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Original Article

Effects of observation of hand movements reflected in a mirror on cortical activation in patients with stroke

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Abstract. [Purpose] The purpose of this study was to examine what changes occur in brain waves when patients with stroke receive mirror therapy intervention. [Subjects and Methods] The subjects of this study were 14 patients with stroke (6 females and 8 males). The subjects were assessed by measuring the alpha and beta waves of the EEG (QEEG-32 system CANS 3000). The mirror therapy intervention was delivered over the course of four weeks (a total of 20 sessions). [Results] Relative alpha power showed statistically significant differences in the F3, F4, O1, and O2 channels in the situation comparison and higher for hand observation than for mirror observation. Relative beta power showed statistically significant differences in the F3, F4, C3, and C4 channels. [Conclusion] This study analyzed activity of the brain in each area when patients with stroke observed movements reflected in a mirror, and future research on diverse tasks and stimuli to heighten activity of the brain should be carried out.

Key words: Cortical activation, Mirror therapy, Stroke

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INTRODUCTION

Dysfunction from upper extremity hemiparesis impairs performance of many activities of daily living (ADL)[1)]. Individuals affected by stroke will learn or relearn competencies necessary to perform ADL. Traditionally, the practice of skills provided in neurologic rehabilitation has focused on reducing motor impairment and minimizing physical disability[2, 3)]. Since 2000, various studies of upper extremity function recovery using interventions such as constraint-induced movement therapy, functional electric stimulation, robotic-assisted rehabilitation, and bilateral arm training have been carried out[4)]. Such interventions were effective in increasing upper extremity functions in patients with stroke and are continually utilized in the clinical field[5–7)]. However, most of the treatment protocols for the paretic upper extremity are labor intensive and require one on one manual interaction with therapists for several weeks, which makes the provision of intensive treatment for all patients difficult[8)]. Hence, alternative strategies and therapies are needed to reduce the long-term disability and functional impairment from upper extremity hemiparesis[9)]. Mirror therapy may be a suitable alternative because it is simple; inexpensive; and, most

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importantly, patient-directed treatment that may improve upper extremity function[8, 10].

Emerging methods in mirror therapy aim to restore motor control through a change in brain function, i.e. motor relearning[11, 12]. Voluntary movements of the paretic upper extremity and hand by referring to a mirror activate the bilateral cortex and cause reorganization for other areas around the damaged brain to replace its function, thereby affecting recovery in motor function[13]. Although such methods are promising, they have failed to restore functional motor control for many patients who have experienced stroke. It is important to explore new methods that may facilitate the recovery of brain function and the restoration of more normal motor control[14].

Many studies have addressed the neurophysiological effects of mirror therapy. The EEG study gave diverse stimulations to the thumb with or without a mirror to examine which area of the cortex was activated. They observed common activation areas in the primary motor cortex (M1), cingulate, and prefrontal cortex[15]. And the study with healthy adults used mirror therapy with functional MRI (fMRI) and showed no difference between the dominant and non-dominant hand. Excitability of M1 ipsilateral to a unilateral hand movement was facilitated by viewing a mirror reflection of the moving hand[16]. This finding provides neurophysiological evidence supporting the application of mirror therapy in stroke rehabilitation. Even though, previous studies concerned healthy subjects and had no interventions, a diversity of studies have shown upper extremity functional improvement through mirror therapy[8]. Thus, the purpose of this study was to examine what changes occur in brain waves when patients with stroke receive mirror therapy intervention.

SUBJECTS AND METHODS

The subjects of this study were 14 subjects (8 males, 6 females; 56.43 ± 10.68 years) who were diagnosed with stroke and were presently undergoing rehabilitation at D Medical Hospital. The number of those with right hemiplegia was 8 (57%), with left hemiplegia was 6 (43%). Participants had not undergone brain surgery with disease duration of 6 months or more, and Mini Mental State Examination-Korean (MMSE-K)≥24 points. Moreover, participants were proved to have no disabilities in visual perceptive functions including neglect by motor-free visual perception test-revised and consented to participate in this study and received approval from their care providers. This study conformed to the ethical principles of the Declaration of Helsinki. This study was approved by the Ethics Review Committee approval number KWNUH 2013-09-003.

This study used a pre and posttest control group design. The subjects were assessed by measuring the alpha and beta waves of the EEG, and the mirror therapy intervention was delivered over the course of four weeks. The experiment was conducted in a calm and quiet environment so that the subjects could concentrate on the evaluation. They came to where the EEG equipment had been set up, sat in the chair in an upright position, and placed their hands comfortably on the desk. Those who were in a wheelchair received assistance when they moved over to the chair. They were seated in the chair with their head at midline; trunk upright; elbow, hip, and knee joints at 90°flexion. For EEG measurement, brain waves were measured using QEEG-32 system CANS 3000 (LXE3208, LAXTHA Inc., Korea), six channels (F3, F4, C3, C4, O1, O2) were attached to the subjects' head, and reference and ground electrodes were attached on the bilateral styloid process. The frequency of alpha and beta waves was set at 8–13 Hz and 14–35 Hz, respectively. This study used a 35 × 35 cm mirror box erected vertically on a desk. The mirror box was placed vertically on the sagittal plane from the subjects sitting in the chair as the standard.

First, the subjects observed the non-paretic hand movement (Hand movement). After that, the mirror was placed on the midline and the subjects placed their paretic hand behind the mirror. They then observed the non-paretic hand movement reflected in the mirror (Mirror observation). They performed a pinching hand movement five times. When the EEG measurement was finished, the electrodes on the subjects' head were detached and the areas were cleaned with water tissue.

For the purpose of this study, the researcher reorganized the mirror therapy program as an intervention based on a program by Yavuzer et al.[8] and the St. Gallen Protocol for Mirror Therapy[17] (Table 1). The experiment was conducted with the subjects sitting in a chair. The mirror was placed vertically on the midsagittal plane on the desk. The paretic hand was placed behind the mirror, and the non-paretic hand was placed in front of the mirror so that it was reflected in it. When the program started, the subjects observed the reflection of the non-paretic hand. In this position, and under the therapist's supervision, they conducted activities repetitively by themselves according to the mirror therapy program. In the intervention, 10 repetitions of each motion were assumed as one set. The subjects conducted five sets each time, five times per week, for four weeks (a total of 20 sessions). After four weeks, the EEG of each subject was measured in the same way as before the intervention.

For the data analysis of this study, SPSS version 20.0 (SPSS, Chicago, IL, USA) was used for the statistical processing. The general characteristics of the subjects were analyzed based on the technical statistics. For brain wave analysis by EEG, differences in alpha waves and beta waves before and after the mirror therapy were analyzed using a repeated measures ANOVA (2 × 2). The significant level was set at α=0.05.

RESULTS

This study analyzed relative alpha power and relative beta power by EEG. Relative alpha power decreased for hand observation in the F3, F4, O1, and O2 channels and increased for mirror observation in the F3, F4, O1, and O2 channels. The situation comparison showed statistically significant differences in the F3, F4, O1, and O2 channels ($^{*}p<0.05$; $^{**}p<0.01$) (Table 2).

Table 1. Mirror therapy protocol

Content	Frequency
Looking at the hand reflected in the mirror	10 seconds
Extending the elbows and raising both arms	10 times
Extending the elbows and moving both arms left and right	10 times
Bending and extending the elbows	10 times
Bending and extending the elbows while holding a plastic dumbbell	10 times
Turning over the palm on the table	10 times
Raising the wrist	10 times
Bending the wrist internally and externally	10 times
Clenching and opening the fist	10 times
Grabbing and releasing a rubber ball	10 times
Opposing thumb to the other fingers in sequence	10 times
Picking up and releasing an object	10 times

Table 2. Comparison of relative alpha power over brain area by hand and mirror observation in pre and post-test (unit=μV)

Variables	Situation	Pre-test	Post-test
F3[a*]	Hand Obs	0.64 ± 0.14	0.57 ± 0.20
	Mirror Obs	0.52 ± 0.17	0.53 ± 0.19
F4[a*]	Hand Obs	0.67 ± 0.16	0.60 ± 0.18
	Mirror Obs	0.59 ± 0.19	0.61 ± 0.19
C3	Hand Obs	0.53 ± 0.15	0.55 ± 0.21
	Mirror Obs	0.51 ± 0.14	0.52 ± 0.20
C4	Hand Obs	0.56 ± 0.18	0.59 ± 0.19
	Mirror Obs	0.53 ± 0.16	0.56 ± 0.17
O1[a**]	Hand Obs	0.52 ± 0.20	0.45 ± 0.21
	Mirror Obs	0.36 ± 0.18	0.33 ± 0.17
O2[a**]	Hand Obs	0.53 ± 0.16	0.46 ± 0.22
	Mirror Obs	0.32 ± 0.07	0.35 ± 0.19

Values are means ± SD. *p<0.05, **p<0.01.
[a]Significant difference between Hand Obs and Mirror Obs
[b]Significant difference between Pre-test and Post-test
Hand Obs: hand observation, Mirror Obs: mirror observation

Relative beta power showed statistically significant differences in the F3, F4, C3, and C4 channels (*p<0.05; **p<0.01) (Table 3). The F3, F4, and C3 channels showed an increase for hand observation and a decrease for mirror observation after the mirror therapy. Among these channels, F3 and F4 showed a statistically significant difference in time, situation, and time ×situation interaction comparison, and C3 showed a statistically significant difference in time and situation comparison. The C4, O1, and O2 channels showed a decrease for, both hand observation and mirror observation after the mirror therapy.

DISCUSSION

This study investigated the effects of mirror therapy on the activation of brain waves in 14 patients with stroke. EEG reflects diverse brain functions, and all diseases that trigger brain function disabilities can be measured by EEG[18]. Among other methods, EEG is often used to examine brain function conditions of patients with stroke[19]. In a study that applied neurorehabilitative training to patients with stroke, brain plasticity appeared on the EEG both before and after the intervention.

Relative alpha power showed statistically significant differences in the F3, F4, O1, and O2 channels in the situation comparison and higher for hand observation than for mirror observation. A person who relaxes with his or her eyes open shows about a 3/4 increase in alpha waves. In general, alpha waves are inhibited and beta waves increase when a person performs tasks that need more attention than when he or his is at rest[20]. Therefore, this brain condition means that a person is more comfortable observing direct hand movement than reflected hand movement.

Table 3. Comparison of relative beta power over brain area by hand and mirror observation in pre and post-test (unit=μV)

Variables	Situation	Pre-test	Post-test
F3 ^{a**b**c*}	Hand Obs	0.30 ± 0.11	0.36 ± 0.11
	Mirror Obs	0.56 ± 0.10	0.41 ± 0.16
F4 ^{a**b*c**}	Hand Obs	0.27 ± 0.14	0.32 ± 0.16
	Mirror Obs	0.49 ± 0.11	0.31 ± 0.16
C3 ^{a*b*c*}	Hand Obs	0.34 ± 0.12	0.34 ± 0.17
	Mirror Obs	0.49 ± 0.09	0. 34 ± 0.15
C4 ^{b*}	Hand Obs	0.38 ± 0.16	0.31 ± 0.14
	Mirror Obs	0.43 ± 0.07	0.31 ± 0.13
O1	Hand Obs	0.36 ± 0.14	0.35 ± 0.12
	Mirror Obs	0.40 ± 0.11	0.38 ± 0.08
O2	Hand Obs	0.39 ± 0.12	0.35 ± 0.13
	Mirror Obs	0.38 ± 0.09	0.37 ± 0.11

Values are means ± SD. *p<0.05, **p<0.01.
[a]Significant difference between Hand Obs and Mirror Obs (Situation)
[b]Significant difference between Pre-test and Post-test (Time)
[c]Significant difference between Situation and Time
Hand Obs: hand observation, Mirror Obs: mirror observation

As a result of this study, relative beta power was statistically significant differences in F3, F4, C3 and C4 channels. This result implies that the M1 and premotor cortex were activated during observation for reflected hand movement, and that the prefrontal cortex was activated because the subjects paid attention to movement. The primary motor cortex was relevant to the initiation of voluntary movement. Also, the M1 has a large region relevant to segmentalized movement. This is in agreement with the following neuroanatomical knowledge. The premotor cortex as a supplementary motor assists normal movement by accepting stimulation from other regions in the brain. Planing and judgment are processed in the prefrontal cortex and are relevant to a high level of mental function[21)]. However, the O1 and O2 channels in the visual cortex showed no statistically significant differences in current study. Beta waves appear when a person carries out mental activities or physical exercise. They are also associated with tense conditions, such as experiencing anxiety, and are affected by auditory, tactile, and emotional stimulation but not visual stimulation[22)].

In a study that measured brain functions by using fMRI, researchers applied mirror therapy as an intervention for eight weeks to patients with chronic stroke. The fMRI analysis results showed statistically significant brain activation in the primary motor area[23)]. Also, in a study that examined the neurological relationship between mirror therapy and subjects, author applied mirror therapy to 18 patients with stroke, and the fMRI analysis showed that the precuneus and the posterior cingulate cortex were significantly activated. These areas are associated with self-awareness and spatial attention. By increasing awareness of the affected limb, the mirror illusion might reduce learnt non-use[24)].

The present study has some limitations. First, the subjects were hospitalized patients; therefore, other biases may have been involved. Because the patients were hospitalized, it was difficult to control the environment outside the treatment room. Second, the mirror therapy program was independently conducted. Some subjects became bored with observing themselves in a mirror for 30 minutes. Therefore, in this study, the supervising therapist motivated the subjects from time to time.

The study results showed differences in brain activity for such patients during mirror observation. Therefore, this study may be utilized as a neurophysiological basis theory when mirror therapy is clinically applied. This study analyzed activity of the brain in each area when patients with stroke observed movements reflected in a mirror, and future research on diverse tasks and stimuli to heighten activity of the brain should be carried out.

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