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Step Training System: An ICT solution to measure and reduce fall risk in older adults*

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Abstract— **Falls in older adults are a significant public heath issue with over 1/3 community-dwelling people aged 65 and over falling each year, many of them multiple times. We have developed and evaluated a set top box PC solution for delivering both fall risk assessment and fall risk reduction programs into the home. Preliminary field tests show that older adults engage with the system but that barriers to maintained use of the system do exist.**

I. Introduction

Declines in physical or cognitive function are associated with age-related degeneration of, or injury to, the brain and nervous system. Neurodegeneration and neural injury contribute to parallel declines in self-confidence, social interactions and community involvement. A cycle is set up, where social isolation leads to further loss of confidence, leading to further isolation. The social circle contracts as friends age or pass away, and a greater emphasis on family is often a result. Fear of a major incident such as a stroke or a bone-breaking fall [1] can lead to the decision to move into a supported environment. Moving from an individual's private home into an aged care setting is then viewed as a major step in the loss of independence and quality of life.

Falls are very common in older people [2] and can have a major impact on their continued independence. Declines in physical and cognitive functioning, that have also been identified as intrinsic fall risk factors [3, 4], may lead to reduced capabilities for taking proactive and reactive steps in order to maintain balance [5, 6]. Impaired stepping has been associated with falls in older people in several studies [7-9]. In response to an external perturbation of balance, older fallers are more likely to: take an inappropriate step (wrong direction, too short), to collide one leg against the other during compensatory crossover steps [8], to be slower in initiating volitional step responses [7], and be distracted when stepping under dual task conditions [9]. In an effort to reduce the risk and incidence of falls in older adults we have explored a home telehealth solution for both measuring fall risk and delivering step training interventions.

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II. Identification of Fall Risk

Several stepping tests exist that discriminate between fallers and non-fallers [7, 10] with limited evidence that cognitive load is needed [9]. The choice stepping reaction time (CSRT) task has shown to be a better discriminator between fallers and non-fallers than other sensorimotor and balance measures [7] and to predict falls in older people, mediated via physiological and cognitive pathways [5]. The reaction time can be significantly affected by cognitively demanding tasks as well as age-related deterioration of information processing [11]. Choice reaction time tasks, in which two or more alternatives are presented to participants [12] have been used to investigate age-related changes in responses that require complex, fast information processing such as to the generation of fast volitional stepping to avoid a fall. However, these tests require the use of relatively fixed and specialised laboratory equipment.

III. Exercise can Reduce Fall Risk

Fortunately, falls are a public health problem that is largely preventable through implementation of targeted exercise programs. Over 50 randomised controlled trials have provided robust evidence to support interventions for preventing falls in older people. Exercise has been shown the most effective single intervention strategy with a fall reduction of up to 47% [13]. However, despite clear evidence demonstrating benefits of exercise for reducing fall risk, uptake and adherence to exercise programs in fall prevention is often disappointing [14, 15]. Efforts to improve exercise adherence are needed to increase the impact of falls prevention programs at a population level.

One method by which compliance with exercise programs could be improved involves the use of enjoyable videogames. Interactive, exercise-based videogames (exergames) that combine player movement, engaging recreation, performance feedback and social connectivity via competition have been shown to promote motivation for, and increase adherence to, physical exercise amongst children and young adults [16, 17]. It has also been shown that certain exergames correspond to moderate intensity exercise in older people [18, 19]. Providing exergame technology to older people for home-based training could increase compliance to effective programs, potentially benefiting more people. In the following we explore the development and evaluation of a modified, open source version of a popular step-based exergame (StepMania; www.stepmania.com) for delivering an in-home fall prevention exercise intervention.

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IV. THE STEP TRAINING SYSTEM

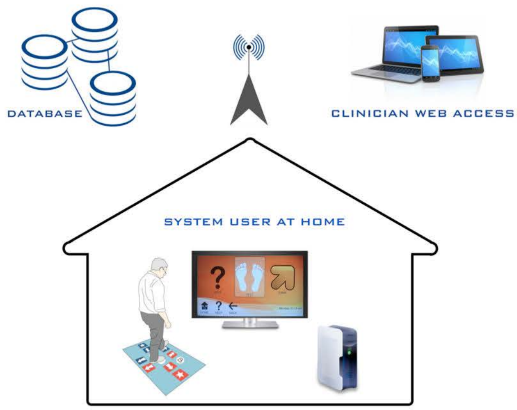

Fig 1: Key components of the Step Training System.

Fig. 1 provides an overview of the main features of the system. A Linux-based set top box was developed for use in-home to (a) measure the CSRT on a weekly basis and (b) deliver a regular (daily) step training exercise routine via an interactive, exercise-based videogame (Stepmania). To overcome any barriers in use of our system by older adults, we considered it important to make use of technologies with which they are already familiar. As the ubiquitous home television set is the dominant information and communication technology already adopted widely by older adults, our solution makes use this as the primary display device.

We modified Fedora, a standard Linux distribution, to run on our set top box solution and provide minimal interaction options for the user with a simple, intuitive interface (Elixos). The only input method required is from a wirelessly connected dancemat to navigate through the key menu items available; "Test", "Game" and "Help". Stepping on either the left or rightward pointing dancemat arrow brings into focus one of the 3 menu items. A step onto one of the other control buttons on the dancemat ("A" or "B") initiates the selected option. A selection of "Test" launches a Choice Stepping Reaction Time test previously described in [20] while selecting "Game" launches Stepmania.

Elixos records and timestamps all interaction with the system by the user, including the outcome of performance on the CSRT test and the Stepmania game. All data for each user of the system is compressed, archived and then sent to a centralised database via the Internet. As we cannot be sure that each household in which the system has been installed has access to the Internet, we have bundled a machine-to-machine wireless modem and dataplan for each to facilitate remote data capture. Apart from aggregating and processing all data for each distributed Step Training System, our database is also responsible for updating the state of each remotely installed system, e.g. for OS patches or updates to the CSRT or Stepmania. Clinicians or researchers can remotely monitor user engagement with the system through a specialised web portal.

The StepMania game requires participants to step as accurately as possible, both in terms of direction and timing, while synchronizing their stepping with instructions presented on the screen. Arrows drift from the bottom to the top of the screen (Fig. 2 red arrow) and over a target arrow (Fig. 2 blue arrows). Participants were asked to time each step so that it corresponded precisely with the drifting arrow

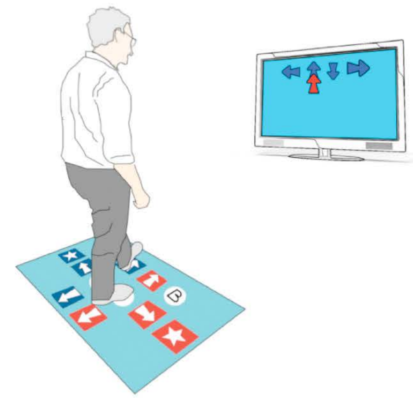

Fig 2: Typical engagement with Stepmania game.

passing over the target (Fig. 2). After each step response, participants were required to return their stepping foot back to the appropriate central stance pad panel. For each step feedback was given in form of a word in the centre of the screen (perfect, good, miss). Points accrued according to how well participants performed the task.

It is important to note that the complexity of the DDR stimulus is defined not only by arrow drift rate (speed) but also the rate of stimulus presentation, i.e. how many steps/per second players are expected to make onto a target location in order to successfully interact with the game. Depending on the game difficulty, target step rate varied between one step every two seconds to a step each second. Participants are instructed to progress to a higher level when they considered they were performing well at their current level or considered the game level to be not sufficiently challenging and return to a lower level if they considered the game level was too difficult.

V. FIELD TRIAL

7 older adults (aged 65 and over), living independently in their own homes were instructed how to use the system and play the stepping game in a 90 minute individualized session at the start of a pilot trial to investigate the implementation of our system. In addition, they received a manual with detailed instructions and important advice regarding the control of the system and the training program. They were asked to play the game as many times as they wished with the recommended dose of 2-3 sessions per week for 15-20 minutes each session over the 8 weeks of the trial. Participants would therefore at a minimum play 240 minutes of StepMania if they played twice per week for 15 minutes per session. Participants were also asked to complete a choice stepping reaction time (CSRT) task once a week.

Observations.

Only two of the participants met or exceeded minimum time suggested for StepMania while three met or exceeded the required engagement with the CSRT task (Table 1).

Follow-up discussion with all participants revealed that those who did not use the system as expected experienced some difficulty finding time to use the system or found the system too complex to understand. Most reported that they would find a telephone helpline useful as well as feedback regarding their own performance and/or the performance of others using the system.

TABLE I. Characteristics of engagement with system

User	Days used		StepMania measures	
	CSRT	Step Mania	Songs played	Minutes played
1	4	-	-	-
2	7	4	7	2
3	3	1	2	<1
4	10*	24	109	203
5	6	8	20	8
6	12*	37	201	407*
7	12*	29	91	250*

* user exceeded minimum recommendation

VI. Conclusion

We have developed a relatively inexpensive (AUD$600) computer system for in-home measurement of the CSRT, a well-established correlate of fall risk in older adults. The system also enables us to deliver exercise-based videogames that can reduce fall risk. We have taken the feedback from the pilot field trial and have improved the system such that it now can provide regular and ongoing feedback to users regarding their performance. In a larger randomized controlled pilot trial we have recently shown that use of the modified system can significantly reduce fall risk in older adults [21].

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