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Effects of Augmented Reality Games on the Upper Extremity Function and Stress of Stroke Patients

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Abstract.

To examine the effects of an augmented reality game on upper extremity function and stress in stroke patients with upper extremity function difficulty. Twenty stroke patients were randomized into a control group of 10 subjects and an experimental group of 10 subjects. The control group received conventional occupational therapy, while the experimental group received the same conventional occupational therapy as for the control group but also played an augmented reality game for 30 minutes per session, three times a week over the course of 8 weeks. The subjects were evaluated using the manual function test (MFT) and CMS-10 (Compact Measuring System) for their upper extremity functions and using the stress scale for psychological factors before and after the intervention. MFT showed significant differences before and after the experiment in both groups (p<.05). However, the comparison between the groups showed no significant difference (p>.05). The range of motion of the elbow joint showed significant differences before and after the experiment in the experimental group only (p<.05). The intragroup and intergroup changes in stress showed significant differences before and after the experiment only in the experimental group (p<.05). The findings of this study revealed that augmented reality games are effective in the improvement of upper extremity function and reduction of stress in stroke patients.

***Keywords**: augmented reality game, stroke, upper extremity function, stress*

1. Introduction

Stroke is the most typical cerebrovascular disease and a major disease that develops in 51.1 per 100,000 people; it is associated with the third highest mortality for single diseases [1]. It leads to various dysfunctions, including motor, sensory, cognitive, and emotional disorders, depending on the area of damage. More than 85% of early stroke patients show upper extremity disorders, and 55–75% of stroke patients still have damaged upper extremity function even after 6 months [2].

Upper extremity function is required to perform detailed motions and activities of daily living, such as eating, personal hygiene, and using and handling objects [3]. Disorders in upper extremity function limit the performance of these activities and interfere with the independent daily life of the patients [4]. As a result, stroke patients must depend on others for an extended period; as a result, they frequently experience psychological withdrawal and stress.

Stress is a general, nonspecific reaction of the body to certain external stimuli [5]. It has negative effects on the immune reaction by destroying the homeostasis of the body; this can increase patients' susceptibility to various chronic diseases [6]. Furthermore, patients experience emotional pain, exhibiting depression, a negative mentality about the

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self and society, frustration with life, low self-esteem, a sense of shame, and other disorders.

Recently, treatments based on virtual reality have been administered in the clinical settings to attract interest to virtual reality's ability to enhance active motivation. In paper [7] yet claimed that treatment based on virtual reality can give a sense of incompatibility in performing motions in the real environment because training in a virtual environment is different from reality. Recently, augmented reality has emerged; this has enhanced the sense of reality in virtual reality. Augmented reality games show the patients directly moving and interacting with virtual objects, such as things, animals, and plants, with the actual environment in which they live reproduced on the screen. Thus, these games are applicable to the actual real environment and provide a high sense of immersion. Another advantage of augmented reality is that it gives repeated opportunities for behavior modification because patients can modify and reorganize their behaviors when they receive visual feedback on their reactions and the results of their behaviors; this has a great effect on motor control improvement [8].

Previous studies have mostly focused on physical factors, such as balance and gait, in intervention methods based on virtual reality [2,9-11]. In contrast, there has been little interest and research on interventions concerned with psychological factors. Therefore, this study was conducted to investigate the effects of augmented reality games on the upper extremity function and stress of stroke patients.

2. Study Method

2.1. Subjects

The subjects were 20 adult stroke patients hospitalized in a rehabilitation hospital in 'G' metropolitan city. The selection criteria were patients who understood and consented to participate in the study, participated at least 6 months after onset of stroke, obtained MMSE-K scores of at least 24 points, exhibited MAS measurement of the upper extremities of Grade 1+ or higher, and had no visual problems and or hemineglect.

2.2. Research Tools

2.2.1. The Manual Function Test (MFT)

The MFT was developed to assess the upper extremity function and motion abilities of stroke patients at the Myeongja Branch of the Riha Research Institute, Tohoku University School of Medicine, Japan. In this study, the Korean version of the MFT was employed; this was translated into Korean by Mi-Young Kim [12]. The MFT consists of 8 general items and 32 detailed items in the three areas of upper extremity motions (4 items), grasp (2 items), and finger manipulations (2 items). The patient receives 1 point if he or she can perform each test item or 0 otherwise. The total score is 32 points, which is converted into 100 points. The test–retest reliability of the MFT is .99 [13], while the test-retest reliability of this study was .96.

2.2.2 The Three-Dimensional Motion Analysis System

The range of joint motion was measured using the compact measuring system for 3D real-time analysis CMS-10 (Zebris, Medizintechnik, GmbH, Isny, Germany) with the 'eating motion' to examine the change in upper extremity function. This system consists of the basic CMS-10 unit, a personal computer, three active markers, a measurement sensor, and a cable adapter.

2.2.3. The Perceived Stress Scale

The perceived stress scale was developed by Neumann and translated, modified, and complemented by Won-Kyung Park [14]. This tool consists of 24 items in total, including 15 items about personal internal stress, 6 items about interpersonal stress, and 4 items about personal external stress. Items were scored on a 5-point Likert scale from 0 to 4, with a higher score representing a higher degree of stress. The reliability of this tool at the time of development was .90 [14], and the test–retest reliability in this study was .91.

2.3. The Study Procedure

Twenty stroke patients were selected as subjects for this study and randomized to the control group of 10 subjects and the experimental group of 10 subjects. The control group carried out conventional occupational therapy, while the experimental group completed the same occupational therapy as the control group in conjunction with augmented reality training for 30 minutes per session, three sessions per week over a course of 8 weeks from August 14 to October 18, 2014. The range of joint motion was measured using the MFT and CMS-10 for assessment of the upper function, while stress was measured using psychological assessment.

2.3.1. The Training Program

For the training program in this study, nine programs that could be completed by patients were examined by the researcher before the experiment, and those which could be appropriately performed on the affected side and were found to be interesting were selected according to the priorities.

2.3.2. Measurement of the Range of Joint Motion Using CMS-10

To measure the functional movements of the affected upper extremity, the 'eating task' was selected by taking into account participants' opinions concerning the motions that are frequently used in daily life; this task consisted of bringing a spoon to one's mouth. The method of performing this task was to sit straight on a chair with an erect trunk straight and the hip joint and knee joint at 90° to each other, grasp a spoon on one's knee, and bring it to one's mouth. This procedure was repeated and measured five times, and the average data of the range of motion of the upper extremity was collected.

The active markers for the measurement of CMS-10 were attached to the wrist carpal bone, elbow lateral epicondyle, and humerus head according to the manual for CMS-10.

2.4. Data Processing

The results of this study were analyzed using SPSS 18.0 for Windows. Frequency analysis and technical statistics were used to analyze the general characteristics; the Wilcoxon test was employed for differences between prior to and after the experiment for each assessment item; and the Mann–Whitney U test was used for inter-group differences. The significance level α was set at .05.

3. Study Results

3.1. Subjects General Characteristics of Subjects

The general characteristics of the subjects who participated in this study are outlined in Table 1. For sex, the control group included five men and five women (50%), whereas the experimental group included four men (40%) and six women (60%). The average ages of the control group and the experimental group were 65.50±13.48 years and 63.10±13.98 years, respectively. The average durations of illness were 11.80±2.93 months and

11.10±2.84 months, respectively. The affected side was the right side in eight subjects (80%) and the left side in two subjects (20%) for the control group. For the experimental group, it was the right side in six subjects (60%) and the left side in four subjects (40%).

Table 1. General Characteristics of Subjects

Variable	Division	Control group (*n*=10)	Experimental group (*n*=10)	χ^2/Z
		Frequency (percentage)	Frequency (percentage)	
Sex	Male	5 (50%)	4 (40%)	.653
	Female	5 (50%)	6 (60%)	
Age (years)	30–49	1 (10%)	2 (20%)	.801
	50–69	4 (40%)	4 (40%)	
	70 or older	5 (50%)	4 (40%)	
	M±SD	65.50±13.48	63.10±13.98	
Duration of illness (months)	Less than 1 year	7 (70%)	7 (70%)	.857
	Less than 2 years	3 (30%)	3 (30%)	
	M±SD	11.10±2.84	11.80±2.93	
Affected side	Right	8 (80%)	6 (60%)	.329
	Left	2 (20%)	4 (40%)	

M±SD=mean ± standard deviation

3.2. Change of Upper Extremity Function Following the Application of Augmented Reality Game Program

3.2.1. Change Of MET After Program Application

The assessment of upper extremity function through MFT showed that the score increased statistically significantly after the performance in both the control and experimental groups ($p<.05$). The intergroup comparison showed that the score of the experimental group improved more than that of the control group, but the difference was insignificant ($p>.05$; Table 2).

Table 2. Change in the MFT After Program Application

Variable	Division	Control group	Experimental group	Z
		M±SD	M±SD	
Total MFT score	Before	41.25±19.36	33.75±17.84	-.701
	After	47.50±20.82	41.87±17.99	
	Difference	-6.25±7.93	-8.12±8.61	
	Z	-2.032*	-2.536*	

*$p<.05$

3.3.2. Change of the Range of Motion of the Elbow Joint After Program Application

As a result of the measurement of the range of motion of the elbow joint using the three-dimensional upper extremity function measurement CMS-10 system, the control group showed an increased range of joint motion after the performance, but the difference was insignificant (p>.05). The experimental group, however, showed increased range of joint motion after the performance and the change was significant (p<.05). The intergroup comparison showed that the joint angle of the experimental group increased more than that of the control group, but the difference was insignificant (p>.05; Table 3).

Table 3. Change of the Range of Motion of the Elbow Joint After Program Application

Variable	Division	Control group	Experimental group	Z
		M±SD	M±SD	
Elbow joint Range of motion (degrees)	Before	77.04±22.11	80.88±12.59	
	After	81.90±26.68	89.72±10.58	
	Difference	-4.86±7.72	-8.84±7.85	-1.323
	Z	-1.784	-2.395*	

**p<.05, **p<.01, ***p<.001*

3.3. Change in Stress Following the Application of the Augmented Reality Game Program

As a result of measuring the degree of stress, the control group showed decreased stress after the experiment in both the total stress score of stress and the scores for the sub-items, but the differences were insignificant (p>.05). The experimental group, however, showed significant decreases in the total stress score and the sub-items of personal internal stress, interpersonal stress, and personal external stress. The intergroup comparison also revealed significantly higher scores of the experimental group compared to the control group in both the total stress score and the sub-items (p<.05; Table 4).

Table 4. Changes in Stress After Program Application

Variable		Division	Control group	Experimental group	Z
			M±SD	M±SD	
Total score of stress		Before	66.20±17.24	70.50±9.61	3.332***
		After	63.30±17.35	49.40±10.57	
		Difference	2.90±6.06	21.10±12.32	
		Z	-1.329	-2.670**	
Sub-items	Personal internal stress	Before	40.00±12.40	41.60±6.23	3.220***
		After	38.20±12.87	28.00±7.54	
		Difference	1.80±4.89	13.60±7.86	
		Z	-.892	-2.805**	
	Interpersonal stress	Before	15.30±4.08	16.30±5.20	-2.561**
		After	15.30±4.02	12.30±3.71	
		Difference	0.00±1.94	4.00±4.08	
		Z	-.368	-2.442*	
	Personal external	Before	10.90±2.60	12.60±2.63	-2.238*
		After	9.80±3.25	9.10±3.28	

	stress	Difference	1.10±1.91	3.50±2.63	
		Z	-1.841	-2.530*	

*$p<.05$, **$p<.01$, ***$p<.001$

4. Discussion

The purpose of this study was to examine the effects of an augmented reality game on the upper extremity function and stress of stroke patients.

An examination of the changes in the upper extremity function of stroke patients using the MFT showed that the upper extremity functions of both the control and experimental groups improved significantly after the experiment. However, the intergroup comparison revealed that there was no significant difference, although the MFT score of the experimental group was higher than that of the control group. In a previous study that applied virtual reality training to stroke patients, in paper [9] reported that the upper extremity function of both groups significantly improved, but intergroup comparison exhibited no significant changes, which is in accordance with the result of this study. In paper [2] however, reported that the upper extremity function of both control and experimental groups significantly improved after the experiment, and the intergroup comparison also showed a significant difference, which contradicts the results of this study.

From examination of the change in the angle of the elbow joint through the three-dimensional motion analysis CMS-10 system to examine the range of motion of upper extremities due alterations in function following the intervention, the control group showed no significant difference after the experiment, while the experimental group showed a significant difference. The above results indicate that the augmented reality training program is more effective in the improvement of upper extremity function than the conventional occupational therapy.

In the results from the perceived stress scale, the control group showed a slight decrease in all stress items after the intervention, but the difference was insignificant. However, the experimental group showed significant differences in the total stress score and the sub-items of personal internal stress, interpersonal stress, and personal external stress. Furthermore, the intergroup comparison also revealed significantly higher improvements of the experimental group. This result coincided with the finding of the study by Pil-Suck Byun [15], who used a video game as a stress intervention program for stroke patients; she found that the stress of the experimental group significantly decreased compared to that of the control group. In similar previous studies, In paper [16] reported that the stress of the experimental group significantly decreased with a combination of music listening treatment and discharge training for stroke patients, In paper [17] while argued that the application of a laughter therapy program significantly decreased stress in stroke patients. Conventional rehabilitation treatments focused on patients' functional enhancement are onerous; because of a sense of obligation, where patients only carry out the treatment for the improvement of their lives, a psychological burden is inherent in their participation. Interventions based on play or patients' interests, however, such as augmented reality games, serve as new elements in the treatment process; they pique patients' interest and give them a sense of novelty. Furthermore, their psychological burden and stress are reduced because they can easily succeed in the task performance; as a result, they feel a sense of achievement.

5. Conclusions

In the assessment of upper extremity function after the application of augmented reality game, the MFT showed significant improvements after the experiment for both groups. The assessment of upper extremity motions using CMS-10 showed significant improvement in the range of motion of the elbow joint in the experimental group.

In the stress assessment, the experimental group showed significant decreases in total stress after the experiment, as well as personal internal, interpersonal, and personal external stresses. The intergroup comparison also showed a significant decrease of stress in the experimental group to which conventional occupational therapy and the augmented reality game had been applied compared to the control group to which the conventional occupational therapy had been applied.

The above findings indicate that augmented reality games have positive effects on the upper extremity function and stress reduction in stroke patients. Therefore, augmented reality games can be applied the recovery of stroke patients in the clinical setting. Future studies should consider a larger number of subjects and more psychological and emotional aspects of stroke patients with a view to more effectively restoring their physical and psychological functions.

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