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Research Report

Behavioral improvements and brain functional alterations by motor imagery training

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ABSTRACT

Motor imagery training is considered as an effective training strategy for motor skill learning and motor function rehabilitation. However, compared with studies of the neural mechanism underlying motor imagery, neuroimaging examinations of motor imagery training are comparatively few. Using functional magnetic resonance imaging, we designed a 2-week motor imagery training experiment, including execution and imagery tasks, to investigate the effectiveness of motor imagery training on the improvement of motor performance, as well as the neural mechanism associated with motor imagery training. Here, we examined the motor behavior, brain activation, and correlation between the behavior of the motor execution task and the brain activation across task-related region of interests (ROIs) in both pre- and post-test phases. Our results demonstrated that motor imagery training could improve motor performance. More importantly, the brain functional alterations induced by training were found in the fusiform gyrus for both tasks. These findings provide new insights into motor imagery training.

1. Introduction

Exploring the neural mechanisms underlying motor function and investigating the training strategies for both motor skill learning and motor function rehabilitation have been the focus of many scientists. In such studies, neuroimaging and electrophysiological techniques (e.g., positron emission tomography (PET) scans, functional magnetic resonance imaging (fMRI), electroencephalography (EEGs), and transcranial magnetic stimulation (TMS)) have been necessary and important tools (Babiloni et al., 2006; Beck et al., 2007; Kwon et al., 2009; Sacco et al., 2006).

Neuroimaging studies have revealed that motor imagery and motor execution shared congruence in functional neuroanatomy, including the primary motor cortex (M1), supplementary motor area (SMA), premotor area (PMA), and cerebellum (de Lange et al., 2008; Gerardin et al., 2000; Rodriguez et al., 2008; Stippich et al., 2002). In addition, attention has recently been given to how training impacts motor function. Previous neuroimaging studies have investigated physical training and motor imagery training with execution and imagery tasks, respectively (Jackson et al., 2003; Lacourse et al., 2005; Lafleur et al., 2002). Data from these experiments revealed that similar brain functional alterations in orbitofrontal cortex (OFC) are

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associated with training for both tasks and indicated that such similar alterations could be observed after either physical or motor imagery training. Moreover, additional studies have compared different training methods by motor execution tasks (Nyberg et al., 2006; Olsson et al., 2008a). Their results demonstrate that increased activity is localized to portions of the motor cortex (e.g., the SMA and PMA) for physical training, whereas the increased activation observed for motor imagery training are in the visual cortex (e.g., the secondary visual cortex and fusiform). Because the function of the visual region is associated with visual memory, the improved motor performance by motor imagery training was interpreted as the formation of a visual memory. It is interesting to note that the improved motor behavior during the motor execution task was not significantly correlated with the activities of the fusiform gyrus, though motor imagery training can alter the activities of the fusiform gyrus for motor execution tasks (Olsson et al., 2008a).

By far, there are still few neuroimaging studies of motor training including physical training and motor imagery training. Moreover, the brain functional alterations induced by motor imagery training for execution/imagery task were inconsistent in the previous studies (Jackson et al., 2003; Nyberg et al., 2006; Olsson et al., 2008a). However, motor imagery training has been increasingly regarded as an effective strategy for both motor function rehabilitation and motor skill learning (Olsson et al., 2008b; Sharma et al., 2006). The aim of the present study was to examine the effectiveness of motor imagery training on behavioral improvement and the neural mechanisms associated with motor imagery training on motor execution and motor imagery tasks. Here, using fMRI, we designed a 2-week motor imagery training experiment, including executing and imagining sequential tapping tasks, and measured the behavior, brain activation, and correlation between the behavior and the brain activities across task-related region of interests (ROIs) before and after training.

2. Results

2.1. *Behavior results*

In the experimental group, the participants performed the sequence tapping at the mean execution rate of 2.0 Hz in the pre-test scanning (Fig. 1a). The solid line in Fig. 1a illustrates that the mean execution rate of experimental group was significantly faster in post-test than pre-test ($T(13)=9.27$, $P<0.001$), however it did not arrive at the required rate of 4 Hz. The execution rate during post-test vs. pre-test for each participant is plotted in Fig. 1b, which shows that all the

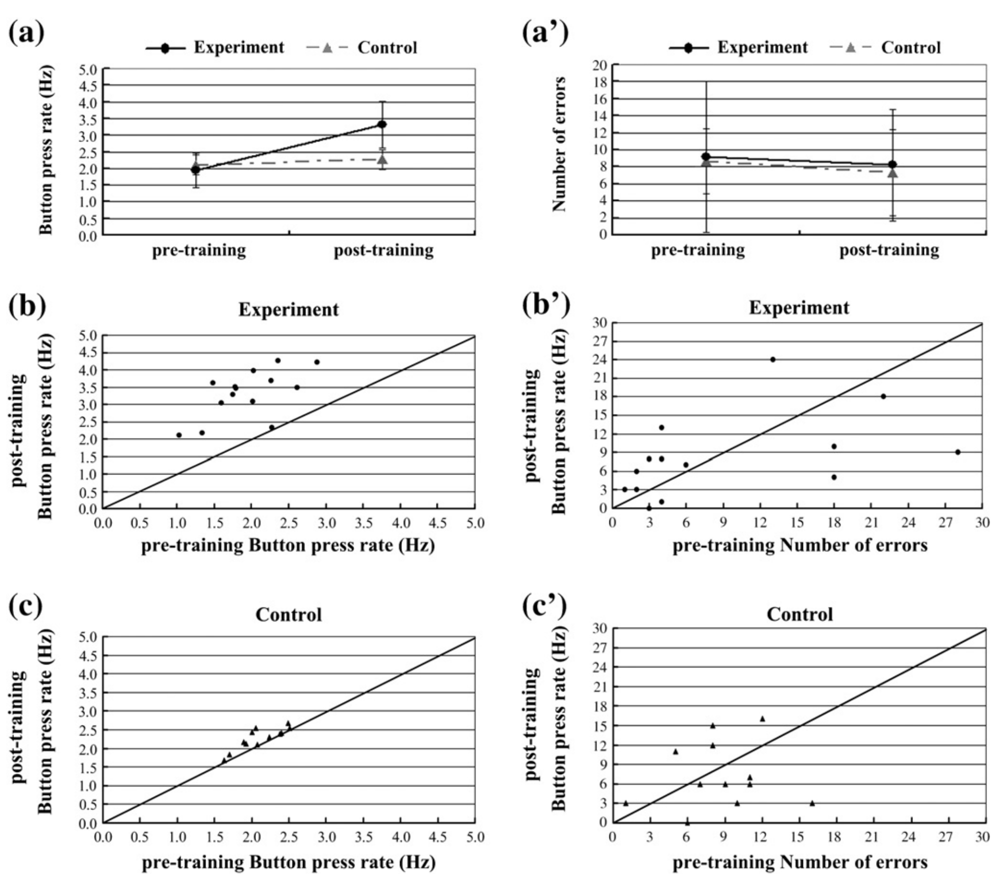

Fig. 1 – Mean button press rate (a) and mean number of errors (a′) for pre-test and post-test of experimental and control groups; the button press rate (b) and the number of errors (b′) for each participant in post-test versus pre-test of experimental group; the button press rate (c) and the number of errors (c′) for each participant in post-test versus pre-test of control group. The diagonals in (b), (b′), (c) and (c′) separate the participants who have improved from who have not.