Effects of real-time visual feedback in the form of a virtual avatar on symmetry and other parameters of gait post stroke

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***Abstract*—Gait asymmetry, one of the hallmarks of post stroke locomotion, often persists despite gait rehabilitation interventions, impacting negatively on functional mobility. This pilot study examines the feasibility and instantaneous effects of real time visual feedback provided in the form of an avatar on gait symmetry. Preliminary results obtained from seven chronic stroke survivors showed no improvements in step length and step time ratios while using three avatar views (back, frontal and paretic side). Improvements in lower limb joint angle symmetry, however, were observed. Faster walking speed and larger paretic step length were also noted during the adaptation and post-adaptation phases. We are currently extending the study to a larger sample to validate the use of real time visual feedback to enhance spatial parameters of gait among stroke survivors.**

Keywords— Avatar; cerebrovascular accident; gait asymmetry; virtual reality.

I. INTRODUCTION

Gait dysfunctions are the most reported problems by individuals with stroke [1]. Post-stroke gait typically features spatiotemporal deviations, i.e: shorter (or larger) step length and prolonged swing phase on the paretic side and prolonged stance phase on the non-paretic side [2]. These inter-limb differences are commonly referred to as gait asymmetry [2]. Gait asymmetry can lead to many negative consequences, including poor balance control, gait inefficiencies and decreased overall physical function [3]. Current gait interventions for gait asymmetry cannot demonstrate specificity and effectiveness [4].

In rehabilitation, visual feedback plays an important role in learning the spatial aspects of a motor task [5]. Moreover, visual feedback in the form of biological cues (as in seeing one's own movements) has shown promising results in motor learning research [6], especially in providing additional and more easily decipherable information about one's gait pattern. However, whether biological cues as a source of visual feedback has the potential to improve post stroke gait symmetry remains unknown. We propose a new method, with the use of visual feedback provided in the form of virtual avatars displaying participant's locomotion in real time, to improve gait symmetry and other parameters of gait in people with stroke. In this ongoing study, the objectives are: (1) to determine the instantaneous effects of using virtual avatars replicating limb dynamics in real time to provide visual feedback on the symmetry of spatiotemporal and other parameters of gait in people with stroke; (2) to determine which view (frontal vs side vs back) is the most effective in improving gait symmetry; and (3) to estimate the extent of short-term lasting effects on gait symmetry once the feedback is removed.

II. METHODS

A. Experimental design and experimental setup

Prior to the start of the experiments, participants were evaluated on their level of motor recovery using the Chedoke-McMaster Stroke Assessment (CMSA). Gait speed was assessed using the 10m Walk Test. During the experiments, participants were assessed while walking on a self pace treadmill (0.6 m X 1.5 m) (Fig 1). The VE scene, projected on a large screen (2.44 m × 3.05 m) mounted in front of the treadmill, consisted of a long city street with a gender and height matched avatar located 3.5m ahead of the participant. Maya LT™ 2016 (Autodesk, USA) was used to design avatars of similar appearance and anthropometric characteristics to those of the participants. During the experiment, real time limb movements were captured at 120 Hz by a 6-camera Vicon Mx system and Vicon Tracker™ (Vicon Motion Systems Ltd, Oxford, UK) based on the displacement of rigid bodies placed on specific

Fig 1. Left: picture of the experimental setup and placement of rigid body markers on a participant. Right: back (top), frontal (middle) and paretic side (bottom) views of an avatar.

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body landmarks of the participants. Pegasus Advanced™ was used to retarget the limb positions at 60Hz onto the virtual avatar that was displayed on the screen and controlled using Unreal Engine 4 (Epic Games, USA).

B. Experimental procedure

After habituation on the self-pace treadmill, participants performed one to two walking trials of each of 3 avatar viewing conditions (back, front, and side) in a random order (Fig. 1, right panel). Each trial had three phases which included 30s of comfortable walking without the avatar (pre-adaptation), followed by 1 min of walking while viewing the avatar mimicking the exact walking pattern of the participant in real time (adaptation), and finally 1 min of walking without the avatar (post-adaptation). The participants were instructed to walk at comfortable speed while paying attention to their gait symmetry when looking at their virtual avatar. They were also instructed to use sliders on the handrails to facilitate balance.

C. Outcome measures

The primary outcome for the spatial component of gait symmetry was step length ratio (SLR), while swing time ratio (STR) was used as the primary outcome for the temporal component. The ratios were calculated using the formula $Variable_{paretic} / Variable_{non\text{-}paretic}$ where the value '1.0' indicates as perfect symmetry [7]. Secondary outcomes included joint excursion symmetry (hip, knee and ankle), paretic hip circumduction and walking speed.

III. Results

Table I summarizes the demographic and clinical information of the 7 stroke participants recruited so far.

TABLE I. CHARACTERISTICS OF THE PARTICIPANTS

Participants	Age (years)	Gender	Onset of stroke (months)	CMSA* (/7)		Walking speed (m/s)	
				Leg	Foot	Comfortable	Fast
1	66	male	25	5	5	0.94	1.19
2	51	female	324	5	2	0.79	0.91
3	66	male	22	6	2	0.34	0.46
4	67	male	12	5	3	0.80	0.91
5	57	male	6	5	4	0.96	1.26
6	56	female	12	4	4	0.89	1.03
7	77	male	40	4	5	0.29	0.38

* *Chedoke-McMaster Stroke Assessment (CMSA)*

Among participants who had temporal asymmetry (initial STR above 1.06 [7], n=6), a tendency towards increased swing time ratio was observed in the post-adaptation phase compared to the pre-adaptation and adaptation phases for all three avatar views (Fig 2, top graphs). For those who had spatial asymmetry (initial SLR above 1.08 [7], n=4), there did not seem to have any change in symmetry across all phases, except that a trend for improved SLR was observed with the side avatar view. While considering all 7 participants, increased gait speed (mean=0.05m/s) and paretic step length (mean=0.02m) between post-adaptation and pre-adaptation phases were observed for all three views (not illustrated). Further analysis on the symmetry of joint excursions of hip (n=3), knee (n=6) and ankles (n=7) revealed an improvement (increased excursion on paretic side and reduced on the non-paretic side) for all three joints in the adaptation phase for the side view.

IV. Conclusion

While visual avatar-based feedback may not improve the temporal symmetry of gait after stroke, the paretic side view specifically may improve spatial symmetry, as reflected by improved SLR ratios and symmetry of lower extremity joints angles. Walking speed and paretic step length also increased during the adaptation phase. Future study should target the

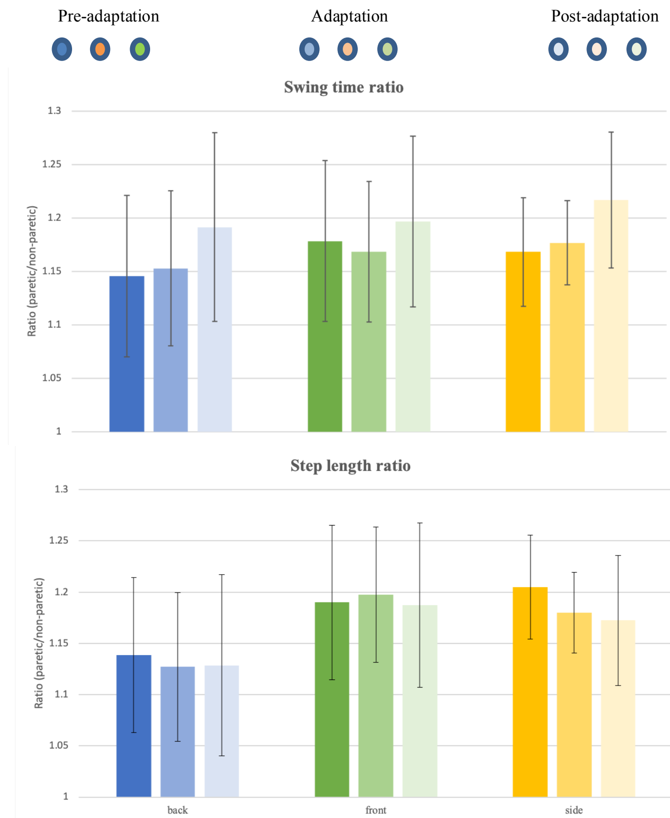

Fig 2. Top: bar graph of means of swing time ratio (n=6) of all three views (different colors) across all three phases (different shades); Bottom: bar graph of means of step length ratio (n=4).

potential benefits of repeated sessions and training for optimal motor learning.

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