·Special Paper·

Brain Representation of Active and Passive Hand Movements in Healthy Aged People

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Abstract

Objective: To reveal the neural network of active and passive hand movements.

Method: Seven healthy aged people were checked, and acquired functional magnetic resonance imaging data on a 1.5T scanner. Active movement consisted of repetitive grasping and loosening of hand; passive movement involved the same movement performed by examiner. Both types of hand movements were assessed separately. These data were analysed by Statistical Parametric Mapping Microsoft.

Result: The main activated brain areas were the contralateral supplemental motor area, primary motor area, primary sensory area and the ipsilateral cerebellum when subjects gripped right hands actively and passively. The supplemental area was less active in passive hand movement than active hand movement. The activated brain areas were mainly within Brodmann area 4 during active hand movement; in the contrast, the voxels triggered by passive movement were mainly within Brodmann areas 3,1,2 areas.

Conclusion: The results suggest that the neural networks of passive and active tasks spared some common areas, and the passive movement could be as effective as active movement to facilitate the recovery of limbs motor function in patients with brain damage.

Key word passive movement; active movement; hand gripping; blood oxygen level dependent-functional magnetic resonance imaging

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Introduction

In China, brain damage such as stroke and traumatic brain injury is one of the leading causes of hand dysfunction[1]. In Canada, up to 85% of persons with complete stroke may have residual arm dysfunction which will interfere with their living ability independently[2].Rehabilitation interventions are the cornerstones of care and recovery after stroke[3]. The rehabilitation therapy after brain damage involves active movement therapy and passive movement therapy. Lots of studies have used functional imaging to examine the brain activated regions of active movement, such as tapping finger[4—5]. However, relatively few studies have investigated the characteristics of brain activated regions during passive hand movement in aged subjects. In this study, blood oxygen level dependent functional magnetic resonance (BOLD-fMRI) was used to reveal the brain representation of gripping dominant (right) hands actively and passively in healthy aged people. Which can help us to understand the similarity and differences between the neural mechanisms of active movement and of passive movement.

Methods

Subjects

Seven healthy aged volunteers participated in this study (three males and four females, age range 56—74 years; mean ± SD, 66.28 ± 6.34 years). All subjects were right-handed. They reported no history of neurological illness, psychiatric disorder or vascular disease. All volunteers understood the experiment protocol, and signed the

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consent forms. This study was approved by the local Ethics Committee.

fMRI Data Acquisition

Magnetic resonance (MR) images were acquired using a Marconi 1.5T EDGE ECLIPSE. The tasks were designed by the block design. First, these volunteers were asked to consecutively actively close and open the right hand for 30 seconds and have a rest for 30 seconds, then repeat the cycle five times. Second, the examiner closed and opened the right hands of the seven volunteers, and the frequency and pattern of movement were the same as active movement. Subjects performed the following tasks with auditory pacing stimulus at 1Hz, and task switching instructions were presented orally. Prior to the scanning, subjects were trained until they were capable of performing the task.

A T1-weighted high-resolution sagittal MR image was acquired with a gradient echo SE sequence (TR/TE/flip angle 300ms/11.5ms/90°, field of view 24cm×24cm, slice thickness/slice gap=7mm/1mm, matrix size=128 × 128). Then T2*-weighted echo-planar MR images were obtained with EPI sequence, using BOLD contrast (TR/TE/flip angle 2000ms/40ms/90°, matrix size 64×64, field of view 24cm×24cm. slice thickness/slice gap = 6mm/1 mm, in-plane resolution=3.75mm×3.75mm. 120 brain volumes were acquired for each run. The first 10 volumes of each run were discarded to reach signal equilibrium.

fMRI Data Preprocessing and Statistical Analysis

Data preprocessing and statistical analysis were performed with Statistical Parametric Mapping Microsoft, Well come Trust Centre for Neuroimaging, www.fil.ion.ucl.ac.uk/spm/). Preprocessing steps included spatial realignment of a series of volumes and unwarping, normalization into the same coordinate frame as the Montreal Neurological Institute (MNI) template brain with transformation parameters derived from segmentation of the high-resolution anatomical image coregistered to the mean functional image, and smoothing using a Gaussian filter of 4 mm full width at half maximum (FWHM).

Analysis were performed using *t*-test. Maps were first thresholded at P=0.05. In these maps, activated clusters were considered significant at $P<0.05$, corrected for multiple comparison. Then using the Xjview 8.10 (http://www.alivelearn.net/xjview) software, the activated brain areas were showed in the standard brain maps. Putting the 7 "spm.mat" data together, the common regions during the 7 subjects actively moving right hand were got, so the statistics brain map and the transverse slices of brain activated maps could be obtained(Fig.1). In the same way, the functional images produced by right hand passively movement could be obtained also.

Results

For active movement, 16 activated cortical and subcortical areas were reported, while for passive movement 21 cortical and subcortical areas were reported. The areas which labeled in Brodmann system were chose to study. The activated brain areas were listed in Table 1.

The voxels of gray matters of contralateral (to hand movement) hemisphere were got, which illustrated the regions of Brodmann areas (BAs) (Table 1). The findings showed that the main activated brain areas were the contralateral BA 6 (supplemental area), BA 4 (primary motor area), BA 3,1,2 (primary sensory area),and the ipsilateral (to hand movement)cerebellum when subjects gripped right hands actively(Figure 1). During the right hand gripped passively, the BA 6 (supplemental area) was activated less than during active hand movement(Figure 2). The activated brain areas were mainly within BA 4 during active hand movement, in the contrast, the voxels triggered by passive movement were mainly within BA 3,1, 2. The BA 40 (supramarginal gyrus considered by some to be part of Wernicke's area) were activated both during passive and active hand movements, particularly during passive hand movements. Several features were found as following: ①The activated areas were more spread than during active movement; ②The representative brain areas on hand passive grip were larger than during active move-

Table 1 Activated Contralateral Brodmann Areas (from Xjview8.10 report)

	activated voxels	
	active movement	passive movement
BA6	58	71
BA4	102	67
BA3	75	56
BA1	-	60
BA2	9	70
BA5	-	66
BA40	2	74

Figure 1 The main activated brain areas was the contralateral BA 6(supplemental area),BA 4(primary motor area),BA 3,1,2(primary sensory areas),and the ipsilateral(to hand movement) cerebellum when subjects gripped right hand actively

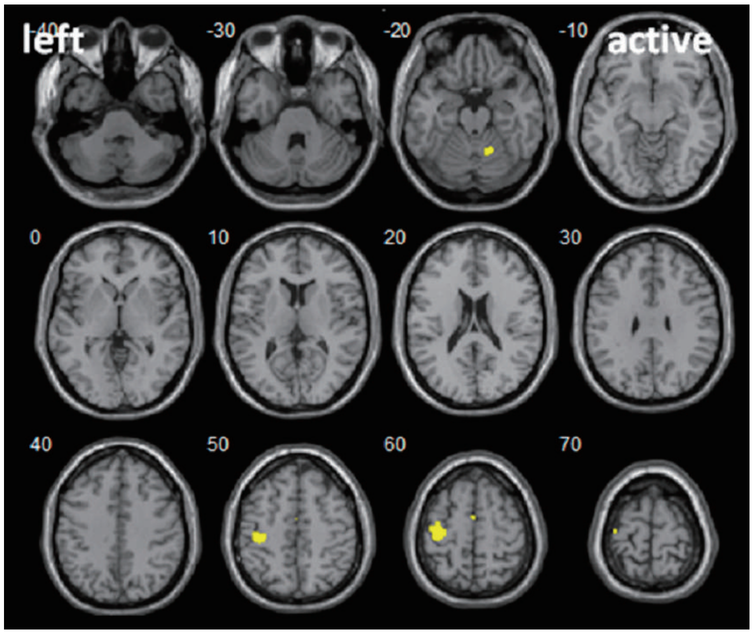
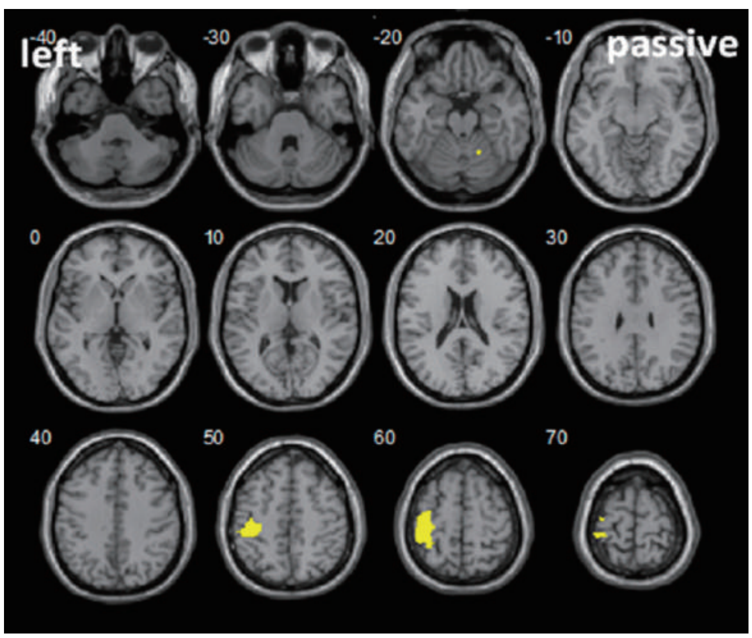


Figure 2 The main activated brain areas were the contralateral BA 6(supplemental area),BA 4(primary motor area),BA 3,1,2(primary sensory areas),and the ipsilateral(to hand movement) cerebellum when subjects gripped right hand passively



ment; ③The passive movement was mainly in BA 3,1,2 regions, in the contrast, the active movement was focus on the areas of BA 4 and BA 6.

Discussion

The present study showed that both active and passive movements of right hands could activate the contralateral BA 6, BA 4, BA 3,1,2 and the ipsilateral cerebellum. The findings agreed with previous other studies[8—10].

Additionally, more activated brain regions were found in premotor aera (BA 6) during active movement execution than during passive movement, and passive movement lead to more active voxels in BA 3,1,2 than during active movement. We proposed that it might be related to the neural network of limb motor, BA 6 being in charge of making plan and initiating the movement, BA 4 responsible for sending messages out to the effect organs (right hand) and making the hand moving, and BA 3,1,2 involving in perceptions of limb motor. Active movement needs motor planning and passive movement has little to do with motor planning.

Guzzetta et al. conducted a functional neuroimaging study to explore brain representation of active and passive hand movements in healthy children. They also found there was no significant difference in the patterns of activation between active and passive tasks[11],both tasks activating contralateral primary sensorimotor cortex (SMC), ipsilateral cerebellum, supplementary motor area (SMA), and lateral premotor cortex(PMC). Comparing with our results, this may be the difference between children and the aged.

The ipsilateral cerebellum is thought to play an important role in sensory-motor integration[12—13], and be the main regions to coordinate the muscles contraction, to control the muscles tones, which can assure the movement more accurately and smoothly. From the present study, the ipsilateral cerebellum were activated during both active movement and passive movement. These phenomenon also were found in some other studies[12].

In our study, BA 40 were activated during active movement and passive movement. It is not clear how the BA 40 area acts on the hand movement actively and passively. Some studies have also demonstrated age-related activations increase in the areas during motor tasks. A number of studies have found extra activities in the ipsilateral SMC in older adults when compared to young adults[9,14,—15]. These changes might be associated with several declines of motor system in aged subjects. Several declines of motor system could decrease the motor ability, so more brain areas were activated to deal with several decline[16].

This study displayed the passive hand movement could activate the same brain areas as the active hand movement[17]. The reason is supposed to be due to nerve connections between sensory cortex and motor cortex, which have been reported in some documents. Passive hand movement could elicit activation of corresponding efferent zones in the primary motor cortex. Sensory input responsible for primary motor activation is primarily via muscle spindle receptor afferent input that is relayed to BA 2 and 3 of primary sensory cortex. BA 1 and 2 have input to the primary motor cortex both directly and indirectly[18—19]. The connections within different cortex may explain the activation within efferent zones of primary motor cortex in response to passive movements.

Because of only 7 subjects participated in this experiment, this was a statistic limitation in this study. Further study with larger number of healthy volunteers or patients is needed to increase the validity of our conclusions.

Conclusions

This study suggests that the neural network of passive movement is similar to active movement. Although there are a few subtle differences in the activated brain areas between the two types of movements, the passive movement may also be an effective rehabilitation therapy as active movement for patients with brain damage.

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