Development of a virtual reality toolkit to enhance community walking after stroke

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***Abstract*—Community walking remains compromised in the majority of stroke survivors even after rehabilitation. We developed a virtual reality (VR) toolkit prototype to provide intensive, task-specific training of complex locomotor tasks as required for community walking in safe yet ecological virtual environments. The toolkit, supported by best evidence and developed using low-cost VR tools, comprises of 6 dimensions that include endurance, walking speed, postural transitioning environmental encumbrance, cognitive load and a more complex dimension combining encumbrance and cognitive load. Feedback collected through hands-on interaction and focus groups with stroke participants and clinicians will be used to refine the prototype. The resulting VR toolkit will be combined to field training practice as part of a multi-centered intervention study to enhance community walking in stroke survivors.**

Keywords—Cerebrovascular accident, community ambulation, endurance, locomotion, obstacle avoidance, omnidirectional treadmill, rehabilitation, walking speed.

I. Introduction

"Getting out and about in the community" is a major concern expressed by the majority of stroke survivors [1]. Only 50%, however, manage to walk in the community after rehabilitation [2], with most presenting limitations that necessitate assistance or supervision [3]. The fact that community walking remains largely compromised even after rehabilitation can be attributed to insufficient or a lack of targeted practice [3-5]. Thus, there is a strong need to develop effective interventions. Virtual reality (VR) is a safe means to provide patient-oriented control over both environmental and personal factors for mobility. Our team is conducting a multi-centered study that involves the development and testing of a new intervention toolkit that combines VR and field training (FT) practice to enhance community walking post-stroke. The VRFT toolkit focuses on individually-tailored intervention grounded in best evidence in community ambulation and principles of motor learning and locomotor control. It is designed to provide targeted, intensive and repeated practice of locomotor adaptations in varied community environments to tackle multiple requirements of community walking [6].

The purpose of this paper is to present the integrated knowledge translation (iKT) approach and achievements made as part of phase 1 of the project, which involves the development and refinement of the VR component of the toolkit. The premise behind the use of the iKT approach is that the participation of clinicians and patients as knowledge users, alongside researchers, will allow for an intervention toolkit that is more relevant and useful, and more likely to be adopted. Low-cost and commercially available VR tools initially developed by the gaming industry are being used with the purpose of generating an affordable and accessible toolkit.

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II. Methods

Phase 1 of this project, presented here, involves the A) development of the VR intervention prototype (equipment and training dimensions) and B) its refinement using the input of patients and clinicians.

A. Development of VR prototype

The development of the toolkit prototype was carried out collaboratively by our team of researchers, engineers, programmers and clinicians working at two different sites. VR materials selected based on their characteristics, cost and availability, include (Fig 1): a low-cost omnidirectional treadmill (Virtualizer, Cyberith, Austria) allowing for change in speed and direction; VR goggles (HTC Vive, HTC & Valve, Taiwan) allowing the visualization of the virtual environments (VEs) and a hand tracking device (Leap Motion Controller, Leap Motion, USA) allowing further interaction in the VEs (e.g. pressing an elevator button, buying a movie ticket).

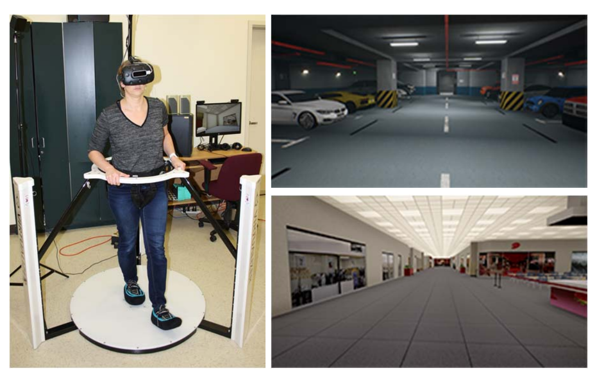

Fig. 1. *Left: Virtual reality set-up with the omnidirectional treadmill, VR goggles and hand motion tracker (attached on VR goggles). Right: Examples of VEs (parking lot and corridor in the virtual mall) used for the VR prototype.*

The VEs, developed in Maya LT (Autodesk, USA) and Blender (Blender Foundation, The Netherlands), are controlled with the Unreal Engine (Epic Games, USA) based on real-time data provided by the VR tools. VEs were collaboratively developed by the team members according to community walking demands and challenges (referred to as 'dimensions') identified by people with and without disability [6]. These dimensions are presented with different levels of increasing difficulty, starting with a baseline level that is tailored according to the patient's walking capacity using the 6-min Walk Test (6MWT). Criteria for progression and mechanisms to provide feedback and rewards based on performance were established.

B. *Refinement of VR prototype*

The refinement stage of the VR prototype involves a hands-on interaction and a focus group at each clinical site. First, participants with chronic stroke (n=8) and clinicians (n=4) will interact with the VR prototype for two 1-hour sessions. Outcomes of task performance include total time, distance, and speed walked for each trial, collisions made, accuracy on memory task, difficulty level attained for each dimension, etc. In addition, usability (Short Feedback Questionnaire), exercise intensity (Borg Scale and heart rate (HR)) and perceived level of mental and physical demands (NASA Tax Load Index) will be recorded. The same participants, as well as clinicians from the stroke rehabilitation program, will further participate in a 2-hour focus group. After a brief presentation on VR technology and the VR prototype, we will question them about their acceptance of the VR technology [7] and obtain feedback on the VR prototype. A directed content-based analysis approach will be used to analyze themes that emerge from each question addressed in the focus group. Subjects' and clinicians' responses will be coded by 2 assistants, and further verified by a researcher (triangulation). The findings will be used to refine and optimize the VR component of the intervention toolkit.

III. RESULTS

To date, results exist only for prototype development (A). Six dimensions related to performance training have been created within a virtual shopping mall. Each is configured, through a graphical user interface, to the patient's capacity. Dimensions include: (1) Endurance; (2) Walking speed; (3) Postural transitioning; (4) Environmental encumbrance; (5) Cognitive load and; (6) a more complex dimension combining Encumbrance and Cognitive load. Each comprises of three levels of increasing complexity. In Dimension 4, for instance, participants are instructed to buy an item at a specific store located in far space, while avoiding collisions with obstacles. As they walk a distance corresponding to 66% (4 minutes) of their 6MWT to reach to the store, they avoid multiple static obstacles (Level 1); multiple obstacles moving at slow speed (Level 2) and; multiple obstacles moving at faster speeds and/or making unexpected changes in speed or trajectory (Level 3). Criteria for success and progression include the completion of the entire walking distance in the absence of a collision while walking at a speed equivalent to 75% of their comfortable speed measured during the 6MWT. As from Dimension 3, participants have the option of completing all levels in the virtual mall or to train in other VEs that include an outdoor city environment (≥ Dimension 3), a foreign touristic destination (≥ Dimension 4) or an outdoor fair in a park (≥Dimension 6). For each walking trial, information about dimension and level, success or failure and key outcomes (speed, distance collisions, etc.) is recorded in Unreal and fed to a secure online REDCap database (REDCap, Vanderbilt, USA). This allows to simultaneously collect data from the VR toolkit at different clinical sites in a centralized location (Fig 2). The hands-on trial and focus groups with clinicians, to be performed shortly, will be used to refine the VR toolkit prototype.

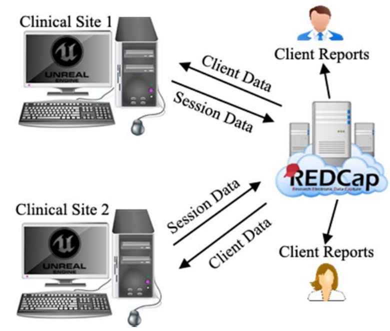

Fig. 2. *Schematic representation of data flow between clinical sites and REDCap database and clinicians (users).*

IV. CONCLUSION

The VR prototype developed allows individuals to train on complex, ecologically-based locomotor tasks as required for community walking. The intervention toolkit, supported by research evidence and developed using state-of-the-art but low-cost technology, will be tested as part of a multi-centered intervention study designed to provide individually-tailored training to enhance community walking in stroke survivors.

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