The Promise of New Technologies in an Age of New Health Challenges
A.J. Maeder et al. (Eds.)

doi:10.3233/978-1-61499-712-2-110

Interactive Games for Home Delivery of Exercise and Rehabilitation Interventions for Older Adults: An Australian Perspective

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Abstract. Over the past few decades there has been a wealth of published scientific evidence for the physical, cognitive and social health-related benefits of increased physical activity, especially in older adults and people living with chronic disease. Despite the clear evidence base demonstrating the health-related benefits of physical activity, uptake and adherence is often disappointing. Therefore, methods for remote delivery of guided exercise programs are required, both to maximise the reach of physical activity promotion initiatives and programs across the older community and to minimise attrition once people begin to be physically active. One method by which we can increase understanding of the importance of, and compliance with, exercise programs involves the use of fun and engaging videogames. In the following we outline two ways in which we are using games technology in an Australian context.

Keywords. Serious games, videogames, fall prevention, stroke rehabilitation, regional health service delivery

Introduction

The majority of the world's increasingly older adult population requires some form of care due to loss of function following failing health or increasing frailty. The costs associated with this care are steadily increasing. In Australia, more than a quarter of Australian government spending is currently directed to health, age-related pensions and aged care. Without an intervention to curtail the increasing financial impact of aged healthcare, the Australian government spending on these areas is projected to increase significantly, pushing total spending to almost half by 2049-50 [1].

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

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such as a stroke or a bone-breaking fall [2] 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.

Continued successful independent living is a high priority for older people and those who work with and for them [3]. Therefore monitoring the physical, cognitive and social markers of health, and comparing them to clinical models, enables us to draw conclusions about the current physical, cognitive and social health of the individual and their capacity to remain living independently. However, assessment of these variables usually depends on labour intensive and obtrusive manual assessment by clinical professionals that require the individual to travel to a central clinic or hospital facility. In remote and rural communities, especially in a country like Australia, the distance, inconvenience and expense of travel often make routine assessment of health very difficult. There is therefore a pressing need to develop automated or semi-automated measures of health status that can be gathered from peoples' home environments, especially for those living in regional, rural or remote Australia.

Daily, weekly or monthly home-based monitoring of health provides the ability to detect and act upon changes in these markers of health should they deviate significantly from an individual's history or accepted clinical models of good health [4]. Telehealth (or telemedicine) technology, which combines digital data acquisition, information and communication technologies and the internet to monitor health status in the home, has proven successful for acquiring accurate, reliable and time critical health marker data [5], reducing healthcare costs [6], empowering patients and promoting disease self-management with resultant improved health care outcomes [7]. Furthermore, a systematic review of studies on telemonitoring of patients with congestive heart failure concluded, "patients were living longer without increasing their use of health-care facilities" [8]. For individuals who may be isolated, either by distance in regional, rural or remote Australia, or functional impairment following neurological damage or disease, broadband-enabled telehealth technologies will also be critical for researchers to fully understand the progression of disease course, or the effectiveness of intervention strategies, over the long term [9].

While telehealth technologies can provide opportunities to significantly alleviate the burden of healthcare and facilitate continued independence of the elderly, implementation of technology also faces barriers related to acceptance and use by older adults, their family and clinical support networks. Barriers may include lack of awareness of available technologies, problems in use of technology amongst older adults, lack of financial incentive/capacity to use or invest in technology, lack of adequate training or support, lack of consensus on the value of the technology, cultural obstacles and absence of adequate technology infrastructure [10]. To overcome these barriers it is important for designers of telehealth technologies to work closely with older adults throughout the design and development process in order to learn how their preferences, attitudes and capabilities relate to technology adoption and how products and services can be designed to promote their widespread and long-term use [11, 12].

The dominant information and communication technology already adopted widely by older adults is the ubiquitous home television set. With the advent of digital television, apart from delivering news, information and entertainment, the television will soon also become the technology platform for delivery of health services to the homes of older adults [13]. In the work presented in this paper we extend this concept and consider ways in which devices that connect to the television, namely interactive videogame technologies, can be leveraged as a telehealth technology. Consumer driven forces for new ways to interact with videogames have led to development of sophisticated video capture and inertial sensing devices for measuring movement of the human body. Until recently, such technology could only be found in expensive and dedicated laboratory facilities. For example, devices such as the Microsoft Xbox Kinect are now at a price point (ca. AUD$200) that it is possible to deploy relatively inexpensively motion capture and feedback technologies directly into the homes of people for use in exercise interventions. In the following we describe ways in which videogames have been used to address two health issues that significantly impact upon the continued independence of older adults: injury and disability resulting from falls and stroke, the risk for both of which are known to be significantly ameliorated by engaging older adults in sufficient levels of physical activity (PA).

The work we describe in the following describes how we have developed videogame technologies to deliver exercise and rehabilitation interventions into the home.

1. Fall risk reduction and monitoring by step training "dance" games

Falls are very common in older people [14] 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 [15, 16], may lead to reduced capabilities for taking proactive and reactive steps in order to maintain balance [17, 18]. 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% [19]. However, despite clear evidence demonstrating benefits of exercise for reducing fall risk, uptake and adherence to exercise programs in fall prevention is often disappointing [20,21]. 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 that target fall risk could be improved involves the use of games that promote high doses of weight transfer and stepping. 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 [22, 23]. Providing exergame technology to older people for home-based training could increase compliance to effective programs, potentially benefiting more people. Through funding from the Australian National Health and Medical Research Council (grants 510385, 568724) author Smith and colleagues modified and evaluated an open source version of a popular step-based exergame (StepMania; www.stepmania.com) and developed an internet connected PC system for delivering an in-home fall prevention exercise intervention [24]. Parameters of game play (speed, colour, drift rate etc of game elements) were informed by an iterative process of design and testing involving collaboration between research staff, technologists and older adults themselves such that the final exercise game delivered was appropriate for the physical, sensory and cognitive abilities of an older population [25].

The system (Figure 1) was designed to measure fall risk as well as deliver exercise-based intervention into the homes of older adults. Several stepping tests exist that discriminate between fallers and non-fallers with limited evidence that cognitive load is needed [26]. 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 and to predict falls in older people, mediated via physiological and cognitive pathways. We therefore developed and validated dance mat-based applications for measuring the physical and cognitive abilities involved in stepping performance [27, 28]. Parameters of physical and cognitive function measured by these applications in the home can then be tracked over time by a remote clinician and decisions made about the ongoing fall risk of the older adult.

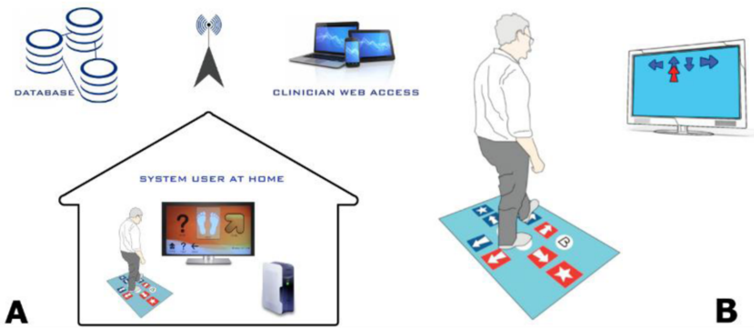

Figure 1. Schematic of main components of the telehealth step training system including sensor mat paired with low-cost PC connected to TV (A). Representation of the modified step training game (B).

The system has been successfully deployed across a number of randomized controlled trials for delivery of a fall risk reduction program into the home. Schone and colleagues [29] installed the system in the homes of 18 older adults residing in independent-living units of a retirement village in Sydney. The intervention recommended that participants engage in 2-3 sessions of dance game activity per week for 10-15 minutes per session for eight weeks. In addition participants were asked to complete a test of stepping reaction time once each week. Usual care control group participants received education material about fall risk reduction and engage in normal activities for the eight weeks. Participants in the intervention group played a median of 2.75 sessions/week and compared to the control group, significantly improved on their stepping reaction times, a standardized physiological measure of fall risk as well as performance improvements in a timed up and go test involving cognitive demand. In a larger randomized controlled trial (N=90, 47 in intervention group) conducted in community-dwelling older adults we extended the range of exercise-based games that could be delivered through the system. These games (Figure 2) include more complex cognitive challenges where tasks required participants to divide their attention, inhibit responses to irrelevant stimuli, switch between tasks, rotate objects and make speeded decisions [30]. Compared to the CG, the IG improved significantly in measures of processing speed, visuo-spatial ability and concern about falling.

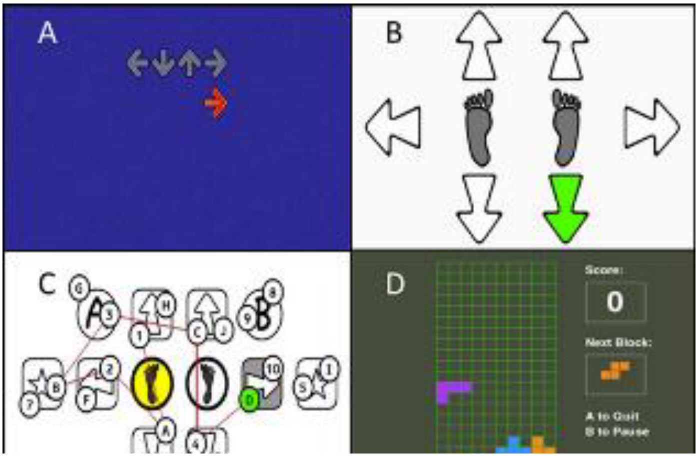

Figure 2. Screen shots of game screens, A. Step training game, B stepping reaction time, cognitive trail making task, D modified version of Tetris. Image from [30] is licensed under Creative Commons.

2. Game-based system for neurological and musculoskeletal rehabilitation

In addition to fall risk reduction, our group is exploring the application of game-based systems for rehabilitation of motor function in older adults. Every year more than 60,000 Australians have a stroke, making it the second largest cause of disability in Australia. More than half of those who survive a stroke require help with normal daily activities. The cost of strokes to the Australian economy is in excess of $2 billion per annum. More than eighty percent of individuals who have suffered a stroke have an initial deficit in limb function and while there is as yet no cure for stroke, there is clear evidence that early rehabilitation after stroke is highly effective. However, delivery of rehabilitation comes with challenges; many patients, particularly those living in regional, rural and remote Australia, find it difficult to access rehabilitation services and those who do don't always comply with treatment. Observational studies in different countries have found that rehabilitation unit inpatients are surprisingly inactive for the vast majority of the waking day. For example, Bernhardt and colleagues have found that 13% of stroke unit patients' day was spent in activities related to functional outcome such as active therapy or walking practice [31].

It is unlikely that rehabilitation units can substantially increase the dose of repetitive exercise within current staffing levels and treatment approaches. Health care resources are limited and as rehabilitation staff costs are already over $700,000,000 annually in NSW alone it is unlikely that substantially more resources (i.e., therapy staff) could be allocated to rehabilitation services. As with fall prevention training in older adults, two factors limiting rehabilitation outcomes are: a) poor patient compliance [32] exacerbated by the repetitive and unstimulating nature of most rehabilitation exercises; and b) restricted access to services due to either a lack of local facilities and staff, or a lack of transportation [33]. To address these challenges we are currently exploring the use of a tailored rehabilitation solution (Jintronix™) that makes use of the motion capture capabilities of the Microsoft Kinect camera to 'gamify' rehabilitation exercise [34].

Figure 3. Screen shots of game screen in the Jintronix rehabilitation system. In this case a weight transfer game involving a right kick of a virtual soccer ball Note elements of gamification such as stars representing feedback for the task as well as progress bar (top left).

Jintronix, a Montreal-based company, has recently launched a Kinect-based rehabilitation system, Jintronix Rehabilitation System (JRS), which provides an easy-to-use software solution for patients to use. The software solution has been designed in collaboration with physical and occupational therapists and draws upon the motor relearning recommendations by Carr and Shepard [36]. As such, upper limb, sitting balance, standing balance and stepping rehabilitation tasks have been programmed in the JRS as fun and engaging video games that can be played at a number of different levels of complexity and speed (Figure 3). The system is also capable of automatically measuring changes in the range, speed and quality of motion to give patients instant feedback on their progress. A second feature of the JRS is a cloud-based client management telehealth system for clinicians to recommend rehabilitation tasks and track and record performance of those tasks (JRS Portal). The Portal allows clinicians to provide patients regular updates and information on what has happened to them with daily, weekly or monthly progress reports on their rehabilitation, either face-to-face or remotely (Figure 4).

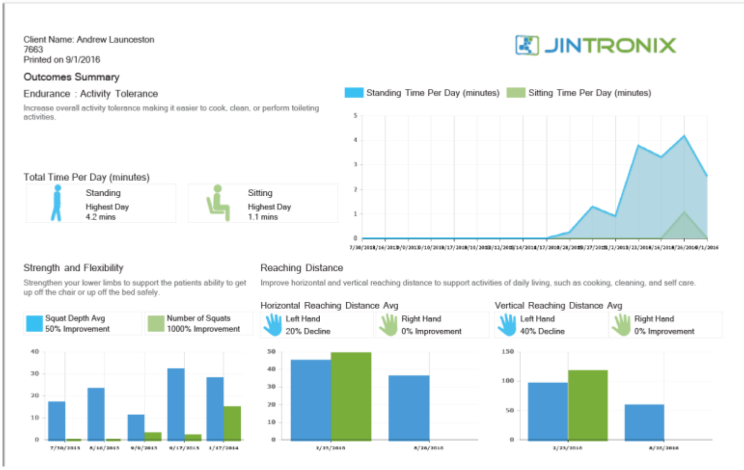

Figure 4. Screen shots of patient summary data for use of Jintronix system. Enables clinicians to get a quick snapshot of patient engagement in activities and current level of function

3. Serious Games for (tele)Health.

Despite the widespread, possibly skeptical, perspective that games can only ever be an indulgent leisure time activity, games are considered ”serious” when they are developed and used in sectors such as education, defense, emergency planning, politics, engineering, urban planning, manufacturing and service delivery. Games also offer the potential to disrupt healthcare delivery. For example, current rehabilitation practice (e.g. following stroke) involves a period of intense, guided rehabilitation during the early stages of recovery, often in an acute hospital setting. Patients are then gradually discharged back into the community, with limited funded ongoing support through transition care programs, to lead the remainder of their lives functionally impaired to various degrees. Often patients are discharged from rehabilitation with sheets of printed instructions for the kinds of exercises they should engage in to aid their recovery of physical, psychological, emotional and social function. For patients returning to regional, rural or remote Australia, the paucity of access to rehabilitation services is particularly distressing.

Imagine instead a world where the person recovering from a stroke is sent home from hospital with a videogame console, pre-loaded with a suite of engaging, informative games to engage them in their rehabilitation program. As they engage in rehab gameplay, their centrally located rehabilitation specialist can monitor performance and adjust challenge posed by the games, ensuring that progress of rehabilitation is guided, informed and encouraging. Furthermore, for the patient who may have formed close social bonds with others on the rehabilitation ward in hospital, they now have the opportunity to “play” against each other irrespective of the physical and functional distance that may separate them. The possibilities for games in telehealth are enormous.

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