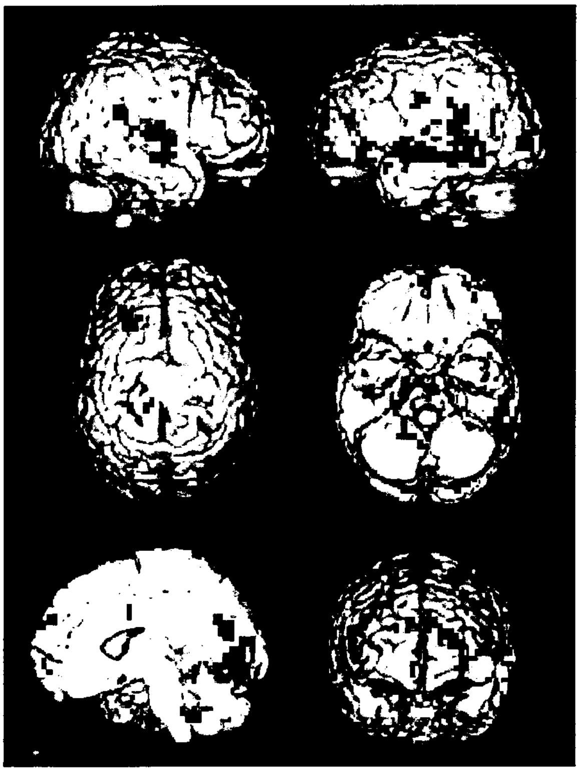

Figure 4. Brain areas more activated by the hilarious *Pansori* (subtraction of the sad from the hilarious one). The left inferior and prefrontal and temporal regions were mainly activated.