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"Playstation eyetoy games" improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial

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***Aim*. To evaluate the effects of "Playstation EyeToy Games" on upper extremity motor recovery and upper extremity-related motor functioning of patients with subacute stroke.**

***Methods*. The authors designed a randomized, controlled, assessor-blinded, 4-week trial, with follow-up at 3 months. A total of 20 hemiparetic inpatients (mean age 61.1 years), all within 12 months post-stroke, received 30 minutes of treatment with "Playstation EyeToy Games" per day, consisting of flexion and extension of the paretic shoulder, elbow and wrist as well as abduction of the paretic shoulder or placebo therapy (watching the games for the same duration without physical involvement into the games) in addition to conventional program, 5 days a week, 2-5 hours/day for 4 weeks. Brunnstrom's staging and self-care subitems of the functional independence measure (FIM) were performed at 0 month (baseline), 4 weeks (post-treatment), and 3 months (follow-up) after the treatment.**

***Results*. The mean change score (95% confidence interval) of the FIM self-care score (5.5 [2.9-8.0] *vs* 1.8 [0.1-3.7], P=0.018) showed significantly more improvement in the EyeToy group compared to the control group. No significant differences were found between the groups for the Brunnstrom stages for hand and upper extremity.**

***Conclusion*. "Playstation EyeToy Games" combined with a conventional stroke rehabilitation program have a potential to enhance upper extremity-related motor functioning in subacute stroke patients.**

KEY WORDS: Video games - Upper extremity - Motor activity - Stroke - Paresis - Rehabilitation.

The authors' previous studies revealed that in spite of a conventional inpatient rehabilitation program, 65% to 77% of the stroke patients were discharged from the rehabilitation clinic of Ankara University without any selective motor control in their paretic upper limb.[1-3] Five years after their discharge, 75% of them still needed assistance in their self-care activities. Treatment protocols for paretic upper extremity are labor intensive and require one-to-one manual interaction with therapists for several weeks, which makes the provision of intensive treatment for all patients difficult.[4] Recent evidence has shown that task-specific, repetitive training with cognitive involvement and progressive complexity induce cortical reorganization and improved motor recovery and activity levels.[5-14] During task-specific training, there should be the individualization of the training goals (*i.e.*, tasks must be at the appropriate level for a patient's

Suppliers.—Statistical Package for the Social Sciences (SPSS) for Windows, Version 11.5; SPSS Inc., 444 N. Michigan Avenue, Chicago, IL. USA.

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ability) and the progression of the training goals over time (*i.e.*, as the patient improves, tasks should become progressively more challenging).[15] Based on the learned nonuse theory postulated by Taub *et al.*,[11, 13] constraint-induced movement therapy (CIMT) which combines intensive training of the affected hand with restraint of the unaffected hand, has been strongly suggested for hemiparetic patients after stroke.[16] However, in the authors' clinical experience, patients had very low compliance to intensive CIMT as they get bored of wearing the sling for 6-8h daily and restrict the amount of their usual daily activities. Moreover, increased risk of falling has been reported because the protective extension of the nonparetic arm is constrained.[17]

Another way to encourage stroke patients to use their paretic upper extremity might be the computer games. Virtual reality (VR) typically refers to the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real world objects and events.[18-20] Users interact with displayed images, move and manipulate virtual objects, and perform other actions within the simulated environment thereby engendering a feeling of presence in the virtual world.[18] VR has the capability of creating an interactive, motivating environment where intensity of practice and feedback can be manipulated to create individualized treatment sessions. VR has been used as a medium for the assessment and rehabilitation of cognitive processes, motor coordination, hand strength, range of motion and speed of movement.[18-24] The studies share a common goal of using VR to construct a simulated environment that aimed at facilitating the client's motor and cognitive abilities in order to improve functional ability. Functional magnetic resonance imaging (fMRI) studies have shown that VR induces cortical reorganization in patients with stroke [25, 26] and cerebral palsy.[27]

"Playstation EyeToy" is a low-cost, off-the-shelf video-capture system enabling to interact with virtual objects that displayed on a TV screen. The EyeToy application includes many motivating and competitive environments which could be played by one or more players as well as different visual effects which encourage active movement, weight bearing and reaching on both sides. As compared to other VR systems such as Gesture Xtreme VR, the EyeToy is sold commercially at a relatively low cost. Rand *et al.*[28] investigated the potential of the "Playstation EyeToy Games" for use in the rehabilitation of 10 elderly people with disabilities. They suggested that the EyeToy system was sensitive and differentiate between young and older participants and between stroke patients.

In this study, the authors hypothesized that VR treatment as provided by "Playstation EyeToy Games" would force the paretic extremity to move while playing, thereby restoring function in the paretic upper extremity. Using a randomized controlled assessor-blinded trial design, the authors evaluated the effects of EyeToy games on motor recovery and upper extremity-related motor functioning of patients with subacute stroke.

Materials and methods

Subjects

The trial included 20 inpatients with hemiparesis after stroke (mean age 61.1 years, mean time since stroke 3.9 months). Stroke was defined as an acute event of cerebrovascular origin causing focal or global neurological dysfunction lasting more than 24 hours,[29] as diagnosed by a neurologist and confirmed by computed tomography (CT) or MRI. Inclusion criteria for patients were: 1) a first episode of unilateral stroke with hemiparesis during the previous 12 months, 2) a score between I and IV on the Brunnstrom stages for the upper extremity; 3) to be able to understand and follow simple verbal instructions; 4) to have no severe cognitive disorders that would have interfered with the study's purpose (Mini Mental State Examination Score>16). The protocol was approved by the Ankara University Ethics Committee.

Sample size

The required sample size was determined by using the pooled estimate of within-group standard deviations obtained from pilot data. Power calculations indicated that a sample of 20 subjects would provide an 80% (β=0.20) chance of detecting a 20% (α=0.05) improvement in the functional independence measure (FIM) self care score between the groups.

Study design

The authors used a randomized controlled design in which the assessor was blind to the group allocation of the subject. Blinding the patients or physical therapist was not possible due to the nature of the

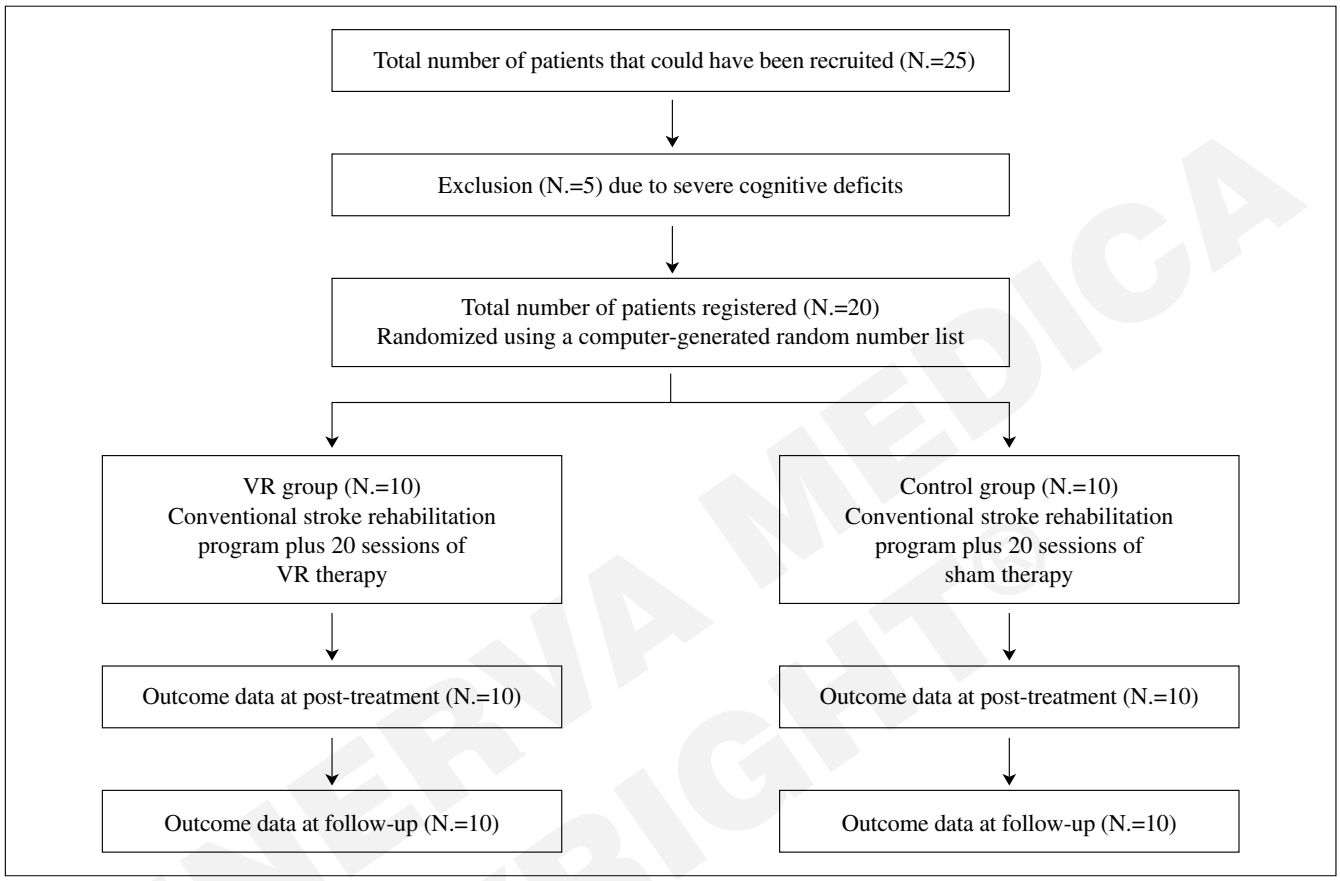

Figure 1.—Flow diagram for randomized subject assignment in this study.

treatment. After signing informed consent and baseline measurements, patients were randomly assigned to either the EyeToy group (N.=10) or the control group (N.=10) using a computer-generated random number (Figure 1). Blocks were numbered, and then a random-number generator program was used to select numbers that established the sequence in which blocks were allocated to one or the other group. A medical doctor was blinded to the research protocol and was not otherwise involved in the trial operated the random-number program.

Interventions

Both the EyeToy group and the control group participated in a conventional stroke rehabilitation program, 5 days a week, 2-5 hours/day for 4 weeks. The conventional program is patient-specific and consists of neurodevelopmental facilitation techniques, physiotherapy, occupational therapy, and speech therapy (if needed). The duration of the treatment for upper limb was approximately 1 hour. For the same 4-weeks of period, the EyeToy group received an additional 30 minutes of VR therapy program. During the VR sessions, patients were seated close to a TV monitor. And ask to follow thirty minutes of treatment with "Playstation EyeToy" games per day consisting of flexion and extension of the paretic shoulder, elbow and wrist as well as abduction of the paretic shoulder using "Kung-Foo", "Goal Attack", "MrChef", "Dig" and "Home-Run" games, in addition to conventional stoke rehabilitation program, 5 days a week, 2-5 hours/day for 4 weeks. The authors chose the games according to the patients' abilities and encouraged the patients in the EyeToy group to use their paretic arm while playing. The game "Kung-Foo" was

used for training reaching. It gets harder when the patient completed the stage, or performance bar reduces to zero according to his level. The authors used "Smashing the ice cubes" and "Demolishing the wall" to train elbow extension (an out of synergy movement). In the game "Dig", the patients were asked to hit the brunches but save the other items, which may help problem solving. The game "MrChef" was very popular among women as it includes cooking activities in a kitchen, while men liked "Kung Foo", "Goalkeeper" and "Dig" games. "Goalkeeper" is a soccer game that really helps the patients shift the weight to the paretic side while standing. During the games the patient had to hit the target by elbow extension in correct order and as fast as possible. Based on the mental practice treatment, the control group only watched the games for the same duration but did not involve into the games physically.

Outcome measures

Main outcome measures were the Brunnstrom stages [30] and the self-care sub-items of the Functional Independence Measure (FIM).[31] Outcome measures were performed at 0 month (baseline), 4 weeks (post-treatment), and 3 months (follow-up) after the treatment.

Brunnstrom stages

Brunnstrom defined 6 sequential stages of motor recovery and described how the hemiplegic arm and hand progress through these stages as a method for assessing recovery.[20] The Brunnstrom stages were chosen because they reflect underlying motor control based on clinical assessment of movement quality. Higher Brunnstrom scores indicate better motor recovery.

FIM

The FIM instrument is widely used for measuring activity limitation through performance observation in terms of how much help the subject requires in order to perform basic physical and cognitive activities. The FIM instrument (maximum score, 126) contains 18 items that measure independent performance in self-care, sphincter control, transfers, locomotion, communication and social cognition. The FIM scores range from 1 to 7: a FIM item score of 7 is categorized as "complete independence", while a score of 1 is "complete dependence" (performs less than 25% of task).[31] In the present study, in order to evaluate the upper extremity-related motor functioning the authors used only self-care subitems (eating, grooming, bathing, dressing upper body, dressing lower body and toileting) of the FIM instrument;[32] the total score ranges from 6 (lowest) to 42 (highest). The reliability and validity of the Turkish version of the FIM has been documented.[33] In an earlier study, the authors reported minimal detectable change (MDC) of Duruoz Hand Index for stroke patients [34] as 1.4 points and MDC for FIM-self care as 4.9 points (unpublished data).

Statistical analysis

The authors analyzed the data using SPSS for Windows version 11.5. Groups were compared at baseline using the t test for independent samples for the continuous variables and the χ^2 test or Fisher exact test for categorical data. In order to investigate whether EyeToy group changed by more than the control group at the post-treatment and at follow up, the authors calculated change scores (subtracting the post-treatment score from the baseline score and subtracting the follow up score from the post-treatment score) for each group and compared them by using Mann-Whitney U-test. Significance was set at 0.05. The authors preferred non-parametric statistics because of the abnormal distribution of the change scores. To test the study hypothesis, they chose ANOVA with repeated measures with a between-subject factor at 2 levels (the 2 groups) and a within-subject factor at 3 levels (the time: baseline, post-treatment, and follow-up). The interaction of group and time served to determine the efficacy of the EyeToy games on the outcome measures.

Results

Pretreatment and post-treatment evaluations were made 1-3 days before and 1-3 days after the 4 weeks of treatment period. None of the patients missed more than one scheduled session during the study and all of them finished the study. The authors did not observe any adverse events. All patients in the EyeToy group reported that they enjoyed the sessions. Control group did not complain while only watching the games but at the end of the study they all wanted to actively participate into the games.

Demographic and clinical characteristics of the two groups are presented in Table I. No significant differences were found between groups in any of the demographic characteristics or in the baseline measurements. In addition, baseline Brunnstrom stages and total FIM self-care scores were similar between the EyeToy and control group (Table I).

TABLE I.—*Demographic characteristic of the VR and control group as well as baseline measurements.*

	EyeToy group	Control group	P value*
Number of patients	10	10	—
Age (years) (mean [SD])	58.1 (10.2)	64.1 (5.8)	0.125 (t)
Time since stroke (months) Mean (SD)	3.3 (3.3)	4.6 (1.3)	0.228 (t)
Time since stroke (months) Median (min-max)	2.4 (1-12)	3.9 (3-7)	—
Female/male	6/4	5/5	0.653 (F)
Paretic side (right/left)	5/5	4/6	0.653 (F)
Dominant (right/left)	8/2	10/0	0.474 (F)
Lesion type (isch/hemor)	10/0	8/2	0.474 (F)
Brunnstrom stages (hand) Mean (SD)	1.9 (1.2)	2.7 (0.9)	0.190 (t)
Brunnstrom stages (hand) Median (min-max)	2 (1-4)	3 (1-4)	0.165 (χ^2)
Brunnstrom stages (UE) Mean (SD)	2.3 (1.3)	3.0 (1.5)	0.280 (t)
Brunnstrom stages (UE) Median (min-max)	2.5(1-5)	3(1-4)	0.329 (χ^2)
FIM self-care (mean (SD)	17.0 (7.8)	18.9 (5.0)	0.739 (t)

UE: upper extremity; FIM: functional independence measure; t: Student's t test; F: Fisher exact test, χ^2: chi-square test. *P value of difference at baseline.

Table II presents the between-group comparisons of the change score for motor recovery, and upper extremity-related motor functioning both from baseline to post-treatment and post-treatment to follow-up. Between-group differences were significant for functioning scores not only at post-treatment but at 3 month follow up as well. Table III presents the motor recovery and upper extremity-related functioning scores of the patients at baseline, post-treatment and follow-up. The mean change score and 95% confidence interval (CI) of FIM self-care score (P=0.018), but not the Brunnstrom stages for hand (P=0.346) and upper extremity (P=0.382), showed significantly more improvement at follow-up in the EyeToy group compared to the control group.

Discussion

This study reveals that "Playstation EyeToy" games in addition to a conventional rehabilitation program was more beneficial in terms of upper extremity-relat-

TABLE II.—*Between-group differences in change scores for motor recovery and upper extremity-related functioning scores. Values are mean (standard deviation).*

Parameter	Baseline - Post-treatment			Post-treatment – Follow-up		
	EyeToy group	Control group	P-value*	EyeToy group	Control group	P value*
Brunnstrom (hand)	0.9 (0.5)	0.1 (0.1)	0.009	0.1 (0.1)	0.3 (0.1)	0.450
Brunnstrom (UE)	0.6 (0.5)	0.1 (0.1)	0.012	0.2 (0.1)	0.2 (0.1)	0.280
FIM self-care	3.2 (0.9)	0.9 (1.1)	0.001	2.5 (1.5)	0.8 (0.3)	0.018

UE: upper extremity; FIM: functional independence measure. *P values obtained using Mann-Whitney U Test.

TABLE III.—*Motor recovery and upper extremity-related functioning scores of patients at baseline, post-treatment and follow-up. Values are mean (standard deviation).*

Parameter	Group	Baseline	Post-treatment	Follow-up	Δ(95% CI)	P value*
Brunnstrom (hand)	EyeToy	1.9 (1.2)	2.8 (1.8)	2.8 (1.8)	-0.2 (-0.65-0.25)	
	Control	2.7 (0.9)	2.8 (1.0)	3.2 (1.2)	-0.5 (-1.1-0.10)	0.346
Brunnstrom (UE)	EyeToy	2.3 (1.3)	3.0 (1.5)	2.8 (1.5)	-0.5 (-1.0-0.03)	
	Control	2.7 (0.8)	2.8 (0.9)	3.0 (1.1)	-0.9 (-1.7-0.11)	0.382
FIM self-care	EyeToy	17.0 (7.8)	20.4 (7.4)	22.5 (6.8)	-5.5 (-8.07-2.9)	
	Control	18.9 (5.0)	19.7 (5.3)	20.7 (5.4)	-1.8 (-3.7-0.10)	0.018

UE: upper extremity; FIM: functional independence measure; Δ: mean change at follow-up from baseline; CI: confidence interval. *P values obtained.

ed motor functioning than a similar treatment without EyeToy games after stroke. The beneficial effect continued during the 3-month follow-up evaluation. However, no significant advantage was found on motor recovery of the paretic upper extremity at follow-up. The group observed was made up of inpatients with severely impaired hand functions after stroke. Total duration of the experimental intervention was only 10 hours, which might be relatively short for a change on motor recovery. On the other hand, 10 hours of extra training by games might be enough not only to protect paretic side from learned nonuse behavior but improve self-care skills on the non-paretic side as well. Unlike Brunnstrom's staging of the paretic side, FIM focuses on the performance of the individual on a specific activity and does not care by which side the activity performed. Patients in the EyeToy group might have developed compensatory self-care strategies by the non-paretic side faster than the control group.

VR is a simple, inexpensive and, most importantly, a patient-directed treatment. Although undersized and not sufficiently controlled, previous studies suggested that VR therapy might be beneficial for motor recovery in the paretic hand.[29-32] In an open study of 8 chronic stroke patients, Merians *et al*.[32] reported that range of motion, speed and isolated use of the fingers were more improved after VR therapy. In another study same group reported that their 3 chronic stroke patients trained with VR therapy for 2 weeks (3.5 hours a day) had an increase in active range of motion, movement speed, and Jebsen Test of Hand Function after VR therapy.[29] Similarly, Boian *et al*.[30] found that 3 weeks of intense VR therapy in 4 chronic stroke patients resulted in a strong recovery of thumb range, finger strength and finger speed. In these previous case series VR therapy software mainly focused on training of fine hand movements and they assessed movement quality as outcome evaluation. On the other hand, in the present study patients forced to move their shoulder and elbow selectively while playing EyeToy games. The different goals of the games may explain the lack of superiority in motor recovery in this study.

Although EyeToy games are originally developed for entertainment and gaming purposes, the authors found that an exercise program delivered via EyeToy games has a potential to stimulate the long rehabilitation process after stroke by improving upper extremity-related motor functioning. The possible mechanisms responsible for improvement in upper extremity-related motor function during self-care activities can be the reinforcement of using the paretic extremity that may reduce the learned nonuse behavior, or the repeated practice of functional tasks that may lead to increased reorganization of the brain. Functional brain imaging studies suggest that reorganization of motor functions immediately around the stroke site (ipsilesional) is likely to be important for motor recovery after stroke, and a contribution of other brain areas in the affected hemisphere remains possible.[35] You *et al*.[25] investigated the effects of VR therapy on cortical reorganization of 10 chronic stroke patients using fMRI. They suggested that VR could induce cortical reorganization from aberrant ipsilateral to contralateral sensoriomotor cortex activation and this might play an important role in recovery of locomotor function in patients with chronic stroke. Similarly, Jang *et al*.[26] investigated the effects of VR therapy on cortical reorganization and motor recovery of 5 chronic stroke patients and demonstrated VR-induced neuroplastic changes using fMRI.

The results of this randomized controlled study including 20 patients with subacute stroke confirm the potential use of "Playstation EyeToy" games as an innovative and effective therapy to improve upper extremity-related motor functioning. Previous studies which used VR for the assessment and rehabilitation of visual perception, attention, memory, sequencing and executive functioning share a common goal of using VR to improve functional ability.[18-24] EyeToy games engage the patients cognitively in repeated movements with increasing challenge. They include many motivating and competitive environments that may be played by one user or more sequentially in a tournament fashion. Games can be classified according to the therapeutic goals and it is possible to adapt levels of difficulty and record performance data in a memory card. Games may also be useful for bilateral training, eye-hand coordination, increasing speed of movement and postural reactions if performed while standing. It requires active movement of the whole body, attention and rapid responses. In patients with severe motor impairments a life jacket connected to a lift for security can be used. It is possible to select right hand or left hand use while playing the games so that the therapist can select the side to train according to the paretic side of the patient.

Currently, there are several VR systems on the market such as VividGroup's GX and IREX platforms and

Sony's Playstation EyeToy.[18] Rand *et al.*[28] compared different video-capture platforms, GX and Eye-Toy to determine their effect on users' sense of presence, level of enjoyment, perceived exertion and side effects. In this study, 18 healthy young adults experienced two games in each platform ("Birds & Balls" and "Soccer" in GX and "Kung-Foo" and "Wishy-Washy" in Eye-Toy) in a counter-balanced order. There was no significant difference in the sense of presence between the two platforms. However, the EyeToy "Kung-Foo" game, which encourages participants to eliminate successive invading warriors by hitting at them, was found to be significantly more enjoyable than the other games. In a continuation of this study, they examined the feasibility of using the EyeToy with healthy elderly users. Ten healthy elderly participants, aged 59 to 80 years, found this platform easy to operate and enjoyable. The results for patients with stroke at a chronic stage (1-5 years post stroke) were similar to the healthy elderly. They thought that it could contribute to their rehabilitation process, and were able to operate the platform independently. The responses of a third group of users, patients with stroke at an acute stage (1-3 months post stroke), were somewhat different. They also reported that they enjoyed the experience; however, they became frustrated while performing the EyeToy games, even when played at the easiest levels.

Patients recruited in this study were referred from all over the country for inpatient rehabilitation. Generally, in Turkey, an estimated 50% of the stroke population is referred to a rehabilitation center if they cannot return home directly after dismissal from the general hospital. According to the authors' inclusion criteria, the findings and conclusions are based on the population of subacute stroke inpatients (all within 12 months post-stroke) that survived from first stroke without severe cognitive deficits.

A potential limitation of this study is the lack of exact duration of the conventional rehabilitation program of the groups. Because few studies have investigated VR therapy for patients with stroke, there is no agreement on aspects such as optimal patient selection, duration and intensity of training of this new therapeutic approach. Incorporating the EyeToy games into the conventional program at the early stages of the treatment and applying it for a long period of time might be even more beneficial to improve upper extremity function.

In this study, the authors evaluated the outcome by FIM self-care items, as main goal of stroke rehabilitation is to maximize function. At follow-up FIM self-care improved with a mean of 5.5 points in EyeToy group and 1.8 points in the control group. In the present study, the authors interpreted the difference clinically relevant in EyeToy group because it was higher than the MCD for FIM self-care items that we calculated as 4.9 points, previously. There are some disadvantages of FIM instrument that the ratings are based on performance rather than capacity and a patient could be independent in activities of daily living by using his unaffected arm. So that future studies may investigate the effects of EyeToy games by using manual dexterity tests and performance tests to estimate the level of activity limitation of the hand and upper limb.

Conclusions

The EyeToy games improve movement performance in self-care activities. Rehabilitation after stroke is a very long process. Being cheap, easy operating, motivating and enjoyable, EyeToy may even be purchased for use at home to provide regular, intensive therapy after discharge from hospital. The full potential of EyeToy games in rehabilitation probably is related to its future use at home, in a tele-rehabilitation setting. It is possible to direct a patient's motor response to train range of motion of different extremity and whole body balance training. EyeToy can also be used to train both sitting and standing balance. By providing the feedback about the patient's body posture and quality of movement it is helpful to treat unilateral spatial neglect and postural reactions. Future studies may investigate the effectiveness of EyeToy games as a home treatment and on other body functions such as postural reactions in patients with stroke.

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