

Chapter 4

Motor Cortex Activation during Mental Imagery of Walking: An fNIRS Study

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ABSTRACT

The authors are developing a hybrid walking rehabilitation system to realize the early recovery of walking ability, which includes both active movement training using walking rehabilitation machines and neurorehabilitation using mental imagery of walking. In this study, the authors compared the activation of the motor area during real walking (RW), virtual walking (VW), and walking observation (WO) using fNIRS (functional Near-InfraRed Spectroscopy). VW was a first-person perspective imagery in which the subjects were shown moving scenes and imagined that they were actually walking in the scenes. WO was a third-person perspective imagery in which the subjects were instructed to imagine that they were walking at the same pace as the person in the video being shown to the subjects. Based on four subjects, results showed that the oxygenated hemoglobin (oxy-Hb) in the motor area during both the VW and WO were on average higher than during the RW. This might be because it was not necessary to pay attention to the movements of the legs and feet during normal walking, whereas movement planning was required when the subjects imagined that they were walking similar to another person. There was no significant difference between the oxy-Hb during the VW and the WO. The importance of the stimulus diversity in the mental imagery of walking was suggested.

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INTRODUCTION

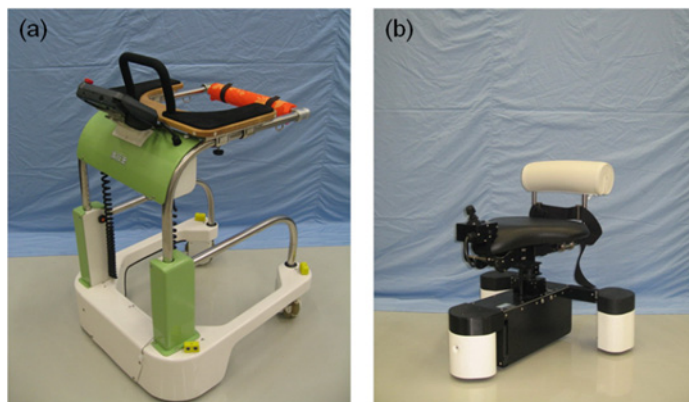
Recently, an increasing number of studies have focused on rehabilitation in the aging population, especially in an aging society with a low birthrate, such as Japan. The number of people suffering from walking impairments due to illness or accident is increasing, and the number of physical therapists cannot meet with the demand of *walking rehabilitation*. Therefore, different types of rehabilitation machines, which can help with early recovery and relieve the burden of physical therapists, have been developed (Okada et al., 2001; Horst, 2009). In previous studies, we developed *omnidirectional walkers*, which can move in any direction while maintaining their orientation, for standing exercises (Tan et al., 2011) and sitting exercises (Wang, Ishida, & Fujie, 2009), as shown in Figure 1(a) and Figure 1(b), respectively. The walker for the standing exercise is designed for patients who are able to maintain a standing posture by themselves, and the walker for the seated exercise is designed for severe patients who are unable to stand. The omnidirectional walking exercise has been proven to be effective for the early recovery of walking disabilities (Ishida, Wang, Nagano, & Kishi, 2008).

To date, most of the developed walking rehabilitation machines aim at enhancing muscle

strength, thus neglecting the recovery of the neural system. However, the causes for walking disabilities include not only muscle weakness, but also neural dysfunctions due to stroke or Alzheimer's disease. Fifty-eight percent of walking disabilities are caused by problems in the neural system. Thus, in addition to muscle strength, brain activities must also be considered in walking rehabilitation in order to improve the efficiency of the rehabilitation. Furthermore, for the severe patients who are completely bed-ridden, it is important to activate the neural system, which is related to walking movement. Therefore, we propose a *hybrid rehabilitation system* that includes both muscle strength enhancements using walking rehabilitation machines and *neuorehabilitation* using the mental imagery of walking.

Motor imagery is commonly used in sports to improve performance, which raises the possibility of applying it as a rehabilitation method. The effectiveness of motor imagery training in restoring motor function after stroke has been indicated by several studies (Sharma, Pomeroy, & Baron, 2006; Dickstein, Dunsky & Marcovitz, 2004). However, the underlying mechanism of motor imagery training-induced improved performance remains unknown. Understanding the effect of rehabilitative techniques on brain plasticity is potentially important in providing a

Figure 1. Omni-directional walkers: (a) is for standing exercise, and (b) is for seated exercise



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