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Functional Brain Mapping During Recitation of Buddhist Scriptures and Repetition of the Namu Amida Butsu; a Study in Experienced Japanese Monks

Deneyimli Budist Keşişlerin Budist Duaları Ezberden Okurken ve Nembutsu Dualarını Tekrar Ederlerken Aktive Olan Beyin Bölgeleri

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ABSTRACT

BACKGROUND: The invocation Namu Amida Butsu (Nembutsu), voices the hope of rebirth into Amida's Pure Land. In the Nembutsu, Buddhists imagine that they are absorbed into Amida's Pure Land. Shiritori, a Japanese word chain game, is a common task used to activate language related regions in Japanese. The purpose of this study was to identify the regions activated during praying of the Namo Amida Butsu (Nembutsu), and the reciting of Buddhist scriptures (Sutra).

MATERIAL and METHOD: Functional MRI (fMRI) was used to identify the regions activated by the Nenbutsu, the Sutra and the Shiritori in eight highly-trained Japanese monks.

RESULTS: The task of repeating the Nenbutsu activates the medial frontal gyrus, which is mainly related to mental concentration and visuospatial attention, similar to the areas activated by meditation. The task of reciting the Sutra activates the left lateral middle frontal gyrus, the right angular gyrus, and the right supramarginal gyrus, which are related to visuospatial attention also involved in the area activated by meditation.

CONCLUSION: These results suggest that different types of meditation in Japanese Buddhism showed different brain regional activation. The Nenbutsu activated the prefrontal cortex, and the Sutra activated the left dorsolateral prefrontal cortex and right parietal cortex.

KEY WORDS: Buddhism, fMRI, Invocation, Sutra, SPM99

ÖZ

AMAÇ: Nembutsu duası; Amidanın saf ve kutsal topraklarında yeniden doğuşu ifade eder. Nembutsu'da; Budistler kendilerinin Amidanın saf ve kutsal topraklarına doğru akacaklarına inanırlar. Shitori: Bir Japon resimli sözcük oyunudur. Bu oyunda dil ile ilgili beyin bölgeleri aktive olur. Bu çalışmada Nembutsu yakarışında ve Budist duaları ezbere okumak ile aktive olan beyin bölgeleri incelendi.

YÖNTEM ve GEREÇ: Üst düzeyde eğitilmiş Budist rahiplerde, Nembutsu yakarışında, ezbere Budist duaları okunması sırasında ve Shirtori oyunu sırasında aktive olan beyin bölgeleri Fonksiyonel MRI ile incelenmiştir.

BULGULAR: Nembutsu dualarının okunması sırasında medial frontal girusun aktive olduğu gösterilmiştir. Bu bölge düşünsel yoğunlaşma ve uzaysal görüntüyü yoğunlaştıran (algılayan) (Visuospatial) merkezdir; bu merkez meditasyon sırasında da aktive olduğu gösterilmiş bir merkezdir. Budist duaların ezbere okunması sırasında ise, sol dış orta frontal girus, sağ angular girus ve sağ supramarginal girus aktive olmuştur. Bu alanlar da uzaysal görüntüyü yoğunlaştıran (algılayan) (Visuospatial) merkezle ilişkilidir, aynı zamanda bu bölgeler meditasyon sırasında da aktive olur.

SONUÇ: Bu sonuçlar Japon Budist inanışına göre yapılan meditasyon sırasında farklı beyin bölgelerinin aktive olduğunu göstermiştir. Nembutsu prefrontal korteksi, Sutra ise, sol dorsolateral prefrontal korteksi ve sağ parietal korteksi aktive eder.

ANAHTAR SÖZCÜKLER: Budism, Fonksiyonel MRI, SPM99, Sutra, Yakarış

INTRODUCTION

Buddhism was officially introduced to Japan in the sixth century after the Common Era, and was absorbed into Japanese culture and reconstituted as Japanese Buddhism (19). Thus, it is impossible to separate Japanese Buddhism from the nation's cultural matrix, or to explicate the one without understanding the other (19).

Japanese Buddhists practice in temples, recite Namu Amida Butsu (I take refuge in Amida Buddha) and chant Buddhist scriptures (Sutra) every day. The invocation Namu Amida Butsu (Nenbutsu), voices the hope of rebirth into Amida's Pure Land. In the Nenbutsu, Buddhists imagine that they are absorbed into Amida's Pure Land (19). Therefore, we decided that the Nenbutsu is a form of meditation. Meditation is one technique which induces the relaxation response. Several studies have shown that meditation is associated with increased brain activity in the dorsolateral prefrontal lobe and the parietal regions, which are well-established components of distributed attention networks (2, 11). Meditation is also associated with increased brain activity related to the autonomic system in the anterior cingulate cortex, amygdala, midbrain and hypothalamus (10, 11).

The sutras are scriptures, in which are compiled the teachings of the Buddha, gathered by his disciples, and which lead people toward a supposed truth. It can be said that they are the words the Buddha (19). The sutra is similar to the New Testament of the Bible, which is said to have been composed by the disciples of Christ after his death, and contains the teachings of Christ while he was alive. Whereas priests and ministers read the Bible quietly, Japanese Buddhists chant the sutras rhythmically, like singing songs learned by heart, in the various rituals. Therefore, the recitation of sutras requires little concentration.

Shiritori, a Japanese word chain game, is a common task used to activate language related regions in Japanese. Shiritori activates the left lateral prefrontal cortices and the medial frontal cortex (17,20).

In the present study, functional MRI (fMRI) was used to identify the regions activated by the Nenbutsu, the Sutra and the Shiritori in eight highly-trained Japanese monks. We anticipated that the Nenbutsu-activated areas would be related to the concentration and spatial attention regions, such as the cingulate cortex, the dorsolateral prefrontal and parietal cortices. We also anticipated that the Sutra would activate areas related to music or singing, such as the right temporal cortices and the right prefrontal cortex. The Shiritori should activate the left lateral prefrontal cortices and the medial frontal cortex, which were described in previous reports.

METHODS

Informed consent was obtained by the Ethics Committee of the Oita University Faculty of Medicine. Eight right-handed healthy male Japanese monks, aged 25-64 years (mean 40.8, SD 12.3 years), with no history of neurological or psychiatric illness, participated in this study. The subjects were working in Buddhist temples located in the Kunisaki Peninsula of Oita Prefecture, and each had recited a sutra daily for more than one hour, for at least ten years. The subjects were on no psychotropic medications.

Image Acquisition and Analysis

FMRI is a noninvasive technique for measuring localized physical changes in areas of the brain associated with brain activity using the blood oxygenation level dependent (BOLD) contrast method (14). FMRI was performed using a SIGNA Horizon LX1.5 T (General Electric Medical Systems, Milwaukee, WI). A time course series of 74 volumes was acquired with a T2*-weighted, gradient echo planar imaging (EPI) sequence. Each volume consisted of 23 slices, with a slice thickness of 5 mm with a 1 mm gap, and covered almost the entirely of the cerebral and cerebellar cortices. The repetition time (TR) was 3000 ms, the echo time (TE) was 50 ms, and the flip angle was 60°. The field of view (FOV) was 240 mm, and the matrix size was 64 X 64. Scan acquisition was synchronized to the onset of the trial. Before functional imaging, structural scans were acquired using a T1-weighted spin echo sequence (TR 650 ms, TE 15 ms, 5 mm slice thickness, slice gap 1 mm, FOV 240 mm, matrix 512 x 256), which facilitated localization.

Image processing and statistical analyses were carried out using Statistical Parametric Mapping (SPM99) software (Wellcome Department of Cognitive Neurology, London, UK). The first four volumes of the fMRI run were discarded because the MR signal was unsteady. All EPI images were spatially normalized with the Montreal Neurological Institute (MNI) T1 template for group analysis. Imaging data were corrected for motion and smoothed with an 8 mm full-width, half-maximum Gaussian filter. Using group analysis according to a random effect model, we identified regions that showed significant responses during the task compared to the rest state. Activation was reported if responses exceeded $p < 0.001$ (uncorrected) at the single voxel level and $p < 0.05$ (corrected) at the cluster level. The xyz coordinates provided by SPM99, which are in the MNI brain space, were converted to xyz coordinates in Talairach and Tournoux's brain space (18). Labels for brain activation foci were obtained in Talairach coordinates using the Talairach Daemon software, which provides state of the art accuracy. The areas identified by this software were then confirmed by comparison with activation maps overlaid on MNI-normalized structural MRI images (9). If adequate Talairach coordinates were not obtained by the Talairach Daemon software, we corrected the labels for brain activation foci referring to the Talairach Atlas.

Tasks

The tasks were administered using a boxcar reference function: four control periods alternated with three activation periods, with each period being 30 seconds in duration (a control period began and ended the scanning session). The experimental design was explained to the subjects before they entered the scanner, and they received all the instructions via headphones in the scanner. Head stabilization was achieved using foam pillow padding. The order of the tasks did not alternate across subjects. In this study, we carried out the three tasks, which included Nenbutsu-related, Sutra-related, and Shiritori-related activation. The order of the task was same for all subjects and was in the order listed from least to most demanding. The order of the task was Nenbutsu-related, Sutra-related, and Shiritori-related activation. As the word-generation task was last, there would not have been as much activation for it. In the Nenbutsu-related activation mode, the subjects recited "Namu Amida Butsu" silently and were told to concentrate their attention on Buddha. A voice, via headphones, was used as an auditory trigger to indicate the onset of each "off" and "on" mode, respectively. Before image acquisition, we asked the subjects about the five sutras familiar to the subjects, and transcribed the beginning of the sutras. We selected three beginnings among the transcribed sutras. At the onset of the Sutra-related task, we read the beginning of a sutra to the subjects via the headphones. The subjects read the sutras silently until they received the "off" signal. Shiritori is a word game in Japan in which one player has to say a word starting with the last syllable of the word given by the previous player. In the Shiritori-activation, the subjects were given a new word at each onset of the activated mode via the headphones, and called words to mind for themselves, until the verbal "off" sign. The subjects closed their eyes in all experiments; they reposed in the rest mode without any outside disturbances. They concentrated on these tasks and there could be no problem with distraction related to the noise of the MRI scanner.

RESULTS

The statistical parametric maps of brain regions showed significant increases in BOLD contrast associated with the activated condition compared to the rest condition. The Nenbutsu-related activation resulted in a significant activation of the medial prefrontal cortex compared to the rest condition in the group analysis. Nenbutsu repetition activated only the medial frontal cortices such as the superior and medial frontal cortex (Figure 1). The Sutra recitation activated the left dorsolateral prefrontal cortices and right parietal cortices (Figure 2). The Shiritori activated the left lateral prefrontal cortices and the bilateral medial prefrontal cortices (Figure 3).

The Talairach coordinates are shown in Table I. The Nenbutsu task activated the left medial frontal cortex and superior frontal cortices (Table I). Ultimately, the Nenbutsu-related task resulted in significant activation of the medial frontal regions. The Sutra-related task resulted in significant activation of the left middle frontal gyrus, the right supramarginal gyrus and the right angular gyrus, compared to the rest condition. The Shiritori-related task resulted in a significant activation of the left inferior frontal gyrus, the left middle frontal gyrus, and the right medial frontal gyrus, compared to the rest condition.

DISCUSSION

The brain areas activated by the Nenbutsu and Sutra tasks differed slightly from the areas activated by language-related tasks, and were rather similar to the areas activated by meditation (2, 11). The relative lack of activation in the Nenbutsu task may derive from the inability to stop and start meditating on a 30s basis. Carry-over of the same task into the neighboring rest periods would make the effects less robust, and make the Nenbutsu task look more like a resting state. The areas activated by the Nenbutsu task were involved in those activated by meditation in previous reports. Although singing or melodic perception activated the right superior temporal gyrus and the right prefrontal cortex (7, 23), the Sutra task activated the left dorsolateral prefrontal cortex and the right parietal cortex in this study. These areas that were activated by the Sutra task were also involved in the meditation related areas, which mainly relate to visuospatial attention. The recitation of the Sutra appears to lead Buddhists to the rhythmic meditative state.

Some reports suggest that the task of meditation is associated with an increased level of activity in the frontal cortices. The ratios of frontal vs. occipital in the regional cerebral metabolic rate of glucose were significantly elevated ($p < 0.05$) during Yoga meditative relaxation using positron emission tomography (PET) (6, 11). Newberg et al. used SPECT to examine cerebral blood flow during meditation on a visual image in highly-trained Tibetan Buddhists (12). They described their meditation as a sense of absorption into a visualized image associated with clarity of thought

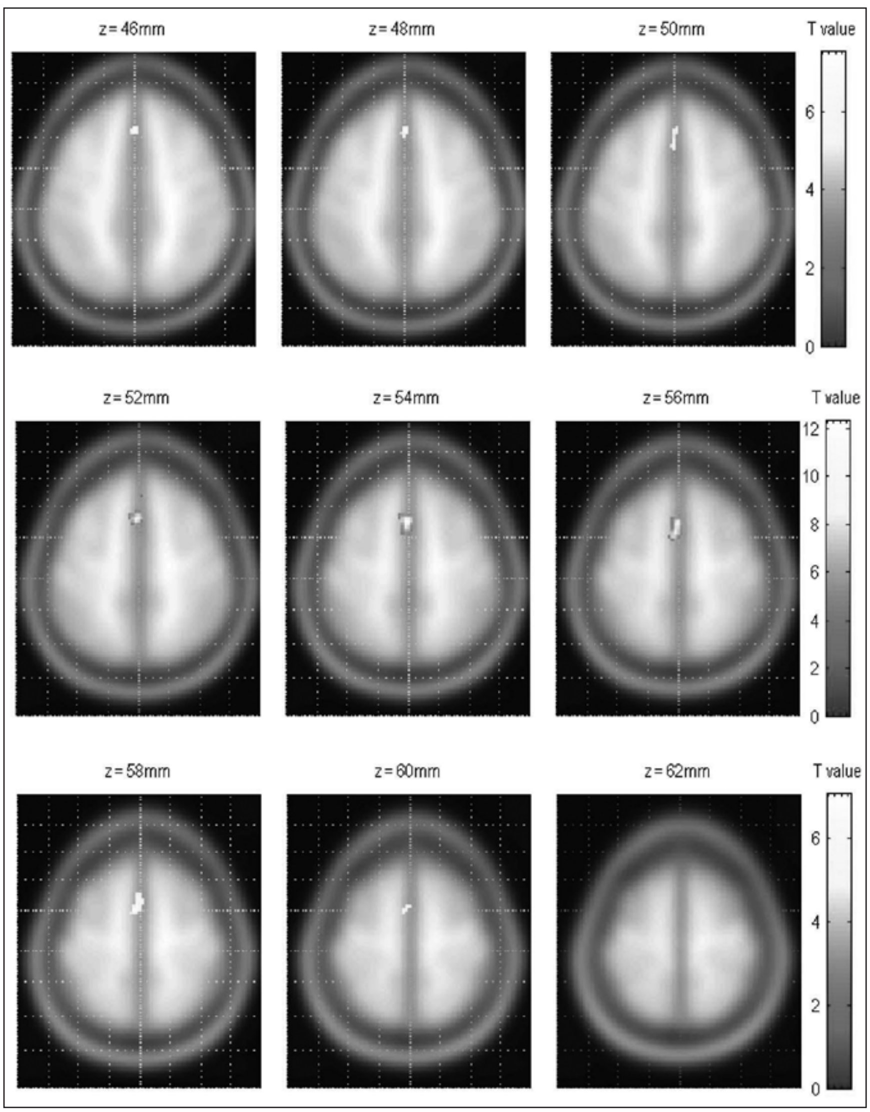


Figure 1: *Statistical parametric maps of brain regions (in the second level group analysis for the eight subjects) showing significant increases in BOLD contrast associated with the Nenbutsu compared to the rest condition at a statistical threshold of $p < 0.001$ (uncorrected) at the single voxel level and $p < 0.05$ (corrected) at the cluster level. Clusters of activation are overlaid onto the axial T1 template images of standard stereotactic space (left hemisphere is represented on left). Clusters of activation showing activations in the medial frontal cortex.*

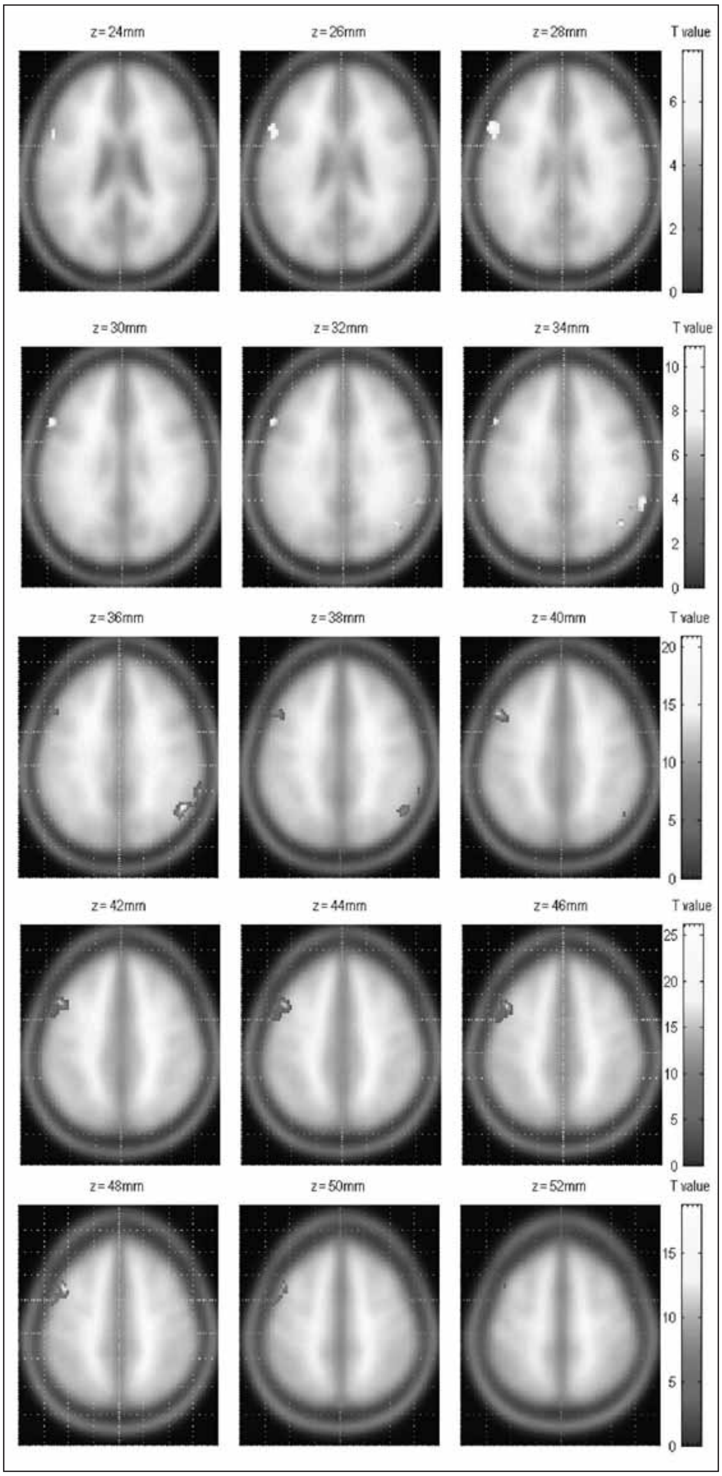
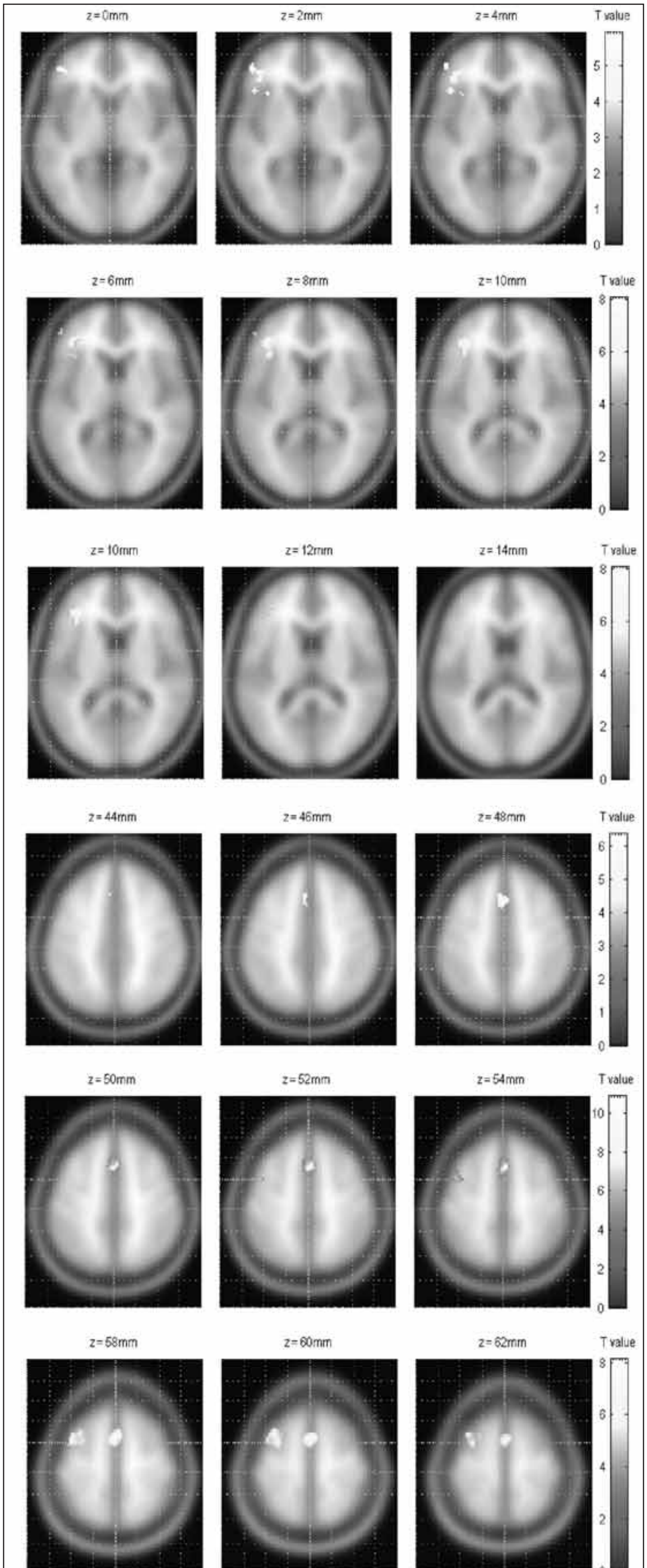


Figure 2: Statistical parametric maps of brain regions (in the second level group analysis for the eight subjects) showing significant increases in BOLD contrast associated with the Sutra compared to the rest condition at a statistical threshold of $p < 0.001$ (uncorrected) at the single voxel level and $p < 0.05$ (corrected) at the cluster level. Clusters of activation are overlaid onto the axial T1 template images of standard stereotactic space (left hemisphere is represented on left). Clusters of activation showing activations in the left dorsolateral prefrontal cortex and right parietal cortex.

and a loss of the usual sense of space and time. This study demonstrated the significant CBF increase in the inferior and orbital frontal cortices, the dorsolateral prefrontal cortices, the sensorimotor cortices, the dorsomedial cortices, the midbrain, the cingulate gyri, and the thalami by ROI analysis. The laterality index was not significantly changed in any of the ROIs. Significant increases of CBF were observed in the right thalamus and significant decreases of CBF were observed in the bilateral superior parietal lobe, the right lateral temporal and the left inferior temporal lobe by SPM analysis. Recently, they measured the changes in cerebral blood flow during "verbal" based meditation by Franciscan nuns involving the internal repetition of a particular phrase (13). They reported that the mean verbal meditation scans showed increased blood flow in the prefrontal cortex, inferior parietal lobes, and inferior frontal lobes. Lazar et al. reported that significant signal increases were observed in the group-averaged data in the dorsolateral prefrontal cortices (10). Lou et al. reported that the PET method showed CBF distribution in the meditative state as well as during the resting state of normal consciousness, and that characteristic patterns of neural activity support each state (11). Neural activity did not increase in the frontal cortex during meditation, but such activity was induced and maintained by auditory stimulation. We found laterality in the frontal cortex during meditation, but no other researchers have reported such laterality. Kubota et al. demonstrated that the frontal midline theta rhythm (Fm theta) activated by Zen meditation is correlated with cardiac autonomic activities. Fm theta reflects mental concentration as well as the meditative state or relief from anxiety (8).

Several functional neuroimaging studies have suggested that meditation activates or alternates the areas related to the attention and autonomic systems. Lazar et al. reported that Kundalini meditation activates the neural structures relating to attention (frontal and parietal cortex) and the autonomic system (anterior cingulate gyrus, amygdala, midbrain and hypothalamus) with an fMRI study (10).



Visual attention is mediated through an interconnected network, including regions of the frontal, parietal, and cingulate cortex. Several studies have described that visuospatial attention causes alteration of activity in the superior parietal lobe, associated with increased activity in the prefrontal cortex (3, 20). The cingulate and medial prefrontal cortex were activated by spatial attention (15). The anterior cingulate cortex was differentiated into a dorsal cognitive division and a ventral affective division. The dorsal cognitive division is included in the attention network, and has reciprocal interconnections with the lateral prefrontal cortex, parietal cortex, and premotor and supplementary cortex. The ventral affective division is connected to the amygdala, periaqueductal gray, nucleus accumbens, hypothalamus, anterior insula, hippocampus and orbitofrontal cortex, and regulates the autonomic, viceromotor and endocrine systems (5). In this study, Nenbutsu and Sutra tasks mainly activated the areas related to visuospatial attention not but the areas related to the autonomic system.

Shiritori, the last-syllable word chain game, is a common task used to activate language-related regions in Japanese. Some studies in Japan have shown the usefulness of Shiritori for language-related activation in fMRI studies (17). In this study, the language task of Shiritori activated the left lateral prefrontal cortices and the medial frontal cortex, which were consistent with the activated areas in previous studies. In the Multicenter PET activation study, a verb generation task in Japanese activated the left lateral prefrontal cortices and the medial frontal cortex, at the two centers observed

Figure 3: *Statistical parametric maps of brain regions (in the second level group analysis for the eight subjects) showing significant increases in BOLD contrast associated with the Shiritori compared to the rest condition at a statistical threshold of $p < 0.001$ (uncorrected) at the single voxel level and $p < 0.05$ (corrected) at the cluster level. Clusters of activation are overlaid onto the axial T1 template images of standard stereotactic space (left hemisphere is represented on left). Clusters of activation showing activations in the left lateral prefrontal cortex and the medial frontal cortex.*

Table I. Talairach coordinates and z scores of the peak activation for the group-averaged results

	Area	Side	Talairach coordinates X	Y	Z	Z-score
Nenbutsu	Superior Frontal Gyrus	Lt	0	5	62	4.71
	Superior Frontal Gyrus	Lt	-8	1	63	3.89
	Superior Frontal Gyrus	Lt	-4	-8	67	3.41
	Medial Frontal Gyrus	Lt	-2	14	49	4.56
	Superior Frontal Gyrus	Lt	-2	6	51	4.14
	Medial Frontal Gyrus	Lt	0	27	41	3.82
Sutra	Middle Frontal Gyrus	Lt	-44	14	42	5.20
	Middle Frontal Gyrus	Lt	-55	19	29	4.05
	Middle Frontal Gyrus	Lt	-50	6	44	3.49
	Supramarginal Gyrus	Rt	51	-53	36	4.95
	Angular Gyrus	Rt	44	-61	33	4.14
	Supramarginal Gyrus	Rt	61	-43	33	4.12
Shiritori	Medial Frontal Gyrus	Rt	2	14	47	4.59
	Inferior Frontal Gyrus	Lt	-32	35	7	4.11
	Inferior Frontal Gyrus	Lt	-44	43	-2	3.59
	Inferior Frontal Gyrus	Lt	-35	24	6	3.58
	Middle Frontal Gyrus	Lt	-40	12	51	3.82
	Middle Frontal Gyrus	Lt	-32	12	55	3.72
	Middle Frontal Gyrus	Lt	-28	5	55	3.61

Stereotaxic coordinates (in mm) identify the location of the maxima of hemodynamic responses corresponding to the atlas of Talairach and Tournoux 1988). Lt, left hemisphere; Rt, right hemisphere

with a 2D scanner (20). The activated areas in this study were compatible with the areas activated by Shiritori in our study. The activation in the medial frontal gyrus with similar coordinates has been found in picture naming, covert word generation, covert singing, and speech execution (1, 4, 16, 22). Nenbutsu and the Shiritori tasks were that participants recited single word rhythmically, but Sutra task was that participants recited long sentences. So, Nenbutsu and the Shiritori tasks might activate the medial frontal gyrus. In conclusion, language-related tasks to recall words activated mainly the left lateral prefrontal cortices and the medial frontal cortex.

There are some limitations in this study. First, the time period of the tasks was 30 seconds, much shorter than in the previous report. Thus, the subjects might not have reached the peak of meditation, but rather only the initial stages. Nevertheless, we were able to visualize the activation in the initial stages of Nenbutu and Sutra-tasks. These findings could be due to the ability of highly-trained Buddhists, who can focus their attention, and hold it on a single object for hours, or shift it rapidly, as many as 17 times in the span of a finger snap (2). In contrast to the significant decrease in CBF of the parietal cortex in the study of Newberg et al. (12), the Sutra task activated the right parietal cortex. This finding is due to the effect that we evaluated the initial stages of Sutra meditation in our study and not the peak stages, therefore, the Sutra task activated the visuospatial attention-related areas. And also, the Nenbutsu and Sutra tasks activated the areas related to visuospatial attention, not the areas related to autonomic systems, in the initial stage of meditation. Second, we could not statistically exclude the possible artifacts related to sub-processes other than the meditation-related processes from the activated areas identified in this study. For example, subjects (professional monks) were required to repeat silently Nenbutsu or to recite silently Sutra, in which they performed the tasks with not only the meditation-related processes but also several sub-processes (e.g., internally phonological process or other language-related process). There is a possibility that the activated regions may reflect any sub-processes as well as the meditation-related processes. To detect the "pure" meditation process in each task, we should remove activations related to the sub-processes (e.g., internally phonological processing) from activation patterns identified in comparison with the resting condition. Third, there were not any subjective measures regarding how successful the meditation was. It was impossible to conclude the Nenbutsu task induced mental concentration. Fourth, the power in such a small number of subjects and only one scan apiece: A random effects analysis on 8 subjects is woefully underpowered, and can be driven substantially by the effects of just a few outliers. Four subjects individually showed a similar pattern to the group effects.

The fundamental findings in this manuscript contribute not only clinical neuroscience, but also to the neurosurgical field. Understanding different fMRI activation patterns in identical groups (Japanese monks) could be of practical help for neurosurgical planning. Moreover, interpretation of fMRI result on the basis of clinical neuroscience is getting more important in current clinical neurosurgical situations.

CONCLUSION

The Nenbutsu task rapidly activated the medial prefrontal cortex, which is related to visuospatial attention. The Sutra task activated the left dorsolateral prefrontal cortex, the right angular gyrus, and the right supramarginal gyrus, which is also related to visuospatial attention. These activated areas were involved with those activated by meditation, which were reported previously. The Nenbutsu and the Sutra are different forms of meditation.

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