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A Study of Analysis of the Brain Wave with Respected to Action Observation and Motor Imagery: a Pilot Randomized Controlled Trial

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Abstract. [Purpose] The purpose of this study was to compare the effects of action observation training and motor imagery training on recovery from chronic stroke. [Subjects] Thirty patients (who were over six months post stroke) participated in this study and were randomly allocated to three groups. [Methods] The action observation training group practiced additional action observation training for five 30-minute sessions over a four-week period. The motor imagery training group practiced additional motor imagery training for five 30-minute sessions over a four-week period. Electroencephalogram were used to compare brain waves between the three groups. [Results] The action observation group showed significant changes in relative alpha power in Fp1 and Fp2 and relative beta power in Fp2 and C3. [Conclusion] Action observation induces higher levels of cognitive activities than motor imagery and physical training. Action observation is expected to be more effective for stroke patients.

Key words: Action observation, Motor imagery, Stroke

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INTRODUCTION

Therapeutic approaches to stroke recovery include neurodevelopmental treatment, functional electric stimulation, constraint-induced therapy, and robot-assistance training[1–4)]. Also, motor imagery and action observation are applied to the rehabilitation of stroke patients in the form of cognitive intervention methods[5)].

Motor imagery is a conscious cognitive processing of the brain that induces activation of muscles related to actual motion output by imagining motions[6)]. During motor imagery, activation of the premotor area, supplementary motor area, cingulate gyrus, parietal lobe, basal ganglia, and cerebellum is known to occur in a manner similar to that during actual performance of activities[7)]. Some studies have reported the effectiveness of motor imagery not only in recovering from injuries and improving motor skills in healthy individuals and athletes[8)], but also in enhancing motor skills in stroke patients[9)]. However, the effects of motor imagery differ according to the individual ability of imagery, functional level of the learner, and cooperation and concentration of the learner[5)].

Action observation, based on the same neural mechanism as motor imagery, has been suggested as an alternative intervention that can complement the limitations of motor imagery training[10)]. Action observation, which is based on mirror neurons that are active both when people perform an action and when they watch it being performed, is a cognitive intervention technique that is applied to patients with motor disorders as well as athletes and healthy people to improve and learn motor skills, and it is known to be effective in enhancing functional activities in the elderly[11)].

However, while there have been many studies that examined immediate changes in brain activity caused by either action observation or motor imagery[12)], studies focusing on long-term changes in brain activity taking several weeks at least to be caused have been lacking. The aim of this study is to determine the changes in the chronic stroke patient's brain activity after four weeks of action observation training and motor imagery training.

SUBJECTS AND METHODS

Of 59 consecutive registered stroke patients, 30 patients who fulfilled the selection criteria were enrolled in this study. For more information about subjects, refer to Table 1. Detailed inclusion criteria were as follows: (1) having a first-time ischemic or hemorrhagic stroke, (2) over six months since onset, (3) able to walk independently more than 10 m, (4) more than 24 points on the Mini Mental State Examination, and (5) fewer than 36 points on the Vividness Motor Imagery Questionnaire-2. Exclusion criteria were as follows: (1) severe cognitive disabilities, such as unilateral neglect, dementia, and depression, and (2) severe aphasia. After baseline measurements were obtained, patients were randomly assigned to groups by selection using sealed envelopes.

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Table 1. General characteristics of the participants

Characteristics	Action observation training group (n=9)	Motor imagery training group (n=9)	Physical training group (n=9)
Gender (male/female)	7/2	6/3	7/2
Stroke type (ischemic/hemorrhagic)	5/4	5/4	7/2
Paretic side (right/left)	6/3	5/4	3/6
Age (year)	55.3 ± 12.1 [a]	54.8 ± 8.8	59.8 ± 8.9
Height (cm)	170.4 ± 7.6	168.0 ± 9.1	168.7 ± 8.7
Weight (kg)	65.8 ± 14.9	71.2 ± 10.7	62.1 ± 7.8
Onset (month)	8.3 ± 3.3	7.3 ± 0.7	8.5 ± 3.6
MMSE	27.2 ± 2.6	26.9 ± 2.4	27.1 ± 2.1

[a] Mean ± SD; MMSE-K: Mini Mental State Examination

Participants in the action observation group participated in 20 sessions of 30-min observation training five times per week. The training program of the action observation training group consisted of viewing a task video for 20 minutes, followed by physical training with a therapist for 10 minutes based on the video. The models in the of videos were normal adult males and females in their 50s, which was similar to the mean age of the patients, so as to raise their levels of concentration with regard to understanding the motions. The training program consisted of four stages, according to the content, including trunk flexion, trunk rotation, sit to stand, and crossing obstacles.

Participants in the motor imagery group had attended their training for 30 minutes, 5 times a week for 4 weeks. Motor imagery was conducted for 20 minutes according to the motor imagery program played through a computer speaker, and the participants then underwent physical training for 10 minutes based on the training contents. All participants in this study underwent neurodevelopmental therapy for 30 minutes, twice per day, five days per week for a period of four weeks, according to the schedule of the institution in which they were hospitalized. The exercise program included training of the trunk for learning supine to rolling movements, sit to stand, and normal gait pattern.

A Poly-I (Laxtha Inc., Daejeon, Korea) was used to take EEG measurements. Measurement of EEG is likely to be influenced by internal factors, such as eye movements and blinks and hiccups, and external factors, including temperature, illuminance, noise, and smell of a room; therefore, measurements were performed in a separate quiet space with a constant temperature and illuminance. Measurements were taken before and after the training. Each EEG measurement was recorded for one and a half minutes while the subjects were instructed to maintain a comfortable posture with the eyes closed and refrain from speaking or moving in order to minimize interference from artifacts.

EEG electrodes were attached to four places on the scalp using the monopolar derivation method. The four places included frontopolar 1 (Fp1), frontopolar 2 (Fp2), central lobe 3 (C3), central lobe4 (C4), occipital lobe 1 (O1), occipital lobe 2 (O2) in order in accordance with the International 10–20 system. Moreover, a reference electrode and a ground reference electrode were placed behind the right earlobe and the left earlobe, respectively. The electrodes used were gold-plated disc-shaped EEG electrodes (ElefixZ-401CE, Nihon Kohden, Tokyo, Japan).

For EEG data analysis, a quantitative analysis was conducted using Telescan2.98 (Laxtha Inc., Daejeon, Korea). Among the overall EEG raw data, 70 seconds of each measurement after excluding the first and last ten seconds was analyzed. Raw EEG data were converted into frequencies using a fast Fourier transform (FFT). Then relative alpha power (8–13/4–50 Hz) and relative beta power (13–20/4–50 Hz) were analyzed.

SPSS statistical package version 17.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.Pairedt-tests were used to determinewhether the changes in relative alpha power and relative betapower between before and after trainingdiffered significantly within a group.One-way ANOVA was used to determine whether values that changed between before and after training differed significantly between the three groups. The LSD test was used for posthoc analysis. An alpha level of $p<0.05$ was considered significant.

RESULTS

General characteristics of the subjects are shown in Table 1, and there were no significantly differences between the three groups.In alpha power, asignificant decrease in Fp1, from 0.0864 before training, to 0.0546 after training ($p<0.05$), and in Fp2, from 0.091 to 0.0592 ($p<0.05$), was observed in theaction observation group.Numerical changes were observed in other channels of action in the action observation and motor imagery groups, however, no significant differences were observed (Table 2).In beta power, a significant decrease in Fp2, from 0.0681 before training, to 0.1096 after training ($p<0.05$), and in C3, from 0.1110 to 0.1512 ($p<0.05$), was observed in theaction observation group (Table 2).

DISCUSSION

Through a certain period of training the brain learns to control brainwaves within a certain range and remembers the results for a long period of time[13)]. This study aimed to

Table 2. Comparison of relative alpha and beta power between groups

		Action observation training group (n=9)		Motor imagery training group (n=9)		Physical training group (n=9)	
		Before	After	Before	After	Before	After
Relative alpha	Fp1	0.0864 ± 0.03[a]	0.0546 ± 0.02*	0.0736 ± 0.05	0.0601 ± 0.04	0.0800 ± 0.07	0.0844 ± 0.07
	Fp2	0.0910 ± 0.04	0.0592 ± 0.03*	0.0845 ± 0.05	0.0759 ± 0.05	0.0760 ± 0.06	0.0881 ± 0.07
	C3	0.1475 ± 0.10	0.1322 ± 0.06	0.1689 ± 0.11	0.1608 ± 0.08	0.1385 ± 0.08	0.1492 ± 0.13
	C4	0.1655 ± 0.05	0.1230 ± 0.05	0.1280 ± 0.07	0.1203 ± 0.07	0.1580 ± 0.10	0.1799 ± 0.14
	O1	0.1514 ± 0.04	0.1124 ± 0.07	0.1789 ± 0.10	0.1582 ± 0.08	0.2315 ± 0.13	0.2057 ± 0.15
	O2	0.1627 ± 0.05	0.1286 ± 0.07	0.1456 ± 0.08	0.1322 ± 0.09	0.1616 ± 0.08	0.1490 ± 0.08
Relative beta	Fp1	0.0681 ± 0.04	0.1096 ± 0.08	0.0684 ± 0.05	0.0964 ± 0.05	0.0573 ± 0.02	0.0621 ± 0.03
	Fp2	0.0852 ± 0.08	0.1164 ± 0.07*	0.1099 ± 0.10	0.1216 ± 0.09	0.0735 ± 0.03	0.0794 ± 0.03
	C3	0.1110 ± 0.07	0.1512 ± 0.08*	0.1254 ± 0.08	0.1591 ± 0.11	0.0837 ± 0.06	0.0902 ± 0.06
	C4	0.1322 ± 0.09	0.1535 ± 0.08	0.1064 ± 0.05	0.1265 ± 0.06	0.1014 ± 0.06	0.1089 ± 0.07
	O1	0.1078 ± 0.06	0.1444 ± 0.08	0.1144 ± 0.06	0.1300 ± 0.10	0.1122 ± 0.08	0.1222 ± 0.04
	O2	0.1256 ± 0.06	0.1467 ± 0.07	0.1144 ± 0.06	0.1278 ± 0.07	0.1178 ± 0.09	0.1244 ±0.07

[a]Mean± SD; *p<0.05; Fp1, frontopolar 1; Fp2, frontopolar 2; C3, central lobe 3; C4, central lobe 4; O1, occipital lobe 3; O2, occipital lobe 2

identify the changes in brain activity during action observation training, motor imagery training, and physical training by observing changes in EEG during each type of training.

EEG signals can be divided into spontaneous potentials (SP) and evoked potentials (EP). Then SPs can be classified into five types according to the frequency domain, among which alpha power, between 8–13 Hz, is usually detected in a comfortably conscious state when an individual is relaxed, comfortable with the eyes closed, or meditating[14]. Alpha power increases in a relaxed state or a state of a moderate level of awareness, while it decreases as the intensity of cognitive activity increases[15].

According to the results of this study, a lower occurrence frequency of alpha power was observed inthe action observation group, compared with the motor imagery group and the physical training group,and significant differences were revealed between before and after training in Fp1 and Fp2. This suggests that even though motor imagery induced an increase in cognitive activity, action observation training led to a higher level of cognitive activity than motor imagery or physical training did. In C3 and C4, decreases in relative alpha power, though not significant, were observed as in the other areas. Such responses in the parietal lobe indicate that brain activity occurred not in a localized area but across all brain areas while information about stimuli given during observation were processed[16]. Action observation is known to activate the cerebral cortex more effectively than motor imagery because it involves the direct activity of multisensory systems and forms clear motor representations of given tasks[10]. In this study, the action observation group was encouraged to watch the task video, composed of several stages, intensively for a certain period of time and then to understand the order of the motions and details in the mind. In comparison, the motor imagery group was instructed to imagine relevant motions based solely on auditory signals. Therefore, subjects who had not normally experienced the motions in real life presumably found it difficult to form clear representations of the tasks. In addition, decreased concentration during motor imagery training may have hindered learning, and this is probably why the action observation group showed a relatively lower occurrence frequency of relative alpha power than the other two groups. Beta power, between 12–35 Hz, is detected when an one is engaged in solving problems that require concentration including when one's cognitive effort increases with the purpose of performing difficult tasks, one is thinking logically, or one's conscious activity regarding the body rises[17]. In most cases, alpha power is suppressed, while beta power increases, when an individual is executing tasks that require concentration rather than remaining in a stable state[18].The activation of beta power is known to reflect an increase in cognitive function resulting from cognitive information processing activity at an intense level[19]. Pfurtscheller et al.[16] analyzed the occurrence frequencies of beta power in the sensorimotor area while subjects were imagining foot, hand, and tongue movements. The results revealed that there was no significant change during the imagination of tongue movements, while the occurrence frequencies of beta power significantly increased during the imagination of foot or hand movements. These results suggest that the intensity of cognitive activity required can vary according to the characteristics of the task. The action observation training program adopted in this study was composed of task-oriented training categories, such as a trunk exercise while sitting, horizontal weight shift while standing, level walking, and obstacle crossing while walking. These types of training are thought to have increased the subjects' levels of cognitive activity required to understand the motions. Furthermore, action observation training, unlike motor imagery training, allows participants to identify the differences between their internal plans and observed models while observing their motions[20], and the activation of such a feedback mechanism can raise the level of cognitive activity in participants. The results of this study also suggested that the action observation group showed higher relative beta power values than the other two groups and indicated significant differences in Fp2 and C3 between before and after training. In the premotor cortex, the neurotransmission process occurs in real time from the cerebral cortex to relevant muscles both when people perform an action and when they watch it being performed[21], and such activity of the cerebral cortex seems to have enabled the action observation group to show relatively high levels of relative beta power.

The results revealed that action observation training induced higher levels of cognitive activity than motor imagery or physical training did. The effectiveness of motor imagery training has been proved in various fields. Nevertheless, for stroke patients and others with central nervous system injuries, in particular, motor learning through action observation training is expected to be more effective in terms of the provision of easier, clearer representations of motions.

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