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Efficacy of closed loop feedback system with augmented virtual reality visual cues training on gait and functional performance in stroke patients

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ABSTRACT

The traditional gait training techniques, which are not based on principles of motor control lack requisites in terms of training intensity, duration and enough practice to have any meaningful carryover effect. Therefore, the aim of this study is to investigate the efficacy closed loop visual cues incorporated augmented reality environment on functional gait and community ambulation in stroke patients. A randomized control trial with control group was designed and 14 subjected were recruited in each group. Four weeks of augmented reality based closed loop visual cue training was given to experimental group. Compared to control group, the Walking speed, cadence, stride length of paretic and non-paretic limb, symmetrical walking and SIS-SF score improved 25.1%, -5.5%, 29.3%, 8.3%, 5.3% and 29.1% respectively. The finding of our study supports the beneficial effect of augmented reality based closed loop visual cue training for improving the gait and functional ambulation in stroke patients.

INTRODUCTION

Stroke is one of the most devastating condition leading to life long morbidly and mortality. The stroke survivors suffer from various sensorimotor impairment of gait and posture leading to moderate to severe disability (Duncan et al 2002). Patients with stroke presents with multiple postural deficits including loss of anticipatory postural reaction, postural sway, uneven weight bearing and inability to maintain upright posture. These deficits increase the risk of falling and ultimately affect the ambulation and activities of daily living (Dickstein et al 2000). Depending upon the severity of stroke most patient recover gait function, though a very small percentage of stroke survivors become community ambulatory (Mackintosh et al 2005). Recent studies proposed that the post stroke impairment of mobility functions, such as, reduced walking speed, asymmetrical weight bearing, unequal step and stride length etc. may be due the inability of the patients to regulate the anticipatory postural reaction (Hill et al 1997). Over and above, the impaired coordination directly affects all the aspects of ambulation including; turning, obstacle avoidance, relative foot placement and velocity regulation, required for independent community ambulation (Roerdink et al 2007). Synthesis of recent literature supports an intensive task specific gait training targeting symmetrical gait pattern may improve ambulatory function (Hollands et al 2012)

The existing evidence suggest that the visual inputs are most import external sensory cues regulating walking and due the impaired sensory inputs the stroke survivors excessively rely on vision to maintain dynamic stability (Kim et al 2012). Gait training incorporating external sensory feedback, which has been found to be very effective in Parkinson's disease (Fuzail et al 2007) have recently begun to be used to investigate functional walking tasks in stroke populations (Bonam et al 2004). In a natural closed loop feedback control system, the physical motion of the body generates the visual cue in response to ambulation and in the absence of movement these cues are not generated (Hollands et al 2010).

The traditional gait training techniques, which are not based on principles of motor control lack requisites in terms of training intensity, duration and enough practice to have any meaningful carryover effect (Rizzo et al 1997). Novel interactive Virtual reality (VR) technologies, creating an immersive environment for stroke patients simulating real-world experience, can help address the limitations posed by traditional approaches (Cikajlo et al 2009). Augmented reality (AR) can improve the implicit knowledge of movement by immersing the desired training regimen in a real-world environment (Azuma et al 2001). A recent systemic review had showed strong scientific evidence supporting the beneficial effects of virtual reality on upper limb motor recovery in stroke patients (Viñas Diz 2016). A recent home based virtual reality training had shown beneficial functional training effects; suggesting that it may be useful as a neurorehabilitation tool (Villiger et al 2017).

To the best of our knowledge, till date, there is no randomized controlled trial demonstrating the efficacy of closed loop visual cues incorporated augmented reality environment on functional gait and community ambulation in stroke patients. Therefore, the aim of this study is to investigate the efficacy augmented reality based closed loop visual cue training on gait and functional ambulation in sub-acute stroke patients.

MATERIAL AND METHODS

Design: A randomized control trial comparing the effect of proposed intervention with control group was designed. Based on the 80% power and an alpha value of .05 the sample size calculated to be 14 participants in each group. The subjects were randomly selected based on lottery method and allocated to either closed loop visual cue augmented reality group or to control group receiving traditional gait training. The subjects were selected based on the following inclusion criteria; (a) patients having single episode of stroke (b) onset of stroke must have occurred before months, (c) presence gait deficit due to hemiplegia, (d) patient must be able to walk independently, and (e) must be medically stable without any visual or cognitive defect. Patient having other comorbidity affecting gait function were excluded from the study.

All the subjects recruited in the study underwent a structured one-hour physical therapy session 6 day a week for four consecutive weeks. In addition to this the subjects in the experimental group subjects participated in an additional closed loop visual cues training through a head mounted device (HMD) with partial bodyweight supported treadmill training (Walker et al 2010). The HMD generated visual cues matched to walking symmetry bringing the sensory feedback signals closer to the eyes, making the sensory effect more pronounced, easier to follow and to learn. The closed loop visual cue training was provided every alternate day for 4 weeks.

Outcome measurements

The following outcome measurements were taken by a therapist at baseline and again after 4 weeks of training. Gait function were measured using GAITRite (GAITRite; CIR system Inc., Havertown, PA, USA). The standard GAITRite walkway contained six sensor pads encapsulated in a rolled-up carpet with an active area of 3.66

FIGURE 1. Percentage changes in the outcome variables in both the groups after 4 weeks.
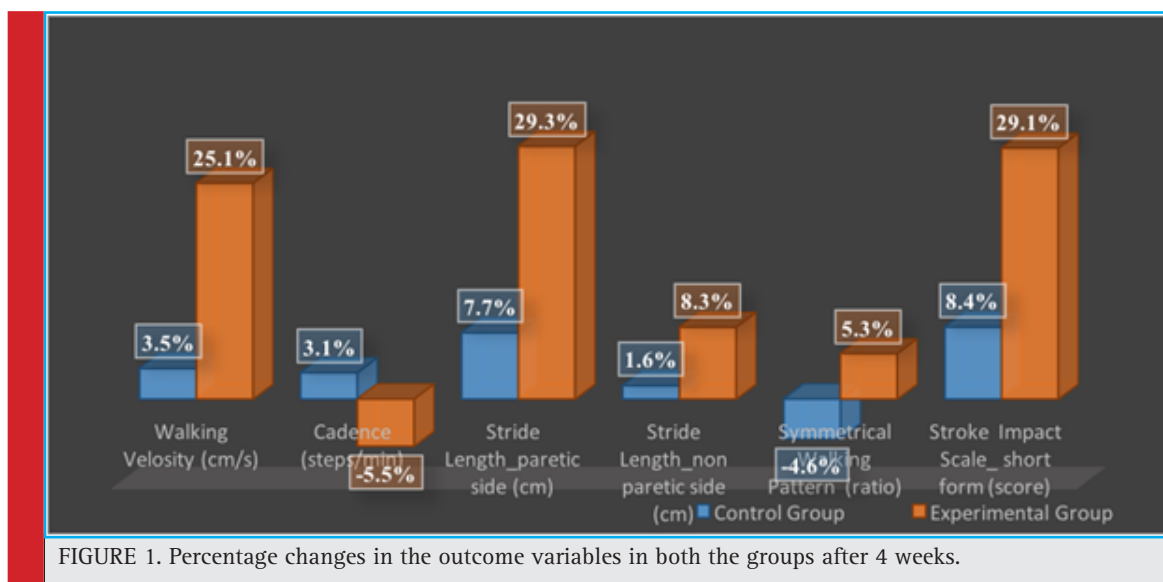
m (length) 0.61 m (width). GAITRite will be used for measurement of the spatiotemporal parameters, including gait velocity, cadence, step length, and stride length (Mc Donough et al 2001). (Uden et al 2004) investigated the reliability of measurements performed using the GAITRite system as a video-based analysis system and found excellent reliability (Intraclass Correlation Coefficient (ICC) Z0.94).

A short for stroke impact scale (SF-SIS) was used to measure the perceived community participation content, convergent, and discriminant validity (Rachael et al 2016).

RESULTS

Total 28 patients were enrolled in the study with a mean age of 44.7+12.3 years and the mean stroke onset was found to be 20.5+9.2 months. Fourteen subjects were randomly allocated in control and experimental group. Two patients dropped out of the control group and 3 subjects dropped out from the experimental group due to various reason.

An independent t-test was performed to check the uniformity of data which showed that there is no difference in all the selected variable. The results are provided in below mentioned table 1.

It was found that, in the group getting general physical therapy program, there was an increase of 4% in walking velocity, 3% increase in cadence, 8% improvement in walking symmetry, 2% increase in stride length of the paretic limb, 5% decrease in stride length of the non paretic limb and 8% improvement in the SIS_SF scores. A paired t-test was conducted, with an alpha level of .05 between the baseline and post test scores,

Table 1. Baseline Characteristic						
Variables	CG		EG		T	p
	Mean	SD	Mean	SD		
Age (years)	46.5	13.4	42.7	11.3	.727	0.475
Stroke Onset (months)	20.5	11.5	20.6	6.5	-.012	0.991
Walking Velocity (cm/s)	35.3	9.8	38.5	11.6	-0.717	0.481
Cadence (steps/min)	71	7.0	69.8	8.8	0.357	0.725
Stride length-paretic side (cm)	0.63	0.10	0.6	0.1	0.222	0.827
Stride length-non paretic side (cm)	58.5	3.2	58.8	3.0	-0.247	0.808
Symmetrical Walking Pattern (ratio)	59.8	2.4	60.5	3.2	-0.529	0.603
Stroke Impact Scale_ short form (score)	20	4.3	22	3.4	-1.127	0.272
CG: Control Group, EG: Experimental Group, SD: Standard deviation						

Table 2. Result of pairwise comparison of baseline and post test scores of outcome variables in the control group.

	CG (M±SD)	EG (M±SD)	T	p
Walking Velocity (cm/s)	35.3±9.8	36.5±13.5	.438	.670
Cadence (steps/min)	71±7	73.2±8.5	1.116	.288
Stride length-paretic side (cm)	58.4±3.7	59.3±5.9	.557	.558
Stride length-non paretic side (cm)	59.8±2.4	57.1±5.5	1.817	.096
Symmetrical Walking Pattern (ratio)	0.63±0.1	0.67±0.13	1.339	.208
Stroke Impact Scale_ short form (score)	20±4.3	22±5.8	1.301	.220

CG: Control Group, EG: Experimental Group, M±SD: Mean ± Standard deviation

Table 3. Result of pairwise comparison of baseline and post test scores of outcome variables in the experimental group.

	CG (M±SD)	EG (M±SD)	T	p
Walking Velocity (cm/s)	38.5±11.6	48.1±11.1	4.545	0.001
Cadence (steps/min)	69.8±8.8	66±6.9	2.329	0.042
Stride length-paretic side (cm)	58.8±2.9	63.7±4.1	3.331	0.008
Stride length-non paretic side (cm)	60.5±3.2	63.6±5.5	1.665	0.127
Symmetrical Walking Pattern (ratio)	0.62±0.14	0.8±0.07	4.225	0.002
Stroke Impact Scale_ short form (score)	22±3.4	28±4.6	3.545	0.005

CG: Control Group, EG: Experimental Group, M±SD: Mean ± Standard deviation

which showed that none of the improvement is statistically significant (table 2)

After comparing the baseline and post test scores in the group getting closed loop visual cues training, it was found that there was an increase 25% in the waking speed, which was found to be statistically significant (t=4.545, p=.001). The cadence showed a decreased of 5% which was statistically significant (t=2.329, p=.042). The stride length of the paretic limb increased by 8% which was found to be statistically significant (t=3.331, p=.008). Even though, there was an increase of 5% in

stride length of the non paretic limb, it was found to be statistically not significant (t=1.665, p=.127).

Compared to control group, the Walking speed, cadence, stride length of paretic and non paretic limb, symmetrical walking and SIS-SF score improved 25.1%, -5.5%, 29.3%, 8.3%, 5.3% and 29.1% respectively. An independent t-test was utilized to find the effectiveness of both the treatment regimes. The result presented in table 4 suggests that, all the outcome variables showed a statistically significant improvement in the experimental group getting closed loop visual cues.

Table 4. Result of comparison between the control and experimental group on all outcome variables.

Variables	CG		EG		T	p
	Mean	SD	Mean	SD		
Walking Velocity (cm/s)	36.5	13.5	48.1	11.1	-2.236	0.036
Cadence (steps/min)	73.2	8.4	66.0	6.9	2.213	0.038
Stride length-paretic side (cm)	0.68	0.13	0.8	0.1	-2.822	0.01
Stride length-non paretic side (cm)	58.3	4.6	63.7	4.1	-3.012	0.007
Symmetrical Walking Pattern (ratio)	57.1	5.5	63.6	5.5	-2.858	0.009
Stroke Impact Scale_ short form (score)	22	5.8	28	4.6	-2.969	0.007

CG: Control Group, EG: Experimental Group, SD: Standard deviation

DISCUSSION

The aim of this study was to find the effectiveness a novel method utilizing the augmented reality based closed loop visual cue training to improve the gait function for better community participation in stroke patients. The result of this study has showed an improvement of all gait related variable in the experimental group except stride length of the non paretic limb, which may be due to the relative improvement of the paretic limb's stride length. The result of our study is similar to the study done by (Lee et al 2014). where they have used a virtual reality based postural control for improving the gait function in the stroke patients. Their study showed a significant difference in all gait variables except cadence but in our study we found that the cadence was significantly decreased by 5%. This decrease may be in response to the significant increase in the paretic limb's stride length, which would have caused longer but less steps/minute. We also found an insignificant increase in the non paretic limb's stride length, which is in contrast with the study by (Lee et al 2014). This may be due to the improved motor control of the paretic side, causing leveling of stride length on both the side.

A recent study by XI et al (2017) suggests cortical plasticity by increased activation of cortical regions in stroke survivors as a probable mechanism for better recovery of mobility function associated with virtual reality based training. Another important finding of our study was 29% significant improvement in symmetrical walking pattern in the experimental group subjects. This finding is similar to the result of the study conducted by (Sami et al 2015) here the symmetrical walking pattern significantly improved due to increased muscle strength and coordination.

As stroke patients are unable to cope with the challenges of varying environmental demands required for community walking due to their impairments. As stroke patients live a relatively sedentary lifestyle any interventions which consistently augments activity level and induces demand on lower limb's motor control may improve the walking pattern (Hendricksan et al 2014). Therefore, the improvement seen in our study may be attributed to the determined efforts of the patients in response to the closed loop visual cues for effectively controlling their lower limbs.

The most noteworthy finding of our study was a substantial improvement in perceived community participation among the subjects closed loop visual cue training group. We saw a 29% increase in perceived community participation which is in line with the findings of Sami et al 2015. (Warren et al 2016) in their study established a direct relationship between decreased community participation and slower walking speed, which may explain the magnified perception of community participation due to increased walking speed.

CONCLUSION

The finding of our study supports the beneficial effect of augmented reality based closed loop visual cue training for improving the gait and functional ambulation in stroke patients.

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