Driving Reform: Digital Health is Everyone's Business
A. Georgiou et al. (Eds.)

doi:10.3233/978-1-61499-558-6-43

StepKinnection: A Fall Prevention Game Mindfully Designed for the Elderly

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Abstract. This paper presents the StepKinnection game, a Kinect-driven stepping game for the elderly that delivers stepping exercises to train specific cognitive and physical abilities associated with falls. This system combines a set of suitable age-related features, meaningful exercise routines and an embedded clinical test for fall risk assessment. The combination of these three aspects makes the game potentially useful in practice as the game is appealing to the elderly cohort, trains one of the most important abilities to prevent falls and at the same time allows for a continuous assessment of health outcomes; characteristics not available in the literature nor in current commercial games.

Keywords. Kinect, elderly, fall prevention, stepping game, user-centered design, natural interaction, embedded clinical assessment

Introduction

Falls are the main cause of injury and death in the elderly [1]. Recent studies show that 30% of the population aged 65+ experiences at least one fall every year [2]. In most cases, an individual might suffer numerous physical injuries such as bruises, cuts, sprains, fractures and even a traumatic brain injury. The latter often requires hospitalisation and may result in death for 13% of the cases [3].

Physical activity and structured exercise have been shown to be to most effective strategy to reduce the risk of falling among the elderly [4]. Programs targeting the lower limbs have been demonstrated to improve several dimensions associated with falling such as gait speed and balance coordination [4].

The use of exergames has become a popular approach to engage the elderly in physical activity. A common drive due to the entertainment factor inherent in video games, which increases levels of motivation and enjoyment. However, recent studies have also shown that commercial games, which were originally designed for much younger audiences, might not always be perceived as enjoyable nor beneficial by the aged [5]. One of the main reasons is the usability deficiencies of these games to address the inherent needs of the aged that relates to deteriorations in the human body [6].

In a prior study [7], the authors found a set of hidden usability problems in four commercial balance games which could put an aged player at risk as these games do not accommodate their special needs. For example, a disconnect between what is on the screen and what the user is actually doing, may cause confusion for the player, resulting in feelings of anxiety and frustration while also affecting their balance reflex and mental satisfaction. These findings were crucial to identify key design aspects to suit the needs and preferences of the aged cohort. Later in [8], the authors explored the

use of game technology to reliably perform a clinical test for fall risk assessment. The findings showed that the Kinect [9], an off-the-shelf motion sensing input device, was able to reliably compute a time-based clinical test to assess stepping performance in the elderly.

In this paper, the author now presents a Kinect-based video game that delivers stepping exercises for the elderly. This system explores the combination of: (1) appropriate age-related features; (2) exercise routines aligned to the problem of falling in the elderly; and (3) time-based clinical test that has shown to reliably discriminate between fallers and non-fallers. Characteristics not available in current commercial games.

The remainder of the paper is structured as follows. Section 1 presents a brief summary of related work in the field of games for fall prevention and rehabilitation. In Section 2, the methodology of this study is presented. Section 3 describes the design process and the aspects considered for both clinical assessment and suitability for elder users. Finally, the discussion and conclusions can be found in Sections 4 and 5.

1. Related Work

In the area of fall prevention and safety for the elderly, the use of exergames has shown positive results. An example can be seen in the work done by Kim et al. [10], where the use of a commercial Kinect game showed improvements on hip muscle strength and balance control in older adults after completing an 8-weeks intervention.

In the work done by Yeung et al. [11], a Kinect-based system was used to assess body sway in the elderly. In this system, a person is asked to face a camera-based sensor and stand as still as possible for a certain period of time. Through the collection of spatial data, the amount of displacement in relation to the centre of mass is then calculated and used for diagnosis. Although this system tackles an important risk factor for falling in the elderly, this approach lacks the fun component that engages users to interact with these systems. Uzor et al. [12] developed a series of mini games with the purpose of rehabilitating older adults after experiencing a fall. The main input device used in this system is a pair of inertial sensors that are attached to the player's lower limbs in order to capture leg movements. Each mini game (or task) aims to train a specific function associated with the recovery of muscle strength and power. Exercises range from sit-to-stand and back-to-sit movements, to side steps while holding onto a chair for support. While this system addresses effective strategies to rehabilitate a person after falling, the potential of using the technology to assess the effectiveness of the intervention may not be fully exploited. Although game scores may give a good indication of improvement, these cannot determine progress and the achievement of the expected health outcomes in a reliable manner. In the work done by Schoene et al., [13] a flat dance mat was used to deliver stepping exercises in the form of a dancing game. Its main purpose was to provide a tool to exercise the stepping abilities of older adults. Unlike the commercial game, this version has been adapted to a range of stepping speeds including slow responses. Also, this system allows for the collection of stepping performance data that can potentially predict falls in the elderly. However, while this system trains an important strategy for preventing falls, the mat itself could potentially expose the older person to an increased risk of falling.

In this paper, we describe a Kinect-based video game that delivers stepping exercises for the elderly. This system includes: (1) an appropriate game design

achieved through the use of user-centered design methodologies; (2) three stepping routines that train the ability to take quick reactive steps and avoid obstacles; and (3) a hybrid version of the Choice Stepping Reaction Time (CSRT) task as a clinical assessment instrument [14], a test that has shown to reliably predict falls in older adults.

These aspects make this game potentially useful as an effective tool to reduce the risk of falling in older people as: (1) it was purposely designed for the appeal and needs of the aged cohort; (2) it trains specific physical and cognitive functions associated with falls; and (3) it allows for a continuous assessment of their health outcomes in order to evaluate their progression. None of these characteristics are available in current commercial games.

The following section sets out the methodology used for conceiving this system and the most relevant aspects that were considered through the design process.

2. Building the Game

In order to gather the requirements for the development of this game, a literature review was conducted on the following topics: (1) clinically proven strategies to prevent falls in the elderly; (2) design guidelines for developing entertainment systems for the aged cohort; and (3) validated performance-based tests for falls risk assessment in older people. Based on this review, the following design criteria was developed:

1. The system needs to include appropriate age-related features in order to suit the age-related changes that affect the playability and enjoyment of such games [6]. Also, it should promote a natural interaction as this enhances the operability and engagement with the system.

   Subsequently, the Kinect was selected as the main input device as it facilitates the interaction with the game as no remote controllers are used. This is ideal for the elderly as minimal computer literacy is required. Also, guidelines for developing video games for the elderly where taken into account throughout the design process and several focus groups were conducted to assess the usability of the system.
2. The game should promote physical exercises targeting lower limbs as muscle strength and power are important factors in the risk of falling in the elderly [3]. Exercises should have direct alignment to the specific health outcomes in order to train specific functions associated with the problems of falling in the elderly.

   For that reason, stepping routines with and without a motor inhibition component were incorporated as this ability has been shown to be one of the most effective strategies to prevent a fall from happening [15]. By taking a proactive or reactive step a person can increase their base of support and subsequently regain balance [16].
3. The system should allow the automated identification of health improvements through the incorporation of a clinical test for fall risk assessment [8].

   Then, the Choice Stepping Reaction Time task (CSRT) was selected as a prior study showed that this test it is feasible to measure with the Kinect and is also suitable for translation into a videogame [17]. More importantly, this test has been validated in more detail in older populations including large prospective cohort studies with falls follow-up [18].

3. The StepKinnection Game

The description of the Kinect-based system is described as follows: In this game, the player is an explorer who travels around the globe visiting colorful countries, hunting for treasures and seeking different adventures. Each country presents a challenge where the player gets to experience their traditional music and collect exotic fruits. Completing each challenge takes the player one step closer to winning a trophy. However, the further they travel the more difficult the tasks become. Game play starts with a series of basic levels where players will have the chance to become familiar with the game and coordinate their movements accordingly. Once they have finished these levels, players can move up to more challenging ones related to speed, precision and cognitive complexity.

Figure 1. Short caption Interacting with the Game.

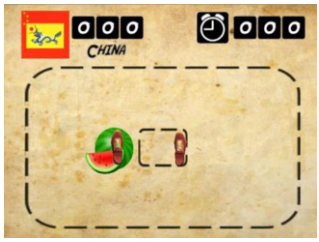

Figure 2. The player collects the fruits by stepping on them.

Figure 3. Training Motor Inhibition.

In order to play the game, the player needs to stand in front of the TV facing the Kinect. Shortly after, the main menu will be presented (Figure 1), where players can select from a list of counties to visit. The player can wave either hand to move the cursor to navigate the menu. Once the level is selected the user moves to the main stepping task.

3.1. Training Stepping

Throughout the game, fruits will appear on the screen every now and then, and the player is expected to collect them. In order to achieve this, the player needs to reach the fruits by stepping on them (Figure 2). As the user moves through the levels, the speed of the appearance and the size of the fruits decrease. This is to encourage players to perform quicker and more accurate steps (i.e., increase in skill) as they advance to higher levels. This task reinforces the ability to take proactive steps that could help an individual to regain balance and avoid falls [19]. Also, as the stepping area decreases, the user needs to be more coordinated to be able to step on the fruits.

3.2. Training Motor Inhibition

In the mid-levels, a lady bug might randomly appear on the screen (Figure 3). Stepping on the lady bug will take two (2) penalty points off their current score reducing their chances of winning. However, if the player remains in position, one (1) point will be awarded.

This motor inhibition task is incorporated with the purpose of adding varied difficulty to the game by slightly increasing its cognitive demand. According to [20], adequate motor inhibition plays an important role in avoiding falls. Training this ability is therefore ideal for situations where avoiding an obstacle can prevent a fall from occurring.

3.3. Training the Ability to Take Quick Reactive Steps

In the higher levels, dollar coins will randomly appear on the screen for a split-second of time. These coins are bonus points that can help players to move faster in the game, with the purpose of encouraging them to step faster. For each dollar coin that they collect, two (2) bonus points will be added to their current score to reward the player. This feature trains the ability to respond quickly to a hazardous situation [19]. This training feature is ideal for circumstances where the person has initiated a step but the environment suddenly changes.

For all the above stepping tasks in the game, the accuracy of the responses is automatically processed by the hybrid clinical test for fall risk assessment that is embedded in the game [8].

4. Discussion

Physiotherapy is moving towards using more portable and practical devices in order to achieve better diagnosis and treatment [21]. The StepKinnection games aims to fill the existing gap in the area of fall prevention through the combination of playful routines, meaningful tasks and the ongoing assessment of health outcomes, aspects that commercial games do not address. A set of stepping exercises available in the literature were found to be easily adapted and translated into this application. Additionally, this game has the potential to provide the physiotherapist with current and historical data of the patient's performance to enable practitioners make informed decisions on the patient's treatment. More importantly, the StepKinnection game has the potential to be used as a cost-effective and portable fall prevention tool that could increase compliance to physical exercises through the fun factor and engagement inherent to video games. Nevertheless, further research is still required to determine whether the system is suitable for clinical practice.

5. Conclusions and Future Work

This paper describes the development of StepKinnection, a Kinect-based video game that delivers a range of step training exercises that aim to prevent the risk of falling in older people. The game-based system builds the Kinect features to allow continuous real time tracking and provisioning of feedback. This is ideal for players with no computer literacy as no game controllers or wearable devices are required to interact with the game. This system not only combines a set of appropriate age-related features with a series of meaningful tasks, but also allows for the collection of clinical data in order to assess progression and the achievement of health outcomes in a reliable manner. This implementation has the potential to be used as a means to provide home-

based therapy with increasing levels of motivation and adherence to physical exercise. The continuation of this work includes the development and integration of a cloud-based system where user's performance information can be stored, automatically analised and accessed remotely. This cloud-based feature aims to help to close the gap between practitioners and patients. The next stage of this study will involve a series of studies in which the feasibility and responsiveness of the system will be evaluated.

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