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Bilateral Frontal Activation Associated with Cutaneous Stimulation of Elixir Field: An fMRI Study

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Abstract: Elixir Field, or Dan Tian, is the area where energy is stored and nourished in the body according to traditional Chinese medicine (TCM). Although Dan Tian stimulation is a major concept in Qigong healing and has been practiced for thousands of years, and while there are some recent empirical evidence of its effect, its neurophysiological basis remains unknown. We used functional magnetic resonance imaging (fMRI) to study brain activations associated with external stimulation of the lower Elixir Field in ten normal subjects, and compared the results with the stimulation of their right hands. While right-hand stimulation resulted in left postcentral gyrus activation, stimulation of the lower Elixir Field resulted in bilateral activations including the medial and superior frontal gyrus, middle and superior temporal gyrus, thalamus, insula, and cingulate gyrus. These findings suggest that stimulation of the Elixir Field is not only associated with activation of the sensory motor cortex but also with cortical regions that mediate planning, attention, and memory.

Keywords: Cutaneous Stimulation; Dan Tian; Cortical Activation; fMRI.

Introduction

Dan Tian, or "Elixir Field," according to traditional Chinese medicine, refers to the areas in the body where the energy is stored and nourished. The concept of Dan Tian has a very long history in Qigong practice, and it is generally believed that Dan Tian activation is

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vital for mental and physical health. According to the Qigong concept, the Qi (bioenergy) that circulates along the Ren (conception) and Du (governing) meridians is supplied by the Dan Tian. Thus, insufficient energy in the Dan Tian will lead to poor circulation of the meridians, resulting in various kinds of illnesses. Therefore, gathering and filling the energy of the Dan Tian is a fundamental concept in Qigong for healing purposes. There are three Dan Tian regions along the mid-line of the body. The lower Dan Tian, located at the lower abdomen below the navel, is the most common site of practice for healing purposes.

Recently, the effect of Qigong has been studied empirically, and improvements in illnesses have been reported after individuals practiced Qigong (Iwao *et al.*, 1999; Lee *et al.*, 2003; Lehericy *et al.*, 2000; Wu *et al.*, 1999a), or when external stimulation was applied on the individual (Chan *et al.*, 2003). However, there is a lack of empirical studies on the neurophysiological basis of Dan Tian stimulation. The concept behind Qigong rests on the training of the inner mind and body, therefore, a scientific understanding of the mechanisms behind the interaction of the brain and Dan Tian stimulation is important. Given that individuals often reported feeling more attentive, intuitive, and productive after practicing Dan Tian stimulation, we speculated that stimulation of the Dan Tian may activate the cortical regions that are responsible for human attention, planning, and creativity (that is, the frontal regions). Thus, the purpose of the present study was to conduct brain imaging to examine brain activities associated with the stimulation of the lower Dan Tian.

It is well understood that the postcentral gyrus in the cortex is the primary somatosensory region. Discrete activations of the postcentral gyrus, but no activation in other regions of the brain, resulted from tactile stimulation of the hands, have been reported by functional magnetic imaging (fMRI) studies (Backes *et al.*, 2000; Blankenburg *et al.*, 2003; Golaszewski *et al.*, 2002; Rolls *et al.*, 2003; Rumeur *et al.*, 2000). Thus, the present study aimed to compare the cortical systems that are associated with tactile stimulation of the right hand with those of the lower abdomen, which corresponds to the lower Dan Tian. We hypothesized that stimulation of the right hand would be associated with the classic activation of the somatosensory cortex, whereas stimulation of the abdomen would lead to more extensive cortical activations, including those in the frontal regions where attention, planning, and creativity are mediated.

Materials and Methods

Subjects

Ten right-handed normal subjects (four males and six females, with a mean age of 29.9 years) voluntarily participated in the experiment. All of them reported no histories of psychiatric and neurological problems. Prior to the experiment, written consent was obtained from each subject. The experimental design was approved for human subjects by the Clinical Research Ethics Committee of the Joint Chinese University of Hong Kong-New Territories East Cluster Hospitals of Hong Kong.

Stimulation Procedure

Before the experiment, the procedure was explained to each subject and stimuli were applied to the hand for demonstration. All subjects reported that the poking sensation was acceptable. The subjects were instructed to close their eyes and relax for the duration of the experiment. Each subject participated in two two-minute experimental sessions. The first session was stimulation of the Dan Tian which was applied to the midline of the body about three inches below the navel. The second session was stimulation of the right hand which was applied to the medial right arm. Each two-minute session consisted of six blocks: three rest periods and three stimulation periods, with each block lasting 20 seconds. The sequence of rest and stimulation in the two experimental conditions was identical. The only difference was in the location of stimulation. The stimulation tool and the method used in the present study have been described elsewhere (Chan *et al*., 2003). The tool is a 13-inch-long medical hammer, with seven dull needles fixed to the head. This tool was specifically designed to provide a stinging sensation without damaging the skin. Stimulation, applied by one of the investigators, was done by continuously poking the subject on the two respective regions for 20 seconds each. No stimulation was applied to the region during the rest period.

MR Acquisition

MR images were obtained on a 1.5T MRI scanner (Philips Gyroscan ACS-NT) with a circularly polarized head coil. High resolution structural T1-weighted images covering the whole brain were acquired using a spin-echo sequence (TR = 30 ms, TE = 5 ms, flip angle = 40°). These structural MR images were later co-registered with the functional images.

The functional images were obtained using a gradient-echo, echo-planar imaging sequence [echo time (TE) = 40 ms, repetition time (TR) = 2000 ms, flip angle (FA) = 90°, matrix size = 128 × 128, field of view = 220 × 220 mm]. Sixteen axial images covering the whole brain parallel to the anterior–posterior commissure lines were obtained. Each functional phase consisted of 60 volumes, producing 960 images for each subject.

Data Analysis

Data analysis was performed with the fMRI software package BrainVoyager 2000 (ver. 4.9.6, Brain Innovation, Maastricht, Holland). Before statistical analysis, motion corrections were performed by aligning the time series of functional images for each slice to minimize the signal variations due to small movements of the subjects during image acquisition. Gaussian filtering was applied at both temporal (FWHM = 2 time-point) and spatial (FWHM = 4 mm) levels. Linear trend removal and 0.016 Hz temporal high-pass filtering were also performed on the data. The complete functional dataset for each subject was then transformed into Talairach space. The individual brain image was aligned by rotation in the anterior commissure (AC)–posterior commissure (PC) plane, and coordinates of each brain were transformed to the coordinates of the Talairach brain (Talairach and Tournoux, 1993). Re-aligned images were then co-registered to the high-resolution structural images.

Data were analyzed on the whole-sample and individual-subject levels. To obtain the activation pattern for the whole sample, general linear modeling (GLM) was applied to analyze the data, based on the boxcar model with hemodynamic response. The signal values during the stimulation and the rest blocks were the effects of interest to be explored. A three-dimensional statistical map was generated for each condition by corresponding to each voxel with the F value for the specified set of predictors and calculated by the least-mean-square solution of the GLM. The effect was accepted as significant only when the corresponding regression coefficient was greater than 0.50 ($p < 0.01$, corrected) with a threshold of 15 voxels. Clusters less than the threshold were not displayed.

Within each individual, regions of interest (ROIs) were identified as those having significant activation in the group analysis. The functional images were co-registered with each individual's own brain image for the identification of ROIs. The data were also analyzed with a general linear model with boxcar response functions using an uncorrected threshold of $p < 0.01$, corresponding to correlation coefficients greater than 0.3. The number of subjects showing significant activation of the ROI was then counted and compared.

Results

Group Analysis

Consistent with many studies on somatosensory stimulation, the left postcentral gyrus (BA 2 & 40) was activated during stimulation of the right hand (Fig. 1). While only the somatosensory cortex was activated during the stimulation of the right hand, several additional regions of the brain were active during Dan Tian stimulation, including significant bilateral activation of the middle frontal gyrus (BA9/46) and right superior frontal gyrus (BA10). In addition, bilateral activation of the temporal lobes (BA22, 37, and 42), thalamus, insula, and cingulate gyrus, including both anterior (BA32) and posterior regions (BA29/30) were also observed during Dan Tian stimulation (Fig. 1).

The specific brain regions activated during Dan Tian stimulation and their corresponding p values are shown in Table 1. As illustrated in Table 1, the brain regions activated during Dan Tian stimulation was more extensive than those for right-hand stimulation. The time course analysis, comparing the blood oxygen level dependent (BOLD) percentage signal change in the Dan Tian stimulation with the rest condition (Fig. 2), showed significant differences in the right frontal lobe ($p < 0.05$, paired t-test) and left temporal lobe ($p = 0.01$, paired t-test). The BOLD signal changes for the thalamus (right: $p < 0.01$, left: $p < 0.05$) and insula (right: $p < 0.01$, left: $p < 0.01$) were also significant.

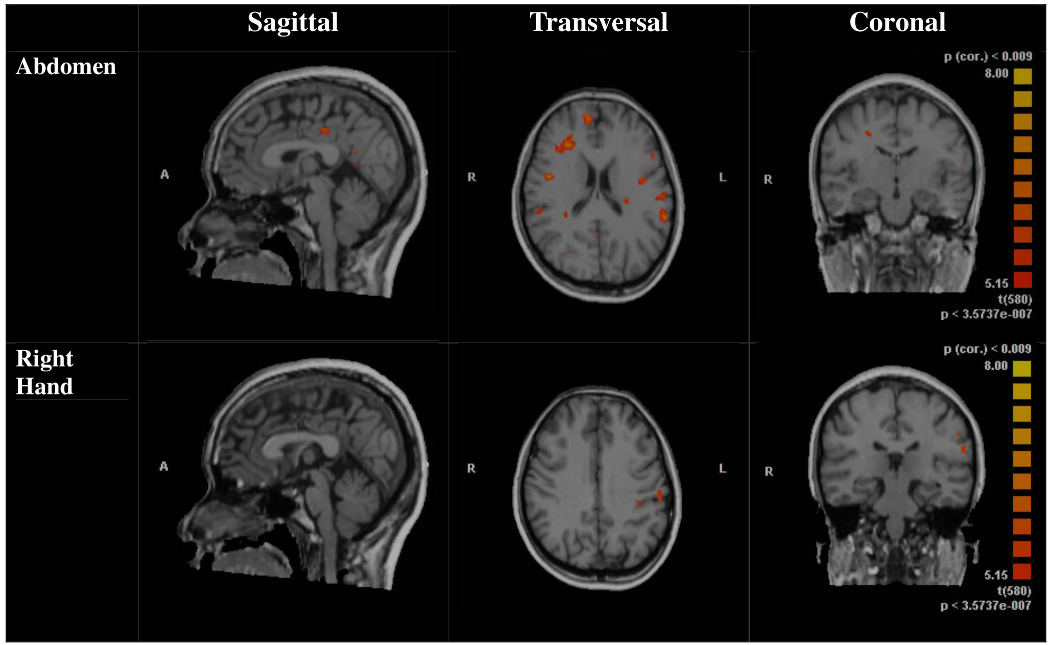

Figure 1. Brain activation associated with somatosensory stimulation of the right hand and the abdomen. The group results showed left postcentral gyrus activation for right-hand stimulation and bilateral postcentral gyrus activation for abdominal stimulation. Bilateral frontal and temporal lobe activations were also observed with abdominal stimulation. The presence of the activations is significant at $p < 0.01$, corrected for multiple comparisons, but has a threshold of $p < 0.00001$, showing the extent of the activation.

Table 1. Analysis of the Functional Data for Each Subject — Spatial Location of the Activations

	Abdominal Stimulation					Right-Hand Stimulation				
Region	**Side**	**Equiv-Z**	**Coordinates**	**p-value**	**No. of Subjects/ Total**	**Side**	**Equiv-Z**	**Coordinates**	**p-values**	**No. of Subjects/ Total**
Middle Frontal	L	6.661	(−35, +15, +26)	6.33E − 11	10/10					
Gyrus	R	7.833	(+31, +46, +35)	2.28E − 14	10/10					
(BA 9)										
Superior Frontal										
Gyrus	R	6.741	(+31, +46, +33)	3.81E −11	10/10					
Middle	L	7.827	(−50, −63, +5)	2.38E − 14	8/10					
Temporal Gyrus	R	5.641	(+49, −60, +5)	2.65E − 08	10/10					
Superior	L	7.462	(−59, −18, +9)	3.13E − 13	9/10					
Temporal Gyrus	R	5.676	(+40, −39, +11)	2.17E − 08	10/10					
Thalamus	L	6.799	(−11, −21, +5)	2.63E − 11	7/10					
	R	7.587	(+7, −6, +5)	1.31E − 13	8/10					
Insula	L	9.4	(−41, −6, +14)	1.25E − 19	9/10					
	R	8.532	(+31, +12, +11)	1.26E − 16	8/10					
Postcentral	L	7.191	(−59, −18, +14)	2.00E − 12	10/10	L	6.224	(−59, −21, +20)	9.30E − 10	8/10
Gyrus	R	8.702	(+46, −27, +35)	3.36E − 17	9/10					
Anterior										
Cingulate	R	6.838	(+22, +36, +17)	1.97E − 10	7/10					
Posterior	L	7.834	(−2, −54, +8)	5.36E − 13	8/10					
Cingulate	R	5.941	(+25, −69, +11)	4.90E − 09	7/10					
(BA 30)										
Cingulate Gyrus	L	6.071	(−1, −27, +38)	2.30E − 09	9/10					
	R	6.578	(+1, −27, +39)	1.07E − 10	9/10					

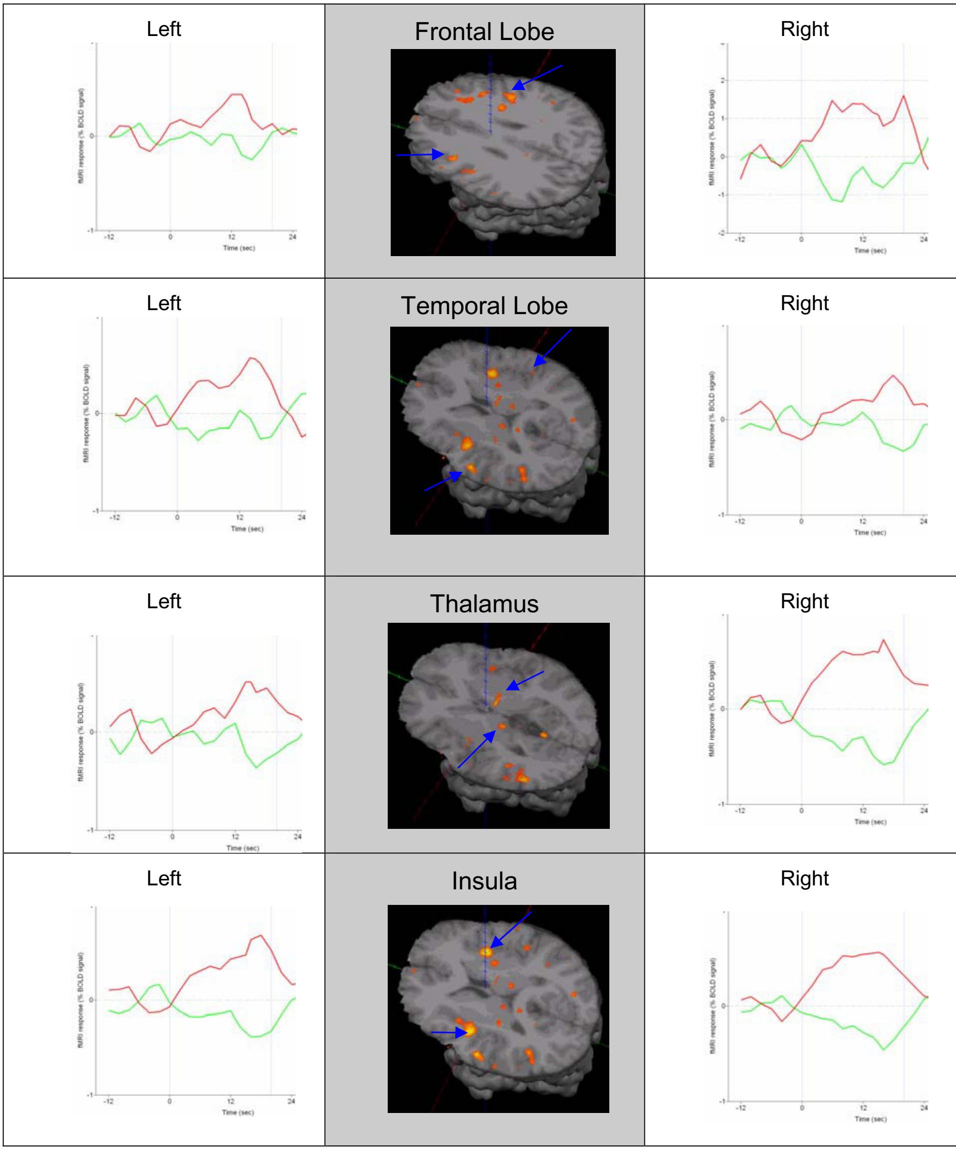

Figure 2. Brain activation associated with somatosensory stimulation of the abdomen, with the averaged time courses showing the percentage of signal change in the frontal lobe, temporal lobe, thalamus, and insula. Each region of interest is indicated with a blue arrow, and the corresponding averaged time courses for the left and right hemispheres are displayed along each horizontal slice. The red line denotes the time course of abdominal stimulation and the green line represents the time course of the no stimulation (control) condition.

Individual Analysis

Analysis of the functional data for each subject confirmed the group data, with the spatial location for the activation being very consistent across subjects (Table 1). This table shows that over 80% of the subjects exhibited similar regions of activation as observed in the group map. Among the ROIs, the activation of the bilateral middle frontal lobe and right temporal lobe was most consistent, with all subjects demonstrating significant signal changes.

The mean percentage signal change during stimulation relative to the rest condition for each ROI during the whole time course was calculated. For each ROI, the time course that consisted of a total of 30 volumes for stimulation and 30 volumes for rest condition were averaged, respectively. The average mean BOLD signal change was calculated by taking the mean of the three blocks of stimulation for each corresponding time course. As shown in Fig. 2, the percentage change in the BOLD signal for each subject was compared for both stimulation locations. The percentage change for Dan Tian stimulation was higher overall than that for right-hand stimulation. Within-subject t-tests showed significant BOLD signal change in the right medial frontal lobe ($t = 2.70$, $p < 0.01$), and marginally significant change for the left temporal lobe ($t = 1.18$, $p = 0.08$). The differences in the thalamus and insula did not reach statistical significance.

Discussion

Our study demonstrated significant bilateral frontal activations during stimulation of the lower abdomen that corresponded to the lower Dan Tian, while discrete activation in the postcentral gyrus was found on hand stimulation. It is well understood that the postcentral gyrus is the primary somatosensory cortex, with many brain imaging studies demonstrating activation of this region during sensory stimulation of the hands or fingers (Backes *et al.*, 2000; Blankenburg *et al.*, 2003; Golaszewski *et al.*, 2002; Rolls *et al.*, 2003; Rumeur *et al.*, 2000). Since the present result has replicated previous findings in showing significant signal change in the left postcentral gyrus during stimulation of the right hand, the method and imaging technique used in the present study should be valid. Thus, the findings on the stimulation of the Dan Tian cannot be simply explained by the difference in methods, techniques, or choice of human subjects.

The stimulation of the Dan Tian was associated not only with activation of the postcentral gyrus, but other brain activations. The regions activated included bilateral frontal and temporal lobes, the thalamus, and the insula. Comparing the results obtained from right-hand stimulation with those of Dan Tian stimulation, it seems that the latter indeed led to more extensive cortical stimulation that could not be attributed simply to somatosensory input. In trying to interpret the results, we questioned whether the extensive brain activation observed was due primarily to the stimulation, or to thoughts or feelings elicited by the stimulation. It could be argued that the subject might have mentally reacted differently in reaction to stimulation of the abdomen and stimulation of the hand, as the abdomen usually receives less somatosensory input in daily life compared with the hand.

Stimulation on the abdomen might have led to some sort of associative thinking or feeling, which might have caused the observed brain activations rather than the stimulation itself. To examine this issue, we compared the brain activations involved in associative thinking reported in the literature with the present findings. In some studies on semantic fluency tasks, activations predominantly on the left side of the frontal lobes have been observed (Gaillard *et al*., 2000; Hertz-Pannier *et al*., 1997; Litscher *et al*., 2001). This coincided with the present findings in which left frontal activation was observed when the abdomen was stimulated. However, brain regions other than the left frontal lobe were also activated during abdominal stimulation. Therefore, even if associative mental processing was involved, it only explained part of the results.

While the present study provided initial empirical data on the neurophysiological pathway associated with the stimulation of the Dan Tian, other studies have been conducted to examine the brain activation associated with the stimulation of other meridian points (Wu *et al*., 1999b and 2002). For instance, Wu *et al*. (2002) compared the brain activation associated with stimulation of the lateral side of the left leg (GB34) along the meridian with another point adjunct to GB34. The authors reported that stimulation at GB34 resulted in the activation of various brain regions other than the postcentral gyrus, including the hypothalamus, the thalamus, and the middle frontal gyrus. Thus, interpreting the present data in light of those reported by Wu and his colleagues, the meridian and Dan Tian system might be a pathway that connects to the brain, even though this may not be evident from an anatomical perspective.

In conclusion, the cutaneous stimulation used in the present study was first described by Huiquing Sun in 1919, and there have been case reports on the positive effect of this treatment method on brain-damaged patients (Bai, 1989). While most of these studies were reported in China, a recent study that examined the effect of cutaneous stimulation was reported in a Western journal. In that study, cutaneous stimulation was administered to a patient who suffered from cerebellar atrophy with severe ataxia, gait imbalance, and limb spasticity. After eight months of intervention, the patient’s ataxia and hypotonia had improved significantly, and he had gained the abilities to grasp objects, sit upright, and monitor an electric wheelchair (Chan *et al*., 2003). Although the clinical effects from these studies seem to be encouraging, the mechanism underlying this treatment remains unknown. The present study has shown that Dan Tian stimulation leads to extensive cortical and subcortical activation. These data provided a starting point for further empirical studies on the neurophysiological basis of cutaneous stimulation.

Acknowledgments

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