NEONEO Balance Ball: Designing an Intergenerational Interaction Exergame for In-home Balance Training

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Abstract. This paper describes a tangible interactive prototype, aiming at reducing the risk of falling in older adults and ensure their adherence to the in-home balance training. The design of the prototype derived from our research on the effectiveness of different training modes in balance. An exergame created for this prototype, appealing to youngsters, might result in them (older adults and young people) playing together. This may not only provide motivation to exercise but also a platform increasing communication between two generations, which is beneficial to older adults' mental health. Therefore, perceiving benefits aforementioned, older adults could get more interested and even develop a long-term habit of playing such exergame. Researches had been done regarding the older adults' perspective when designing intergenerational games or exergames. Here, our concept focuses on involving both older adults and young people to play the exergame together. In this paper, an experimental plan has been designed to gain insights from young people for better solutions to motivate them to play the game with older adults.

Keywords: Balance training · Older adults · Tangible serious game · Intergenerational interaction

1 Introduction

Aging is associated with the decline in mobility and balance, rising the rate of falling in older adults, causing huge threats to their functional independence and health [1]. Falling is the most common injuries to elderlies which will bring burden on medical care, family, or society level [2]. Many population-based studies showed that every third senior (over 65) falls once a year and half of those are recurrent fallers [3]. Previous studies revealed that the proper training with the focus on balance could reduce the risk of falls [4]. The in-home Otago Exercise Program has seen a 35% reduction in falls rates and injurious falls [2]. In addition, the in-home exercise program is important as it's cost-effective and many older adults are reluctant to or unable to attend group exercise classes [5]. Therefore, in-home balance training plays an important role in reducing the rates of falling in society. However, evidence suggests that there is a problem with the adherence to rehabilitation at home [6]. This means that many fallers do not fulfill the recommended

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amount of exercise per week and the benefits of exercise will disappear when exercise is halted [7]. Low confidence to the exercise program can result in the decline of interest [8]. There are also other factors influencing adherence such as motivation and nature of the exercise program [9, 10]. Although there are still debates concerned with the factors contributing to the low adherence in-home training, previous studies revealed the increments in interests and adherence in functional training with the use of exergames.

This paper presents a novel design of an exergame and an experimental design on the prototype. Our concept is to motivate older adults' training by adding appealing features to our exergame that older adults can keep up training for a long duration. Social interaction in the game attracts players and they play for a long time due to the social connectedness of such games [11]. Some studies revealed that intergenerational communication of the game can be an attraction for older adults [12, 13]. Older adults can be motivated more when they play exergame with young people [14]. The participants will be recruited from the university. Our preliminary test will be taken from the youth's perspective because as an important part of our concept, their interests and ideas to the scenario are crucial in designing an exergame that they will play willingly and really have conversations with older adults. So, our aim in this experiment is to get an insight into a scenario that can motivate young people to join in.

2 Related Work

Related work in exergames and intergenerational communication game was really inspiring while carrying out our project.

2.1 Balance Training Exergame for Older Adults

Uzor et al. [15]studied the effects of long-term involvement in exergames compared with the traditional training, and found promising outcomes in motivating training at home with long duration. Donker et al. [16] showed with the interactive tiles for balance training, that real time visual feedback improved the motivation on balance rehabilitation, and also suggested personalization to individual patient training needs.

While focusing on the aspects that could attract elderlies' adherence, the effectiveness of the exergame shouldn't be neglected. Morat et al. [17] highlighted the importance of unstable surface in balance training that requires motor skills relevant to preventing falls.

2.2 Intergenerational Communication Game

Playing multiplayer mode (cooperative or competitive) with partners enhances game enjoyment compared to playing alone [18], and people are more likely to play the social games for a long duration[11]. Both old and young generations think highly of the social game, while younger adults unanimously shared the intention to play more with the older adults in their families [19–23]. Pecchioni et al. [24] argued that playing video games together can be a platform for the expansion of family relationships. Promising results have been seen in co-located exergame playing between grandparent and grandchild [25]. Fuchsberger et al. [12] showed a novel online-intergenerational game for geographically separated grandparent and grandchild.

3 Prototype

The prototype has been implemented to be qualified for our preliminary test. During our implementation, fast iteration was very helpful in putting on a better solution for the prototype. In total, there were two generations of our hardware and many adjustments to the game.

3.1 Design Concept

The NEONEO Balance Ball was designed to motivate older adults to train their balance for a long duration. According to the researches mentioned above, two factors may help us achieve our goals: gamification and intergenerational interaction. Participants would be asked to talk out their feelings about the exergame and scenarios we designed.

User Needs. Older adults need an easily comprehensive system, while their interests in the game are important that they would be willing to learn to play the game despite some barriers in the way [12]. However, youth would get upset sometimes when older adults keep asking questions [26]. Therefore, both of theirs need should be considered during the design and the trade-off be met after our research.

Attributes. Based on the reasons mentioned above, our design should acquire the following features. By doing this research, we want to know how we can better integrate these features into our design.

Unstable Surface. Improvement in balance is very important, and unstable surface is proven to be effective while balance training [17].

Gamification. This game should provide interesting gaming experience that attract both generations.

In-home Usage. Our equipment should be space-efficient and suitable for older adults to use at home.

Easily Comprehensive. There should be a trade-off between comprehensions and attractions concerning both generations. and that's what we need to find out during our research.

Intergenerational Communication. Our exergame should be able to provide chances for two generations (old and young) to communicate.

Use Scenario. It is usually the case in China that three consecutive generations living together in the same household [27]. Therefore, our first scenario presents old and young playing together in the living room. In addition, elderlies can choose to play with their offspring (geographically separated) or other young people through the internet. There'll be two kinds of multiplayer modes (cooperative and competitive). While motor ability and cognitive competence will be considered in game design to narrow the performance gap in competitive mode, the different tasks will be given in cooperative mode that two generations both make their own contributions to the team goal. Figure 1. Presents competitive mode in living room scenario.

Fig. 1. Competitive mode in one physical space.

3.2 Implementation

When reading articles in this field, we encountered a prototype (ActivBOSU) presented by Caltenco et al. [28], having one feature we desired (unstable surface). However, there were problems mentioned in their preliminary test that players found it frustrating to look down for the visual feedback. Therefore, we made some changes to the original design, making it a readily comprehensive exergame with visual feedbacks of their tilt angles on the gaming screen and the scores reflecting their performances. USB cable was removed because we used portable battery to supply power and blue-tooth to transmit signals. In addition, by providing the feedbacks at eye-level which is important in balance training[16] and increasing the stability of the surface, we removed the safety support handlebar to simplify the equipment and made it more space-efficient and suitable for elderly's using at home.

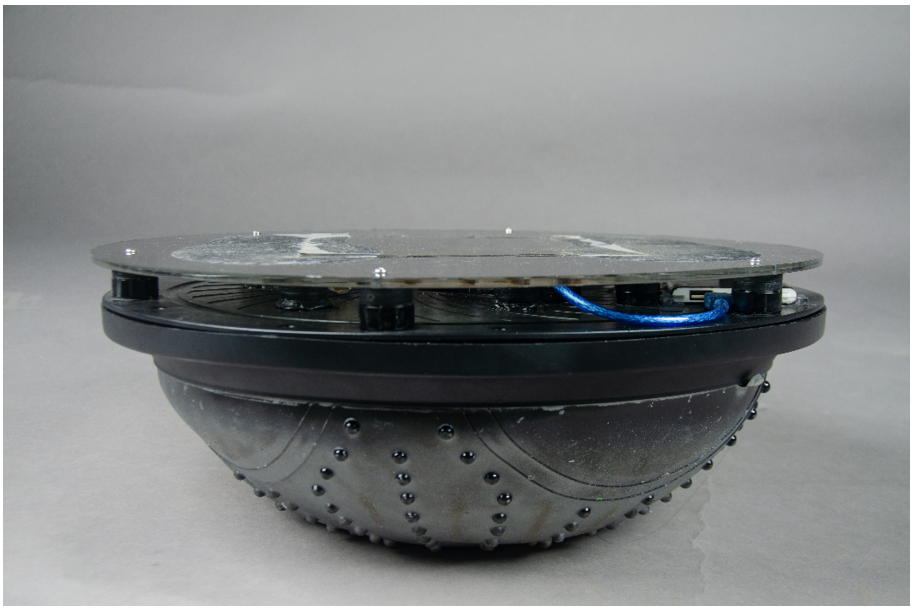
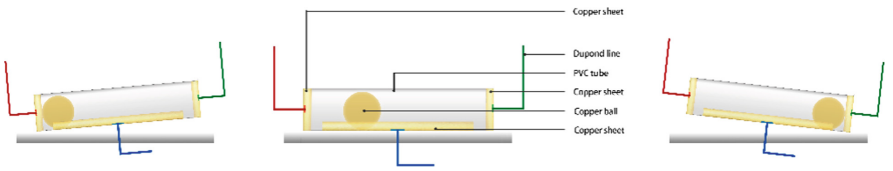


Fig. 2. NEONEO Balance Ball Prototype 1.

Iteration 1. The first generation was made quickly equipped with the sensor designed and made by our team Fig. 2. There's a copper ball inside of the PVC tube, rolling to the side according to the tilt direction of the tube, and it will send signals when it touches either side Fig. 3. The Arduino controller receives and processes these signals, then it can detect the tilt direction of the platform. Figure 4. presents the realization of our sensors placed right-angle with each other to detect two dimensional directions.



(a) Signal to red line (b) No signal (c) Signal to green line

Fig. 3. Mechanism of self-designed sensor.

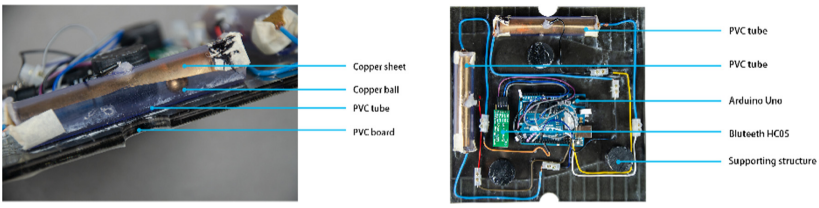


Fig. 4. Self-Designed sensor.

We tested the first prototype by playing the exergame ourselves and found out that without safety handle bars, it's hard to keep balance on the NEONEO 1.0 even after deflating the BOSU ball, which is indicating potential threats to the older adults. After discussions and debates, still resisting the handle bars, we replaced the BOSU ball with four small elastic balls supporting the unstable surface, which might provide enough stabilities. The iteration went well, and the whole exergame system was optimized that it is ready for the preliminary test.

Iteration 2. The final version of our prototypes consists of one acrylic layer (5 mm thick) on the top for players to step on, which is laser cut to roundness ($\Phi = 460$ mm), with foot-shaped non-slip mat indicating the right position for standing Fig. 5.there are four small hemispheroids ($\Phi = 160$ mm, $H = 80$ mm) cross positioned under the acrylic layer. So far, it's much more stable than the traditional BOSU, fitting our design requirements. The digital system consists of an Arduino microcontroller, a blue-tooth device, a gyroscope, and a power-bank Fig. 6. The tilt angle and direction detected by the gyroscope will be sent to the Arduino microcontroller to process, then Arduino will transfer this information to computer games by blue-tooth. Additionally, with a self-carried portable battery supplying power, there is no need for wires to connect the digital system with computers. We managed to get rid of wires due to our attempt to

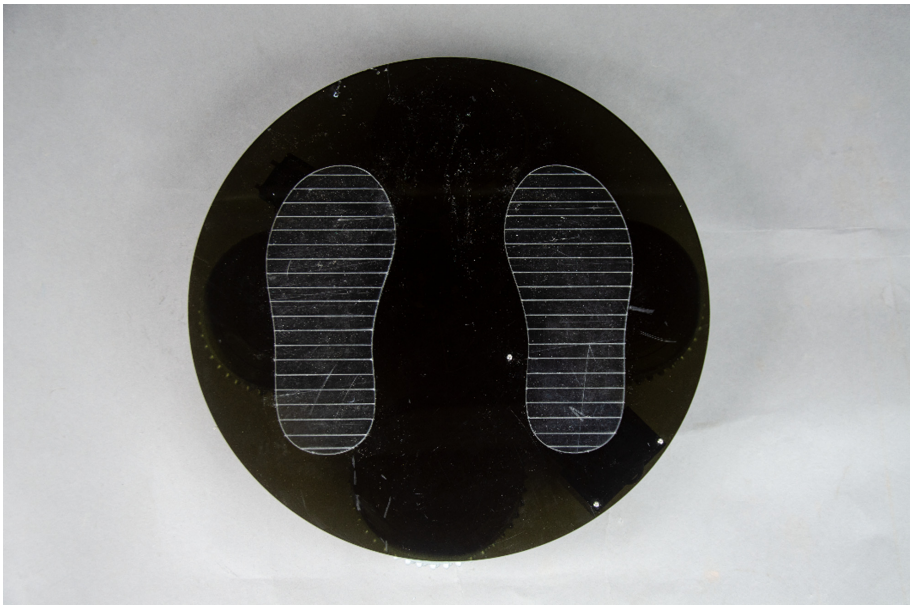


Fig. 5. NEONEO balance ball prototype 2.

meet the required features we made earlier, the same as the reason for discarding safety handlebars, that our training equipment should be easy-to-use and convenient in the home environment.

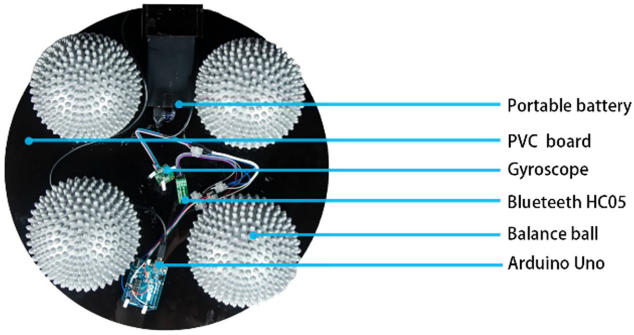


Fig. 6. The structure of the NEONEO Balance Ball

Older adults, putting their feet at the suggested position, which is two pieces of foot-shaped non-slip mat, could control the game character on the screen by changing the dip direction and angle of the board Fig. 7. The game character can move both horizontally and vertically, depending on the tilt direction of the board. And players could speed up the game character by creating a large angle, vice versa (small angle means slow movement).

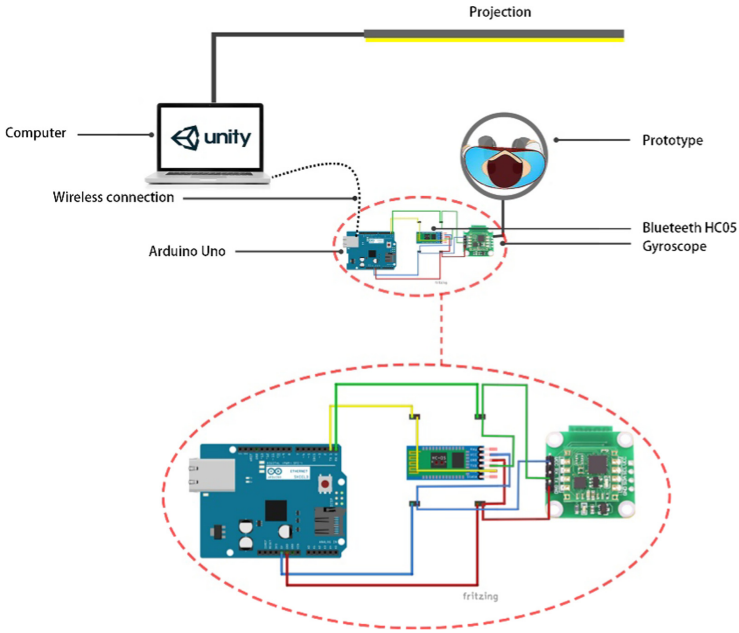


Fig. 7. System overview.

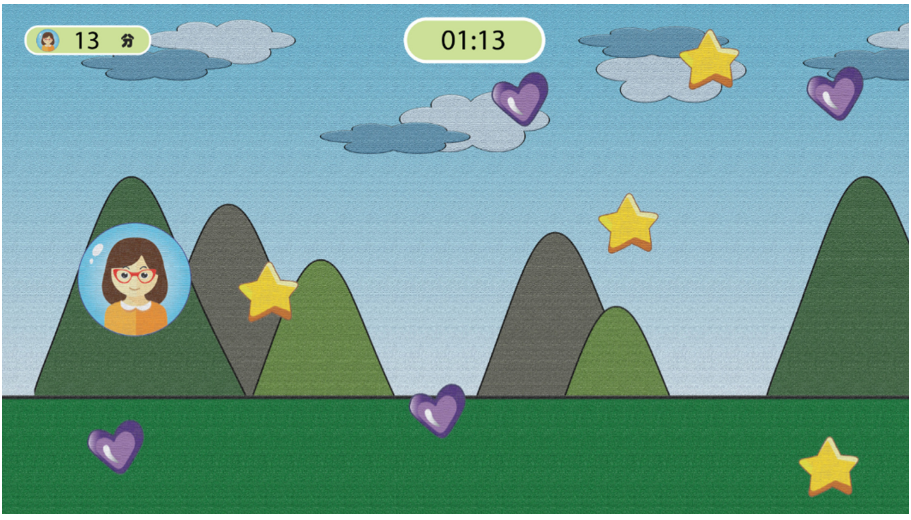


Fig. 8. User interface.

we minimized the UI elements in the game to prevent the frustration caused by overwhelming information, allowing the players to focus on one main task [10]. A screenshot of the game GUI with one player mode can be seen in Fig. 8. The objective of the game is to collect yellow stars, which are randomly positioned vertical, drifting

from right to left. Besides collecting stars, players also need to avoid purple heart-shaped icons which minus the points. In the experimental design for this paper, young adults will be playing this one player mode.

4 Experimental Design

In our plan, we will conduct the user experiments in two stages. In the first stage, we design an experimental plan to test the usability of the prototype, focusing on the perspective of young people. In the second stage, we will come up with a solution that two generations can play together for a long duration. We will recruit both older adults and young people to evaluate social interactions between them.

4.1 Participants

In the primary test, we will recruit 20 university students (10 female and 10 male) with the age from 18–25. Recruitments will be hold on the website: https://tongqu.sjtu.edu.cn/ and WeChat. The experiment will take around 40 min and each participant will be reward 40 RMB.

4.2 Setup

The experiment will be conducted in NEO Bay at Shanghai Jiao Tong University. Figure 9. shows the experimental setup which contains all the components with distances and scales. Participants will stand on the NEONEO Balance Ball, 2 m away from the screen, can ask for help from the assistant sitting in front of the computer. And this assistant will also go through the game menu for participants.

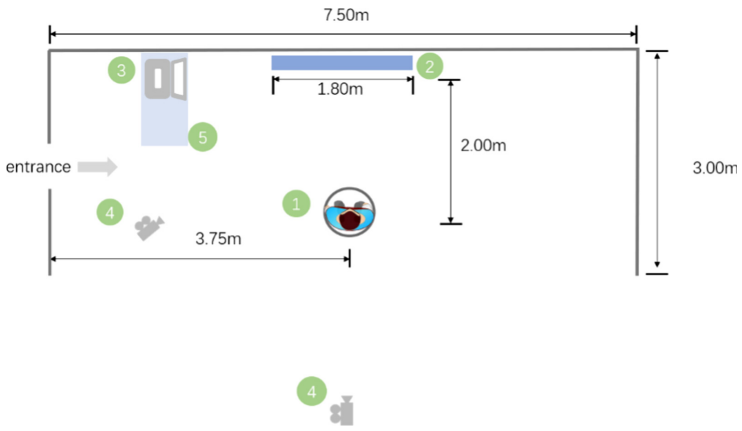


Fig. 9. Experimental setup: (1) the participant standing on NEONEO Balance Ball; (2) screen; (3) computer; (4) camera; (5) table.

4.3 Measurement

We will use subjective questionnaires to measure the usability of the system and the feelings change of the participants after playing the game. Pretest posttest design will be deployed in this experiment using the Positive and Negative Affects Schedule (PANAS)[29] to evaluate and compare participants' affects before and after playing the game. The questionnaire consists of 10 items with five-point Likert-type scale (from not at all true to very true).

Before pretest PANAS questionnaire, demographic information will be collected along with open questions about participant's former experience of gaming, entertainment, and exercise. Example items are "What games have you played sbefore?" "Have you had joint entertainment with older adults?" "What stop you from exercising?".

After posttest PANAS questionnaire, the participant will fill out the Post-Study System Usability Questionnaire (PSSUQ) [30], giving an overall evaluation of the system with seven-point Likert-type scale. The questionnaire consists of 19 items categorized into three subscales: system usefulness (SYSUSE), information quality (INFOQUAL), and interface quality (INTERQUAL). There will be open-questions to the participant about his/her perceptions to play the exergame and communicate with elderlies. Thirteen questions will be asked from three aspects: game experience, kinaesthesis, and social presence, such as "How do you think we can improve this game?" "How does gamification affect your exercise?" "How do you think of intergenerational exergame?".

Qualitative data will be collected from the semi-structured interviews and analyzed by thematic analysis [31]. Some of the interesting items from open-questions will be asked during the eventual semi-structured interview, supplemented with the participant talking freely about their perceptions to our topics. All interviews will be conducted and recorded in Chinese.

4.4 Procedure

First, the participant will read and sign the informed consent form before a pre-test questionnaire using PANAS. Then the researcher will start the game and go through the menu for the participant when he or she is standing on the NEONEO Balance Ball and ready to play. Each participant will be asked to play five minutes before getting scores of the performance. After that, there will be a post-test questionnaire containing PANAS for the evaluation of emotion, PSSUQ on system usability, and open-questions. At last, the semi-structured interview will be conducted to get more insights into the evaluation. Table.1 illustrates the experimental procedure.

Table 1. Experimental procedure.

Experimental Procedures		User Tasks
Before Experiment (10 min)	Signing the informed consent	The participants will fill in the informed consent form, understand the experimental procedure, experimental content and confidentiality agreement, and sign the informed consent forms
	Filling in the pre-test questionnaire	The participants will fill in the paper version of the pre-experimental questionnaire (i.e., demographic information and the PANAS questionnaire)
In Experiment (15 min)	Standing on the prototype	The participant will stand on the prototype
	Starting the game	The assistant will turn on the game for the participant
	Playing the game	The participant will control the characters in the game through interactive devices
After Experiment (15 min)	Filling in the post-test questionnaire	The participant will fill in the questionnaire after the end of the experiment
	Conducting the interview	The researcher will conduct an interview with open questions
Total: 40 min		

5 Discussion and Conclusion

In this paper, we presented an exergame (featuring intergenerational interaction) aiming at reducing the risk of falling in older adults. We hypothesized that the features of our exergames such as intergenerational interaction and interesting gaming experience could make it possible to provide older adults with a platform to play the exergame for a long-duration which is beneficial to their physical and mental health.

An experimental plan from the perspective of young adults (first stage) was presented. In the future, there will be the second stage experiment involving both generations (old and young) to help us gain insights and better integrate desired features into our design.

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