Localization of Sensorimotor Cortex by Using Functional Magnetic Resonance Imaging : Comparison Between Finger Tapping and Palm Scratching in Normal Volunteer

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Abstract

The purpose of this study was to compare the location and intensity of activation of the sensorimotor cortex between finger tapping and palm scratching paradigms in normal volunteers and to consider using passive task instead of motor task in patients who are unable to perform motor task. Multishot echo-planar T2*-weighted imaging sequences at the level of the sensorimotor cortex were performed in axial plane during finger tapping and palm scratching paradigms in 13 normal volunteers. The authors found that the location of activation was slightly posterior only in bilateral passive task compared to bilateral motor task but there was no statistical significance. However, this observation was not seen in unilateral tasks. The intensity of activation of both motor and passive tasks was comparable. The authors conclude that in normal volunteers passive task (palm scratching) can be used instead of motor task (finger tapping) to localize the location of the sensorimotor cortex.

Key word : MRI, Functional Cortical Mapping, Sensorimotor Cortex

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In the past, brain function was known by lesion causing neurological deficit, or ablative paradigm. For the last two decades, with studies from the Photon Emission Tomography (PET) scan, Single Photon Emission Tomography (SPECT), eletrocortical stimulation, magnetoencephalogram and functional Magnetic Resonance Imaging (MRI), the study of brain function has changed to activation paradigm. In 1991, Belliveau et al found activation of the visual cortex during photic stimulation while using gado-

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linium enhancement which was the first functional MRI study of the brain(1). There has been great development in MRI with the emergance of echo planar imaging (EPI). EPI gave better temporal resolution, which facilitated functional study. Functional MRI has been used to study function of the brain including sensorimotor, auditory and visual cortices, and language areas with better spatial and temporal resolutions compared to the PET scan. Functional cortical mapping provided a tool for presurgical evaluation and study of brain plasticity.

In patients with abnormality of the sensorimotor cortex, it was found that they had difficulty in performing motor tasks e.g. finger tapping. If they tried to do finger tapping, they moved their limbs rather than fingers and caused motion artifacts. In a previous study by Lee et al active and passive activation tasks produced largely equivalent results(2). The purpose of the present study was to evaluate whether sensory task could be used interchangeably with motor task, comparing location and intensity of activation.

METHOD

From September to October 2001, 13 normal volunteers (4 males and 9 females), with an age range from 21-40 years (mean 27.07 years), 10 right handed and 3 left handed. None had symptoms and signs of neurological diseases. For each volunteer, sagittal SE T1W and axial FSE T2W images were performed to exclude abnormality. Functional MRI of sensorimotor cortex was studied by MRI 1.5 Tesla using multishot echo-planar T2*-weighted imaging sequences in axial plane with parameters as follows: FOV 28 cm, TR/TE 2000 msec/40 msec, phase encoding 128 steps, slice thickness 10 mm X 4 slices, gap 2 mm, and acquisition time 4 minutes and 19 seconds. The location of the slices is shown in Fig. 1 with the top slice at the inferior margin of the superior sagittal sinus.

Each volunteer underwent fMRI with 6 consecutive paradigms. Each paradigm consisted of activation for 20 seconds alternating with rest for 20 seconds, for the duration of 4 minutes and 19 seconds, starting from rest. The six consecutive paradigms were: 1. Left unilateral finger tapping (LFT), in which the volunteers sequentially tapped each finger of the left hand to the left thumb during activation. 2. Right unilateral finger tapping (RFT) was done like LFT except using the right hand. 3. Bilateral finger tapping (BFT) was performed using both hands. 4. Left palm

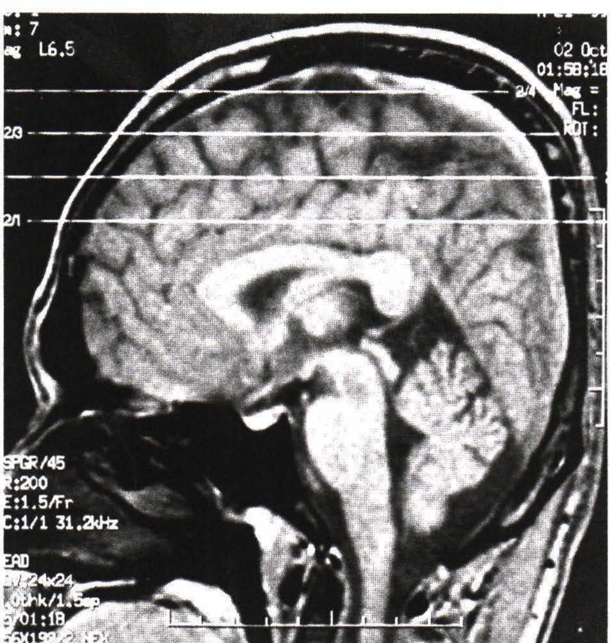


Fig. 1. The image shows the slice positions of fMRI and based images for localization of the sensorimotor cortex.

Table 1. Result of 13 cases.

Name	Age	Sex	Handed	BFT R	BFT L	BPS R	BPS L	RFT R	RFT L	RPS R	RPS L	LFT R	LFT L	LPS R	LPS L
Case 1	28	F	L	+CS	++CS	O	+PoCG ++PoCS	O	+++CS	O	+CS +PoCS +SFG	+++CS +SFG	++PrCG	+CS ++SFG	+SFG
Case 2	20	M	R	+MFG	+++PrCG	+++CS	+++++CS	++CS +MFG	O	O	++++Cs	+++++Cs	++++CS +SFG	+++CS	O
Case 3	21	M	R	++PoCG	+++PrCG	O	++MFG ++PoCS	O	+++CS	O	+PrCG ++PoCS	+++CS	O	++PoCG	++PoCG
Case 4	26	M	L	++CS	+++CS	+++CS	+++CS	O	+++CS	O	+++CS	+++CS	O	+++CS	O
Case 5	40	F	R	+++++CS	+++CS	+++PoCG	+++PrCG	+CS	+++CS	O	++CS	+++++CS	O	+++CS ++PoCS	O
Case 6	29	F	R	+++CS +++PrCG	+++CS +++PrCG	++CS	+++PrCG	O	+++PrCG +PoCG	++ BSFG	+++CS	+++CS	+CS	+++CS +++BSFG	
Case 7	24	F	R	+++CS +SFG	+++++CS +SFG	+PoCG	++PrCG	+PoCS	++++PrCG	+SFG	+++++CS	+++CS +SFG	+MFG	+++CS ++SFG	+MFG
Case 8	21	F	R	+++++CS	+++CS	+++++CS	+++CS ++SFG	++PrCG +PoCS BSFG	++++PrCG	+PoCS	+++CS +SFG	++CS ++++ PoCG	O	+++CS	O
Case 9	21	F	R	+++CS ++BSFG	+++CS	+PrCG ++CS ++sup-parietal lobule	++++CS	+SFG	+++CS +SFG	O	++CS	+++CS +SFG +PoCG	O	+++CS	O
Case 10	21	M	R	+++CS	+++PrCG	++PoCG ++SFG	+++CS	+PrCS	+++PrCG	+SFG	+++CS	+++CS	O	+++CS	O
Case 11	34	F	L	++CS ++SFG	++PrCG	+SFG	+CS	+SFG	+++PrCG	O	O	++Cs +SFG	O	++CS	O
Case 12	29	F	R	+++PoCG	+++PrCG	++PoCG	++CS	+SFG	++++PrCG	O artifact	O	+++PoCG +SFG	O	+++PoCG	O
Case 13	38	F	R	+++CS ++SFG	+++PrCG ++SFG	+++CS	++++CS	O	+++PrCG +SFG	O	+++CS	+++CS	+SFG	+++CS	O

PrCG = precentral gyrus , BSFG = bilateral superior frontal gyri, CS = central sulcus
SFG = superior frontal gyrus, PoCG = postcentral gyrus, MFG = middle frontal gyrus, PoCS = postcentral sulcus

scratching (LPS), the volar side of the left hand of the volunteer was brushed during activation by an assistant. 5. Right palm scratching (RPS) was done like LPS except brushing of the right hand. 6. Bilateral palm scratching (BPS) in which both hands were brushed by two assistants. During the rest period, the volunteer was asked to keep still.

The functional images from each paradigm were calculated for correlation coefficient with functool software of GE company p = 0.001. The activation from the calculated images was added to axial SE T1W based images. The T1W based images were acquired by using TR 600 msec/TE 11 msec. Other parameters were the same as the functional images.

RESULTS

The results of the 13 cases are shown in Table 1. Location of activation varying from pre-

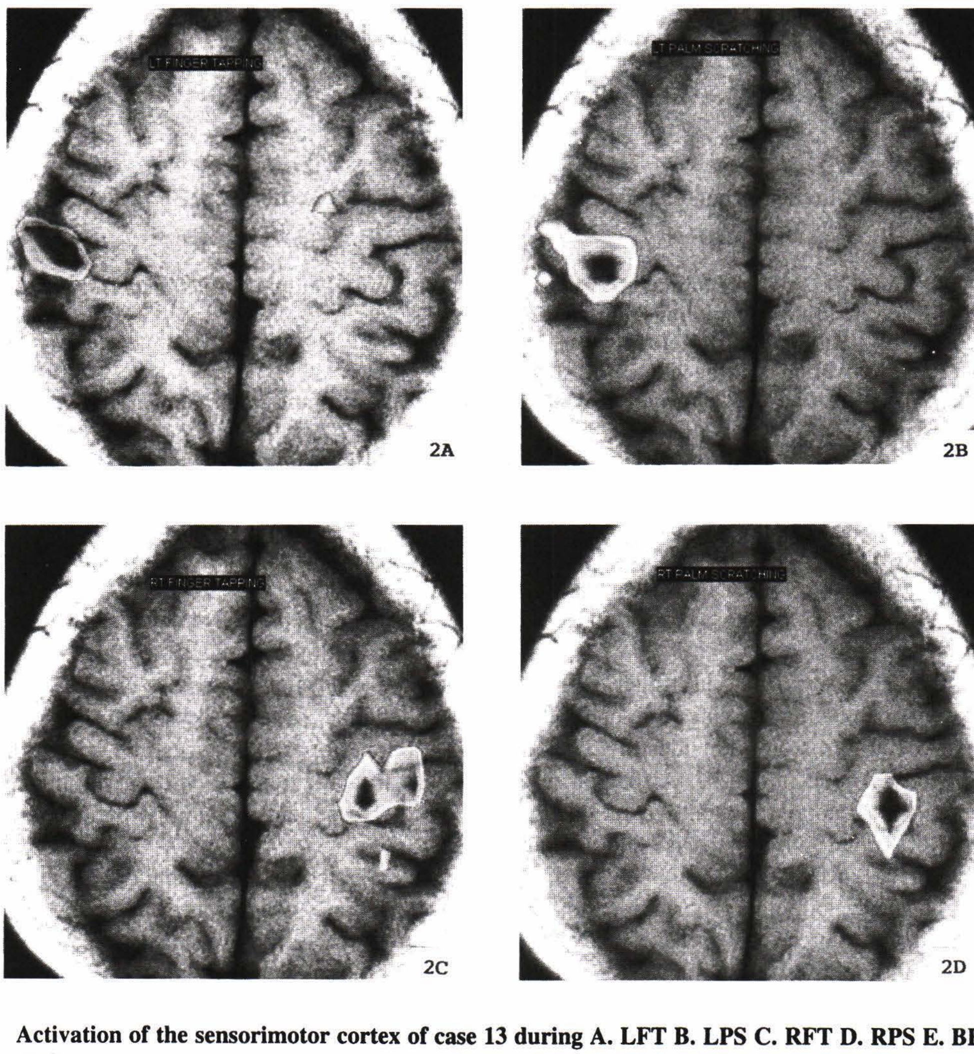
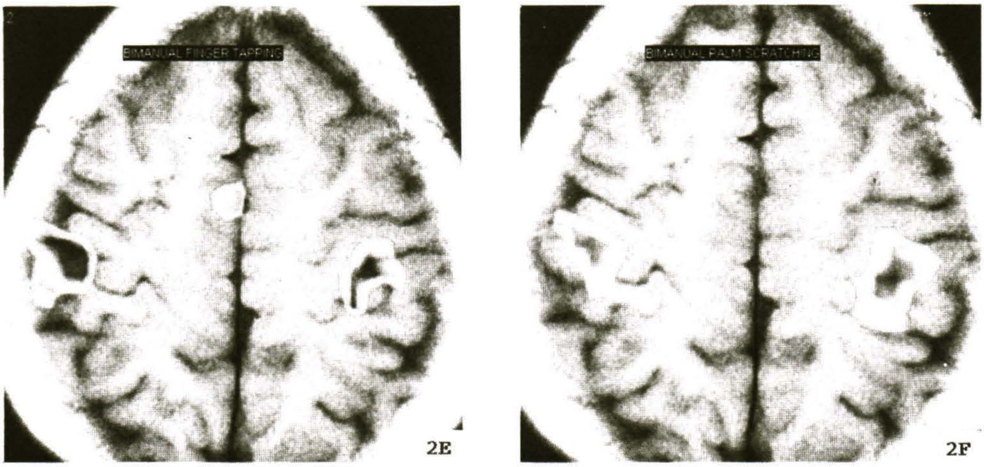


Fig. 2. Activation of the sensorimotor cortex of case 13 during A. LFT B. LPS C. RFT D. RPS E. BFT and F. BPS.

A. LFT; Activation is predominantly at right central sulcus and minimal at left superior frontal gyrus.
B. LPS; Activation is extending from the right central sulcus.
C. RFT; Activation is at the left precentral gyrus.
D. RPS; Activation is at the left central sulcus.
E. BFT; Activation is at the right central, left precentral gyrus and minimal at right superior frontal gyrus.
F. BPS; Activation at left more than right side of central sulcus is found.



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F. BPS; Activation at left more than right side of central sulcus is found.

central gyrus to postcentral sulcus was considered as primary sensorimotor cortex and activation at superior frontal gyrus or middle frontal gyrus was considered as motor association areas.

In the 13 cases, bilateral finger tapping showed location of activation varying from precentral gyrus to postcentral gyrus on both sides in 12 cases and only on the left side in 1 case. Also seen was activation at bilateral superior frontal gyri in 3 cases, at right superior frontal gyrus in 1 case and at right middle frontal gyrus in 1 case.

Right finger tapping revealed location of activation varying from precentral gyrus to postcentral sulcus on the left side in 8 cases, on both sides in 4 cases and only on the right side in 1 case. The authors found activation at bilateral superior frontal gyri in 2 cases, at right superior frontal gyrus in 2 cases, at left superior frontal gyrus in 1 case and at right middle frontal gyrus in 1 case.

In left finger tapping, location of activation varied from precentral gyrus to postcentral sulcus on the right side in 10 cases and on both sides in 3 cases. In addition, activation at the right superior frontal gyrus in 5 cases, at the left superior frontal gyrus in 2 cases and at the left middle frontal gyrus in 1 case were observed.

Bilateral palm scratching study showed location of activation varying from precentral gyrus to postcentral sulcus on both sides in 10 cases and only on the left side 3 cases. Also noted was activation at the left superior frontal gyrus in 1 case, at the right superior frontal gyrus in 2 cases, at left middle frontal gyrus in 1 case and at superior parietal lobule in 1 case.

On right palm scratching, there was motion artifact in 1 case, which was excluded from the study. Of these 12 cases, one revealed no measurable activation. Location of activation varying from precentral gyrus to postcentral sulcus on the left side in 10 cases and on both sides in 1 case was found. Also seen were activation at superior frontal gyrus on both sides in 1 case, at superior frontal gyrus on the right side in 2 cases and at superior frontal gyrus on the left side in 2 cases.

Left palm scratching study revealed location of activation varying from precentral gyrus to postcentral sulcus on the right side in 12 cases and on both sides in 1 case. In these 13 cases, there was activation at superior frontal gyrus on both sides in 2 cases, at superior frontal gyrus on the right side in 1 case and at middle frontal gyrus on the left side in 1 case.

Fig. 2 shows activation from 6 consecutive paradigms in case 13.

The authors expected that the activation of the passive paradigms should be located at the post-central gyrus, which was the primary sensory cortex. So location of the activation was compared between the active and passive paradigms (Table 2). Activation posterior to the central sulcus in BFT was found in 2/13 cases and in BPS it was found in 7/13 cases. These suggested that the locations of activation were more posterior for BPS than for BFT, however, there was no statistical significance (p-value = 0.097). The locations of activation posterior to the central sulcus in LFT, LPS, RFT and RPS were 3/13, 3/13, 1/13 and 1/12 cases respectively. When comparing between LFT and LPS, and between RFT and RPS, there was no statistical significance (p-values = 1.0 & 0.593 respectively).

The intensity of the signal was also considered. The intensity of activation was graded from ++ to +++++. The authors considered that the intensity of the activation equal and more than +++ was easy to see, and observed that the strongest activation ≥ +++ in BFT, BPS, LFT, LPS, RFT and RPS were 11/13, 8/13, 12/13, 10/13, 12/13 and 7/12 cases respectively (Table 3). Comparison between BFT and BPS, LFT and LPS, and RFT and RPS, all revealed no statistical significance with p-value of 0.378, 0.593 and 0.073 respectively.

The intensity of activation between dominant and non-dominant hemispheres in unilateral tasks is evaluated as shown in Tables 4, 5. In right handed, the intensity of activation was found LFT > RFT in 4/10 cases, RFT > LFT in 3/10 cases and LFT = RFT in 3/10 cases for active task, and LPS > RPS in 3/10 cases, RPS > LPS in 3/10 cases and RPS = LPS in 4/10 cases for passive task. For left handed, the intensity of activation was observed RFT > LFT in 1/3 cases and RFT = LFT in 2/3 cases for active task, and RPS > LPS in 1/3 cases, LPS > RPS in 1/3 case and RPS = LPS in 1/3 cases for passive task. There was no statistically significant difference of intensity of activation of unilateral finger tapping and unilateral palm scratching between dominant and non dominant hemispheres for those right and left handed, p = 0.7365, 0.7220, 0.8970 and 0.9584 respectively.

For bilateral task performance (Table 6, 7), the intensity of BFT were left > right 3/10 cases, right > left 2/10 cases and right = left 5/10 cases for right handed and left > right 2/3 cases and right = left 1/3 cases for left handed. The intensity of activation of BPS were left > right 7/10 cases, right > left 1/10 case and right = left 2/10 cases for right handed and left > right 2/3 cases and left = right 1/3 case for left handed. No statistically significant difference of intensity of activation of BFT and BPS between dominant and non dominant hemispheres was found for right and left handed, p = 0.8970, 0.9584, 0.1030 and 0.9584 respectively.

DISCUSSION

The activation detected by fMRI using blood-oxygen-level-dependent technique (BOLD technique)

Table 2. Comparison of the location of activation between finger tapping and palm scratching to the location of the central sulcus (CS).

	Location of activation	
	Posterior to CS	Anterior to or at CS
BFT	2	11
BPS	7	6
LFT	3	10
LPS	3	10
RFT	1	12
RPS*	2	10

* RPS had artifact in 1 case which was excluded from the study
BFT = bilateral finger tapping, BPS = bilateral palm scratching,
RFT = right finger tapping, RPS = right palm scratching,
LFT = left finger tapping, LPS = left palm scratching

Table 3. Comparison of signal intensity of activation between finger tapping and palm scratching.

	Signal intensity	
	> +++	< +++
BFT	11	2
BPS	8	5
LFT	12	1
LPS	10	3
RFT	12	1
RPS*	7	5

*RPS had artifact in 1 case which was excluded from the study
BFT = bilateral finger tapping, BPS = bilateral palm scratching,
RFT = right finger tapping, RPS = right palm scratching,
LFT = left finger tapping, LPS = left palm scratching

Table 4. Comparison of signal intensity of activation between RFT and LFT for the right and left handed.

Handed	Signal intensity in Unilateral finger tapping		
	LFT > RFT	RFT > LFT	RFT = LFT
R	4	3	3
L	0	1	2

RFT = right finger tapping, LFT = left finger tapping

Table 5. Comparison of signal intensity of activation between RPS and LPS for the right and left handed.

Handed	Signal intensity in Unilateral palm scratching		
	LPS > RPS	RPS > LPS	RPS = LPS
R	3	3	4
L	1	0	1

RPS = right palm scratching, LPS = left palm scratching

Table 6. Comparison of signal intensity of activation between right and left sides in performing bilateral finger tapping for the right and left handed.

Handed	Signal intensity in Bilateral finger tapping		
	L > R	R > L	R = L
R	3	2	5
L	2	0	1

Table 7. Comparison of signal intensity of activation between right and left sides in performing bilateral palm scratching paradigm for the right and left handed.

Handed	Signal intensity in Bilateral palm scratching		
	L > R	R > L	R = L
R	7	1	2
L	2	0	1

is the result of vascular changes following neuronal activation. At first, neuronal activation causes increased oxygen consumption and increased deoxyhemoglobin, which in turn results in increased cerebral blood flow and oxyhemoglobin. The net effect is that of increased oxyhemoglobin and a relatively increased signal of the activated area on GRE T2*. This change is very small about 2-5 per cent at 1.5 T.

The fMRI study of the sensorimotor system is easy to perform and needs no additional equipment. Correlation with intraoperative cortical stimulation can be done. The study by Yeltkin et al in 28 patients showed that activation from fMRI was within 20 mm from intraoperative cortical stimulation in 100 per cent and within 10 mm in 87 per cent(2).

The primary motor cortex is designated M1, which corresponds to Broadmann's area (BA) 4. The M1 lies along the paracentral lobule medially and at the precentral gyrus, which is a narrower strip laterally. Stimulation of M1 produces simple motions and no skilled movement. The supplementary motor cortex (SMA), BA 6a α, includes paracentral lobule medially and the posterior portion of the superior and middle frontal gyri. The premotor area (pre-MA), BA 6a α, BA 6a β and BA 6b, occupies superior and middle frontal gyri and the precentral gyrus. The SMA and the pre-MA are involved in motor preparation and execution. The primary sensory cortex is designated S1, corresponding to BA 3, 1 & 2, and is situated along the postcentral gyrus.

In the present study, with on-off technique, it was discovered that the location of the activated signals vary between precentral gyrus, central sulcus, postcentral gyrus and postcentral sulcus, which are considered primary motor cortex plus primary sensory cortex. The majority are situated at the central sulcus. Although more cases of BPS demonstrate activation posterior to the central sulcus, which is the primary sensory cortex, than BFT as shown in a previous study[3], no statistical significance was noted in the present study. This observation was not found between unilateral active and unilateral passive tasks.

With unilateral tasks, activation of the ipsilateral primary motor cortex was observed as in previous studies[4,5]. The explanation is that about 10-15 per cent of fibers remain uncrossed in human pyramidal tracts[6]. Besides activation of the primary sensorimotor cortex, activation at the superior frontal gyrus and middle frontal gyrus, which are SMA and pre-MA, are also seen.

Concerning the intensity of activations, the passive tasks, both bilateral and unilateral, gave comparable signal intensities compared to the motor tasks[7].

The study of Li et al shows that unilateral activation of the dominant hemisphere is less than that of the non-dominant hemisphere[4,7]. The explanation is that a more skilled dominant hemisphere will expend less effort and produce a weaker signal. However, with bilateral performance, that study revealed more activation of the dominant hemisphere. In the present study, of which the sample size is small, no statistically significant difference in the intensity of activation of both the unilateral and bilateral motor and passive tasks between the dominant and non-dominant hemispheres was found.

SUMMARY

The authors conclude that, to localize the sensorimotor cortex in normal volunteers, passive task e.g. palm scratching can be used instead of active task knowing that palm scratching will gives a slightly more posterior location of the sensorimotor cortex, however, without statistical significance, and will gives comparable intensity of the activation.

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การหาตำแหน่งการทำงานของผิวสมองส่วนเซนซอริมอเตอร์โดยใช้เครื่องพลังสนาม-แม่เหล็กแรงสูง : เปรียบเทียบระหว่างการกระตุ้นด้วยการขยับนิ้ว กับการกระตุ้นด้วยการขีดฝ่ามือในอาสาสมัครปรกติ

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การศึกษามีจุดประสงค์เพื่อเปรียบเทียบตำแหน่งและความแรงของสัญญาณของการกระตุ้นผิวสมองส่วนเซนซอริ-มอเตอร์ระหว่างการกระตุ้นโดยให้อาสาสมัครขยับนิ้วเองซึ่งเป็น motor task กับ การกระตุ้นด้วยการขีดฝ่ามืออาสาสมัครซึ่งเป็น passive task เพื่อพิจารณาใช้ passive task แทนที่ motor task ในผู้ป่วยที่ไม่สามารถทำ motor task ได้ การตรวจใช้ multishot echo-planar T2*-weighted imaging sequences ตรวจในระนาบ axial ที่ระดับผิวสมองส่วนเซนซอริมอเตอร์ระหว่างการขยับนิ้วและการขูดฝ่ามือในอาสาสมัคร 13 ราย ผู้ศึกษาพบว่าตำแหน่งของสัญญาณของการกระตุ้นมือทั้งสองข้างด้วย passive task อยู่หลังกว่าตำแหน่งของการกระตุ้นด้วย motor task แต่ทั้งนี้ไม่มีนัยสำคัญทางสถิติ ไม่พบข้อสังเกตนี้ในการกระตุ้นมือข้างเดียว เมื่อพิจารณาถึงความแรงของสัญญาณพบว่า motor task และ passive task ให้ความแรงของสัญญาณเท่ากันไม่ว่าจะเป็นการกระตุ้นมือทั้งสองข้างหรือมือข้างเดียว ผู้ศึกษาจึงสรุปว่าเราสามารถใช้ passive task แทน active task เพื่อหาตำแหน่งของผิวสมองส่วนเซนซอริมอเตอร์ได้

คำสำคัญ : เครื่องพลังสนามแม่เหล็กแรงสูง, การหาฟังก์ชันการทำงานของผิวสมอง, ผิวสมองส่วนเซนซอริมอเตอร์

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