Somatotopic Mapping of the Supplementary Motor Area

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Purpose : The purpose of this study was to assess supplementary motor area (SMA) activation during motor, sensory, word generation, listening comprehension, and working memory tasks using functional magnetic resonance imaging (fMRI).

Materials and Methods : Sixteen healthy right-handed subjects (9M, 7F) were imaged on a Siemens 1.5T scanner. Whole brain functional maps were acquired using BOLD EPI sequences in the axial plane. Each paradigm consisted of five epochs of activation vs. the control condition. The activation tasks consisted of left finger complex movement, hot sensory stimulation of the left hand, word generation, listening comprehension, and working memory. The reference function was a boxcar waveform. Activation maps were thresholded at an uncorrected $p = 0.0001$.

The thresholded activation maps were placed into MNI space and the anatomic localization of activation within the SMA was compared across tasks.

Results : SMA activation was observed in 16 volunteers for the motor task, 11 for the sensory task, 15 for the word generation task, 5 for the listening comprehension task, and 15 for the working memory task.

The rostral aspects of the SMA showed activity during the word generation and working memory tasks, and the caudal aspects of the SMA showed activity during the motor and sensory tasks.

Right (contralateral) SMA activation was observed during the motor and sensory tasks, and left SMA activation during the word generation and memory tasks.

Conclusion : Our results suggest that SMA is involved in a variety of functional tasks including motor, sensory, word generation, and working memory. The results obtained also support the notion that functionally specific subregions exist within the region classically defined as the SMA.

Index words : Brain, anatomy
Brain, function
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Introduction

The supplementary motor area (SMA) is believed to occupy the medial portion of Brodmann's cortical area 6. As defined by electrical stimulation, this area is located anterior to the primary motor area of the foot, and superior to the cingulate sulcus (1–5).

Studies of the human SMA using a variety of brain mapping methods, including functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have shown it to be involved in aspects of motor control, including task sequencing, intrinsic task complexity, and movement initiation (3–18).

Responses elicited by electrical stimulation include bilateral movements of the extremities with assumption of characteristic postures, vocalization, sensory symptoms, aphasia, and autonomic changes (1–3). Evidence exists to indicate that the SMA is involved in various brain functions such as sensory, listening comprehension, speech expression, and working memory (1–3, 18–31). However, the topographic relationships between areas activated by different functional task paradigms are unclear.

The purpose of this study was to assess SMA activation during motor, sensory, word generation, listening comprehension, and working memory tasks using functional magnetic resonance imaging.

Materials and Methods

Sixteen healthy right-handed volunteers (9 men and 7 women, 25–41 years old) were studied. All had English as a second language, no history of neurological disorder, and at least a college level education. Scanning was performed with a 1.5 T whole-body MRI scanner (Vision, Siemens, Erlangen, Germany) using a standard head coil. The participants were instructed to hold their heads still. Sponges and straps were used to stabilize the head.

Anatomic 2-mm-thick reference axial images were acquired with a magnetization prepared-rapid acquisition gradient echo (MP-RAGE) pulse sequence with parameters of 9.7 sec / 4 msec / 1 (repetition time/echo time/excitations), a 240×240 field of view, and a 256×256 matrix. Functional MR imaging studies with 20 axial sections covering the whole brain were performed using a multisection gradient recalled echo single shot echo planar imaging (EPI) pulse sequence. During the acquisition of the echo planar images, five rest periods were alternated with five task periods. Each period had duration of 21.9 seconds. Functional MR images were acquired with parameters of 3599 msec / 41 msec (repetition time/echo time), a 220×220 mm field of view, a 64×64 matrix, and a 6 mm section thickness. A total of 1200 images were acquired (60 images per section) during the 219 seconds required for each functional MR run.

The activation tasks consisted of left finger complex movement, hot sensory stimulation of the left hand, word generation, listening comprehension, and working memory. For complex movement, the left thumb was apposed against each of the other fingers a different number of times, twice against the index finger, once against the middle finger, three times against the ring finger, and twice against the little finger, and then repeated in reversed order (7). For the hot sensory stimulation task, the investigator alternately placed and removed a glove filled with water heated to 50° Celsius on the left palm of each subject. For the word generation task, the subject thought of as many words as possible beginning with a presented letter for each task period. For the listening comprehension task, materials were sampled from an English novel. The novel was divided into five blocks, and the five blocks had story continuity. English was a comprehended but not the native language of all volunteers. The same set of language material was used in all studies. The volunteers were instructed to pay attention to the story, to understand the contents of the hearing blocks, to relax and to make an effort not recall or think anything about the contents of the sentences, that had been presented (23). The two back memory task was used to activate working memory. The stimuli consisted of numbers shown as a random sequence and displayed at the center of a screen. Two back memory task refers to how far back in the sequence of stimuli that the subject had to recall. The two back working memory task required subjects to continually update their mental set while responding to previously seen stimuli. The remainder of the working memory paradigm was conducted with eyes-open at rest (29–31).

The SMA was defined as the area in the medial portion of the superior frontal gyrus (Brodmann's cortical area 6) in front of the primary motor cortex, and superior to the cingulate sulcus. The mid lines defined its medial-upper limit, and its anterior boundary was defined by a line passing perpendicularly through the rostrum of the corpus callosum (1–4).

The time course of the signal intensity in each pixel over 219 seconds was plotted and compared with a reference function by cross-correlation analysis. Functional images were motion corrected using a realignment program. Images were normalized to a standard space using an eight parameter linear transformation implemented in SPM 99 (Welcome Department of Cognitive Neurology, London, UK). Normalized images were smoothed using 8.0 mm Gaussian Kernel in SPM. The fMRI SPM 99 statistics program was used to estimate the effects of conditions at each voxel according to the general linear model. The analysis was entered as an epoch design of the fixed response/box car form. Activation maps were thresholded at an uncorrected $p = 0.0001$. Activated pixels on functional images were overlaid on to corresponding anatomic reference images using an image processing program. The resulting activation-maps for each subject were then standardized into MNI stereotactic coordinates using SPM 99 (32–34).

The number of volunteers demonstrating any activation of the SMA as defined was tabulated and compared across the various tasks.

Results

SMA activation was observed in 16 volunteers for the motor task, 11 for the sensory task, 15 for the word generation task, 5 for the listening comprehension task, and 15 for the working memory task. The coordinates of these activated regions in MNI space were computed, and the local maxima of the activation clusters inside the SMA are listed in Table 1.

The rostral aspects of the SMA (rostral to the anterior commissure line) showed activity during the word generation and working memory tasks, and the caudal aspects of the SMA (caudal to the anterior commissure line) activity during the motor and sensory tasks. However, the SMA activation level associated with the motor, sensory, word generation, and working memory tasks were similar (Fig. 1 and 2).

Table 1. Coordinates (x, y, z) Correspond to the Atlas of MNI of Activated Pixels in the Supplementary Motor Area According to the Type of Task

	Motor			Sensory			Word			Memory			Listen		
V	x	y	z	x	y	z	x	y	z	x	y	z	x	y	z
1	-6	-8	56	-8	-4	60	-8	4	58	-5	0	57	x	x	x
2	8	5	56	11	3	52	-7	13	60	4	9	49	x	x	x
3	-3	-9	60	1	-2	50	-7	4	48	-6	-2	61	x	x	x
4	-4	-7	45	x	x	x	1	20	46	3	11	54	5	8	54
5	8	6	59	8	-1	49	-4	12	47	-8	14	46	x	x	x
6	5	-9	52	4	2	46	x	x	x	2	18	47	x	x	x
7	6	0	44	6	-7	47	-5	0	44	-4	0	52	x	x	x
8	-4	-4	61	x	x	x	0	18	46	-4	-2	60	x	x	x
9	7	3	52	-6	-9	58	-6	8	54	x	x	x	x	x	x
10	-2	-4	47	7	4	48	-2	6	57	-6	2	46	8	-7	50
11	2	-6	46	x	x	x	-7	1	68	7	4	60	-4	0	60
12	1	2	61	x	x	x	8	16	54	8	8	47	x	x	x
13	5	5	62	6	-5	52	-4	23	50	-3	8	55	2	6	57
14	3	-2	46	x	x	x	-1	3	52	-6	4	54	x	x	x
15	-6	1	47	-5	4	55	-8	6	46	-8	13	44	x	x	x
16	6	-4	48	1	-12	60	4	7	47	-7	-3	51	-6	-8	58
Average	1.6	-1.9	52.6	2.3	-2.5	52.5	-3.1	9.4	51.8	-2.2	5.6	52.2			
Stdev	5.08	5.18	6.59	6.29	5.47	5.11	4.73	7.19	6.71	5.48	6.56	5.65			

V: volunteer, Motor: complex motor, Sensory: hot sensory, Word: word generation, Memory working memory, Listen: listening comprehension

The coordinates were obtained after transforming the brain images of individual studies onto the MNI atlas and are shown in millimeters. x, distance to right (+) or left (-) of mid sagittal line; y, distance anterior (+) or posterior (-) to vertical plane through anterior commissure; and z, distance above (+) or below (-) anterior commissure - posterior commissure line.

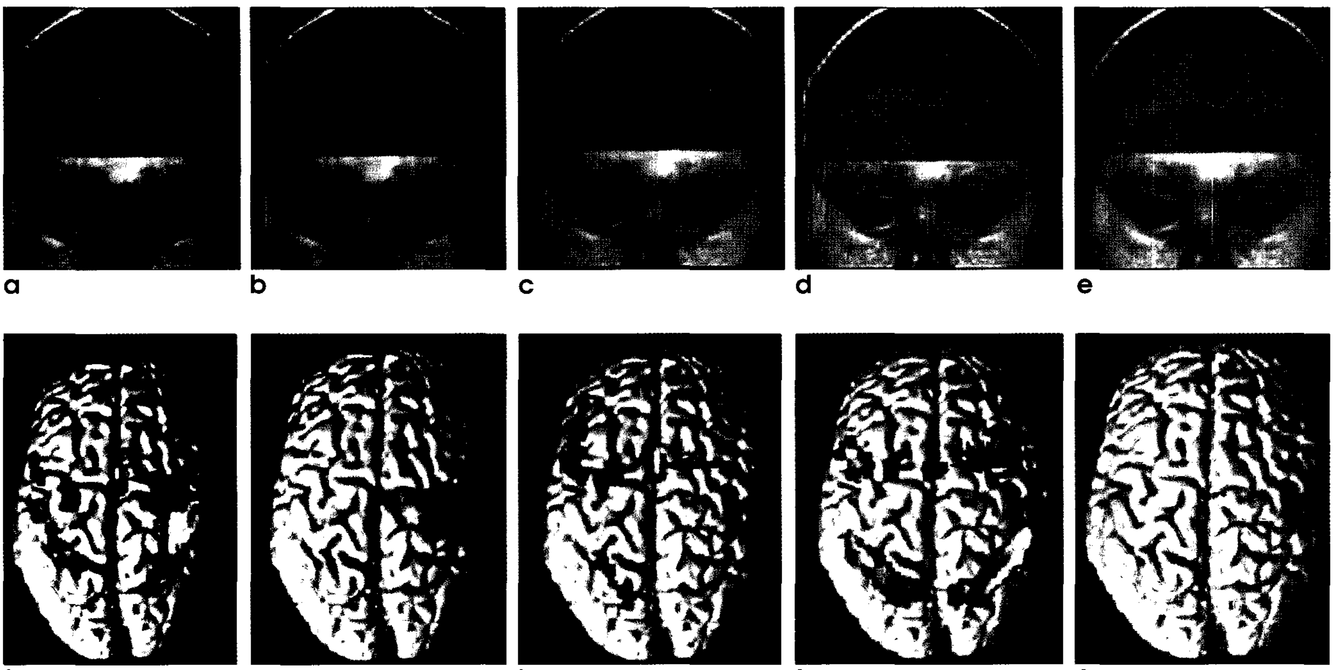
Right (contralateral) SMA activation was observed in the motor and sensory tasks, and left SMA activation was observed in the word generation and memory tasks (Fig. 3).

Discussion

The SMA is often regarded as a pure motor area. However, this and other studies demonstrated SMA activation by motor, sensory, word generation, listening comprehension, and working memory tasks (2, 11, 17–31).

The SMA represents a segment of the premotor cortex located on the interhemispheric aspect of the frontal lobe anterior to the primary motor area of the foot and superior to the cingulate sulcus (1–4). The traditionally defined SMA is now divided into the pre-SMA rostrally and the newly defined SMA caudally. The pre-SMA is particularly active during the learning of new sequential procedures. In contrast, the SMA proper is active during the performance of sequential movements (2–5, 12–15). Recent stimulation studies have demonstrated a somatotopic organization of the human SMA, with the lower extremity, upper extremity, and head representations extending from the posterior to the anterior border. Sensory representation could be either anterior or posterior to the motor representation (19). Talairach and Bancaud reported a crude somatotopic organization with arm responses most posterior, vocalization in the middle, and eye movements most anterior (3). The findings of recent studies show that the SMA should no longer be regarded as a homogenous area, but rather as one composed of subregions with distinct functional roles. We found significantly increased activity in the contralateral, posterior aspect of the classic SMA during complex motor and hot sensory tasks. The word generation and working memory tasks increased activity in the left lateral and anterior aspect of the classic SMA. However, the listening comprehension task increased activity in only 5 of 16 volunteers.

Movement-related SMA activation was observed bilaterally in each subject (4, 7, 14, 15, 35). PET studies on the lateralization of the SMA have typically shown activation that is predominantly contralateral to the moving hand (35). In the present study, SMA was activated predominantly contralaterally in 10 subjects, and ipsilater-



a b c d e

f g h i j

Fig. 1. Functional MR images showing activation in the supplementary motor area during motor (**a**), sensory (**b**), word generation (**c**), working memory (**d**), and listening comprehension(**e**) tasks in the volunteer 13. Volume rendering functional MR images showing activation in the supplementary motor area (arrows) during motor(**f**), sensory (**g**), word generation(**h**), working memory(**i**) , and listening comprehension(**j**) tasks in Group.

ally in 6 subjects during complex motor tasks (Table 1). The greatest activity observed within the SMA was in the right (contralateral side) hemisphere for the motor tasks. Because we only examined left hand complex motor tasks, it was not possible to determine whether the apparent lateralization of activity within the SMA was an effect of unilateral movement or of hemispheric dominance. To clarify this, it would be necessary to repeat this experiment using the right hand.

The SMA receives input not only from the motor and premotor cortices, but also from the sensory cortex (2, 36). Penfield and Welch (1) demonstrated that direct cortical stimulation of the SMA results in both sensory and motor responses, but predominantly the latter. Additionally, PET studies have shown that painful heat sensory stimuli increase regional cerebral blood flow in the contralateral SMA (22). We observed activation in the contralateral SMA in 8 subjects and in the ipsilateral SMA in 3 of 11 subjects during hot sensory stimulation task. Areas of sensory activation in the SMA corresponded to anterior or posterior areas that demonstrated the SMA-type positive motor responses (19). We observed activation in the posterior part of the SMA in six subjects during sensory tasks than that during motor tasks (Table 1). During motor and sensory stimulation, we observed greatest activity in the contralateral hemisphere, in the posterior aspect of the classic SMA. SMA activation was usually observed posterior to the anterior commissure line (negative mean value in column Y in Table 1) during complex motor and hot sensory tasks. Of the five subjects that showed no SMA activation during the sensory tasking, all subjects concerned showed smaller than average volumes of activation in the primary sensorimotor cortex. Caudal SMA activation was observed for complex motor and sensory tasks, whereas more rostral activity was observed for tasks involving word generation, or working memory tasks.

Speech disturbance is observed in patients with tumors involving the SMA or in cases of anterior cerebral artery infarction (25, 26, 37–40). In functional activation

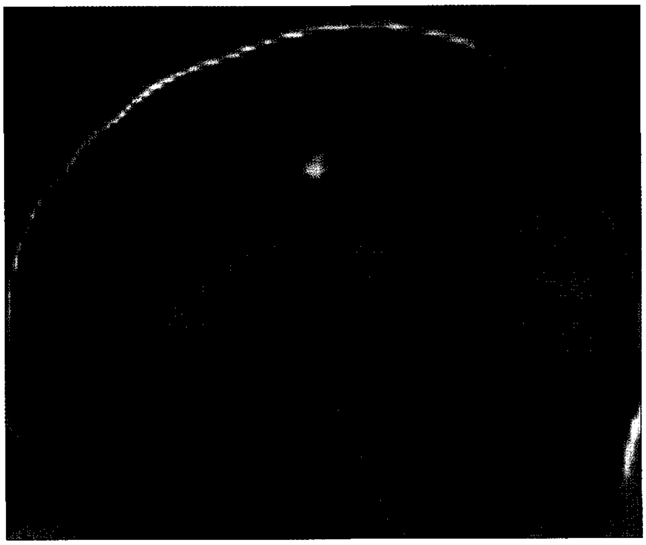


Fig. 2. Sagittal functional MR images of complex motor, hot sensory, listening comprehension, word generation, and working memory tasks.
Functional MR images showing supplementary motor area (SMA) during motor (red), sensory (yellow), word generation (green), and working memory (blue) tasks. The rostral aspects of the SMA showed activity during word generation and working memory tasking, and the caudal aspects of the SMA showed activity during motor and sensory tasks. However, the SMA activation level associated with the motor, sensory, word generation, and working memory tasks were similar.
Red: complex motor, Yellow: hot sensory, Green: word generation, and Blue: working memory tasks.

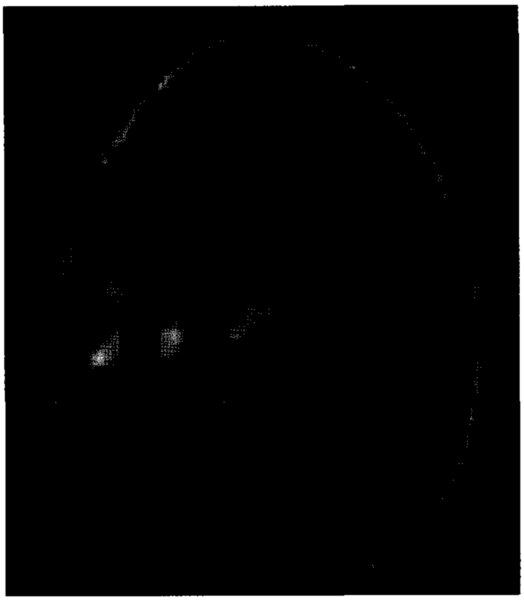


Fig. 3. Axial functional MR images of complex motor, hot sensory, listening comprehension, word generation, and working memory tasks.
Right (contralateral) SMA activation was observed during motor, and sensory tasks, and left SMA activation during word generation and memory tasks.
Red: complex motor, Yellow: hot sensory, Magenta: listening comprehension, Green: word generation, and Blue: working memory tasks.

comparisons of healthy control subjects and aphasic stroke patients, the most consistent compensatory additional activation was found in the SMA, more prominently on the left than on the right side. Significant activation of the left SMA in aphasic stroke patients, therefore, may indicate functional organization of speech to the SMA, which is still intact because of its location outside the territory of the left middle cerebral artery (41). The SMA is involved in the modulation and expression of speech, speech initiation, and the maintenance of speech fluency and volume. Speech disturbance is only observed after resection of the dominant SMA. However, the role of the non-dominant SMA in speech production is controversial. For example, resection of the non-dominant SMA may occasionally be associated with speech dysfunction (2, 25, 37, 40-43). In cases of unilateral SMA damage, the impairment of speech is often transient and the prognosis for recovery appears good. This may result from the bilateral participation of the SMA in the generation of speech (25). We observed SMA activation in the left side in 12 (including x = "0") subjects and in the right side in 3 subjects during word generation tasks (Table 1).

Nakai examined the relationship between the level of language comprehension and brain activation by fMRI. SMA activation was observed both in the English and Japanese tasks (23). The SMA was activated by comprehensive languages but not by non-comprehensive language. This suggests that the SMA is also involved co-operatively in listening comprehension. Listening comprehension task in a subject's native language is relatively sensitive to the demands for syntactic or semantic processing, whereas the demand by a non-native language may be increased. In a prior study, a listening to a tone task was associated with bilateral SMA activation (x= +/-6, y=-5, z=61) (44). In our study, all subjects spoke English, but as a second language. We observed SMA activation in the right side in three cases and in the left side in two cases of five cases showing an activated SMA during the listening comprehension task. There were not shown the SMA activation in the group analysis during listening comprehension task (Fig. 1J).

SMA activation was also observed in the working memory task. Prior n-back studies that specifically examined the relationship between working memory load and the SMA have demonstrated that increasing working memory load produces increasing left SMA activation (28-30). During the two-back working memory tasks, we also observed greatest activity in the left hemisphere, in the anterior aspect of the classic SMA.

Conclusion

In conclusion, our results suggest that participation by the SMA in a variety of functional tasks including motor, sensory, word generation, and working memory can be demonstrated by fMRI. Our results also support the notion that functionally specific subregions exist within the classically defined SMA.

References

1. Penfield W, Welch K. The supplementary motor area of the cerebral cortex. A clinical and experimental study. Arch Neurol Psychiatr 1951;66:289-317
2. Goldberg G. Supplementary motor area structure and function: review and hypotheses. Behav Brain Sci 1985;4:567-615
3. Talairach J, Bancaud J. The supplementary motor area in man. Anatomo-functional findings by stereo-electroencephalography in epilepsy. Int J Neurol 1966;5:330-347
4. Tanji J. The supplementary motor area in cerebral cortex. Neurosci Res 1994;19:251-258
5. Tanji J. New concepts of the supplementary motor area. Curr Opin Neurobiol 1996;6:782-787
6. Picard N, Strick PL. Activation of the supplementary motor area (SMA) during performance of visually guided movements. Cereb Cortex 2003;13:977-986
7. Roland PE, Larsen B, Lassen NA, Skinhoj E. Supplementary motor area and other cortical areas in organization of voluntary movements in man. J Neurophysiol 1980;43:118-136
8. Oliveri M, Babiloni C, Filippi MM, et al. Influence of the supplementary motor area on primary motor cortex excitability during movements triggered by neutral or emotionally unpleasant visual cues. Exp Brain Res 2003;149:214-221
9. Tanji J, Shima K. Role for supplementary motor area cells in planning several movements ahead. Nature 1994;371:413-416
10. Righter W, Andersen PM, Georgopoulos AP, Kim SG. Sequential activity in human motor areas during a delayed cued finger movement task studied by time-resolved fMRI. Neuroreport 1997;8:1257-1261
11. Rao SM, Binder JR, Bandettini PA, et al. Functional magnetic resonance imaging of complex human movement. Neurology 1993;43:2311-2318
12. Toyokura M, Muro I, Komiya T, Obara M. Activation of pre-supplementary motor area (SMA) and SMA proper during unimanual and bimanual complex sequences: an analysis using functional magnetic resonance imaging. J Neuroimaging 2002;12:172-178
13. Kansaku K, Kitazawa S, Kawano K. Sequential hemodynamic activation of motor areas and the draining veins during finger

movements revealed by cross-correlation between signals from fMRI. Neuroreport 1998;9:1969-1974
14. Hikosaka O, Sakai K, Miyauchi S, Takino R, Sasaki Y, Putz B. Activation of human presupplementary motor area in learning of sequential procedures: a functional MRI study. J Neurophysiol 1996;76:617-621
15. Humberstone M, Sawle GV, Clare S, et al. Functional magnetic resonance imaging of single motor events reveals human presupplementary motor area. Ann Neurol 1997;42:632-637
16. Weilke F, Spiegel S, Boecker H, et al. Time-resolved fMRI of activation patterns in M1 and SMA during complex voluntary movement. J Neurophysiol 2001;85:1858-1863
17. Cadoret G, Smith AM. Comparison of the neuronal activity in the SMA and the ventral cingulate cortex during prehension in the monkey. J Neurophysiol 1997;77:153-166
18. Chung GH, Han YM, Kim CS. Functional MRI of the supplementary motor area: comparison of motor and sensory tasks. J Comput Assist Tomogr 2000;24:521-525
19. Lim SH, Dinner DS, Pillay PK, et al. Functional anatomy of the human supplementary sensorimotor area: results of extraoperative electrical stimulation. Electroencephalogr Clin Neurophysiol 1994;91:179-193
20. Korvenoja A, Huttunen J, Salli E, et al. Activation of multiple cortical areas in response to somatosensory stimulation: combined magnetoencephalographic and functional magnetic resonance imaging. Hum Brain Mapp 1999;8:13-27
21. Kakigi R. Somatosensory evoked magnetic fields following median nerve stimulation. Neurosci Res 1994;20:165-174
22. Adler LJ, Gyulai FE, Diehl DJ, Mintun MA, Winter PM, Firestone LL. Regional brain activity changes associated with fentanyl analgesia elucidated by positron emission tomography. Anesth Analg 1997;84:120-126
23. Nakai T, Matsuo K, Kato C, Matsuzawa M, Okada T. A functional magnetic resonance imaging study of listening comprehension of languages in human at 3 tesla-comprehension level and activation of the language areas. Neurosci Lett 1999;263: 33-36
24. Chee MW, O'Craven KM, Bergida R, Rosen BR, Savoy RL. Auditory and visual word processing studied with fMRI. Hum Brain Mapp 1999;7:15-28
25. Zentner J, Hufnagel A, Pechstein U, Wolf HK, Schramm J. Functional results after resective procedures involving the supplementary motor area. J Neurosurg 1996;85:542-549
26. Pai MC. Supplementary motor area aphasia: a case report. Clin Neurol Neurosurg 1999;101:29-32
27. Casey BJ, Cohen JD, O'Craven K, et al. Reproducibility of fMRI results across four institutions using a spatial working memory task. Neuroimage 1998;8:249-261
28. Coull JT, Frith CD, Frackowiak RSJ, Grasby PM. A fronto-parietal network for rapid visual information processing: a PET study of sustained attention and working memory. Neuropsychologia 1996;34:1085-1095
29. Callicott JH, Mattay VS, Bertolino A, et al. Physiological characteristics of capacity constraints in working memory as revealed by functional MRI. Cerebl Cortex 1999;9:20-26
30. Jonides J, Schumacher EH, Smith EE, et al. The role of parietal cortex in verbal working memory. J Neurosci 1998;18:5026-5034
31. Thomas KM, King SW, Franzen PL, et al. A developmental functional MRI study of spatial working memory. Neuroimage 1999;10:327-338
32. Friston KJ. Statistical parametric mapping: Ontology and current issues. J Cereb Blood Flow Metab 1995;15:361-370
33. Bandettini PA, Jesmanowicz A, Wong EC, Hyde JS. Processing strategies for time-course data sets in functional MRI of the human brain. Magn Reson Med 1993;30:161-173
34. Talairach J, Tournoux P. Co-planar stereotaxic atlas of the human barin. 3-dimensional proportional system: an approach to cerebral imaging. New York, NY: Thieme Medical Publishers, 1988;1-122
35. Kawashima R, Yamada K, Kinomura S, et al. Regional cerebral blood flow changes of cortical motor areas and prefrontal areas in humans related to ipsilateral and contralateral hand movement. Brain Res 1993;623:33-40
36. Jurgens U. The efferent and afferent connections of the supplementary motor area. Brain Res 1984;63-81
37. Botez MI, Barbeau A. Role of subcortical structures, and particulary of the thalamus, in the mechanisms of speech and language. Int J Neurol 1971; 8:300-320
38. Arseni C, Botez MI. Speech disturbances caused by tumours of the supplementary motor area. Acta Psychiatr Neurol Scand 1961;36:279-299
39. Green JR, Angevine JB, White JC Jr.,Edes AD, Smith RD. Significance of the supplementary motor area in partial seizures and in cerebral localization. Neurosurgery 1980;6:66-75
40. Laplane D, Talairach J, Meininger V, Bancaud J, Orgogozo JM. Clinical consequences of corticectomies involving the supplementary motor area in man. J Neurol Sci 1977;34:301-314
41. Karbe H, Thiel A, Weber-Luxenburger G, Herholz K, Kessler J, Heiss WD. Brain plasticity in poststroke aphasia: what is the contribution of the right hemisphere? Brain Lang 1998;64:215-230
42. Larsen B, Skinhoj E, Lassen NA. Variations in regional cortical blood flow in the right and left hemispheres during automatic speech. Brain 1978;101:193-209
43. Rostomily RC, Berger MS, Ojemann Ga, Lettich E. Postoperative deficits and functional recovery following removal of tumors involving the dominant hemisphere supplementary motor area. J Neurosurg 1991;75:62-68
44. Binder JR, Frost JA, Hammeke TA, Cox RW, Rao SM, Prieto T. Human brain language areas identified by functional magnetic resonance imaging. J Neurosci 1997;17:353-362

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부운동영역의 뇌지도화

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정경호 · 한영민 · 정수현 · 이 헌 · 진공용 · 이상용

목적 : 운동, 감각, 단어형성, 듣고이해하기, 기억력과제를 주면서 기능적자기공명영상를 이용하여 부운동영역의 기능적 지도화를 한다.
대상 및 방법 : 16명의 오른손잡이 정상지원자를 대상으로 1.5 T 자기공명영상기기를 사용하여 전뇌를 BOLD EPI를 기능적자기공명영상을 얻었다. 왼손가락운동, 고온감각, 단어형성, 듣고이해하기 그리고 기억자극을 주면서 5번의 자극기와 휴식기를 반복하여 영상을 얻었다. p = 0.0001의 역치를 사용하여 활성화된 뇌의 지도화를 시행하였고 역치 이상의 뇌활성화가 보이는 부위를 MNI 공간으로 표시하여 각각의 자극에 대한 해부학적 위치와 활성화를 분석하였다.
결과 : 16명의 정상지원자 중 부운동영역의 활성화는 운동자극시 16명 모두에서, 감각자극시 11명, 단어형성자극시 15명, 듣고이해하기자극시 5명, 그리고 기억자극시 15명에서 보였다.
부운동영역중 앞부분의 활성화는 단어형성자극과 기억자극시 보였으며, 뒤부분의 활성화는 운동과 감각자극시 측정되었다. 운동과 감각자극시 자극부위와 반대편의 부운동영역에서 활성화, 그리고 단어형성자극과 기억자극시 왼쪽반구의 활성화가 주로 측정되었다.
결론 : 부운동영역은 운동과 감각 그리고 단어형성기능과 기억기능에 연관이 있는 뇌부위이며, 부운동영역중에서도 각각의 기능에 해당하는 부위가 존재한다.

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