Health Informatics Meets eHealth
G. Schreier and D. Hayn (Eds.)

doi:10.3233/978-1-61499-858-7-255

Development and Evaluation of Cognitive Games to Promote Health and Wellbeing in Elderly People with Mild Cognitive Impairment

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Abstract. Background: In Europe the number of elderly people is increasing. This population growth has resulted in higher healthcare costs. The purpose of this project was to try to promote active ageing in people aged 65-80 with mild cognitive impairment through cognitive games delivered via a tablet computer. Objectives: Age-appropriate cognitive games were developed targeting different aspects of cognition and then experiences of elderly people using these games were evaluated. Methods: The design of games was developed through iterative user-centered design focus groups with elderly people as participants. The experiences of participants playing the games over a 47 day period were explored through semi-structured interviews. Results: Four games were developed that addressed a range of cognitive functions such as perception, attention, memory, language, comprehension and executive function. The participants were able to play these games without external intervention over an extended period and reported positively on their experiences. Conclusion: Cognitive games can be used successfully by people with mild cognitive impairment to promote active ageing.

Keywords. Psychology, cognition, aging, mobile application, eHealth.

1. Introduction

The World Health Organization has suggested that the proportion of the world's population over 60 years old will nearly double from 12% to 22% between 2015 and 2050 and the number of people aged 60 years and older will outnumber children younger than 5 years [1]. The ageing population of Europe is increasing as well [2]. This demographic shift will pose challenges to the health and social systems in many countries. As individuals age so their healthcare costs increase [3]. The health of elderly people is determined by many components (e.g. mental, physical, interpersonal relationships etc.) and to improve their overall lives active ageing is encouraged [4]. This paper describes the development and implementation of cognitive games for a project designed to enhance the health and wellbeing of elderly people aged 65-80 year with mild cognitive impairment. The DOREMI project [5] (**D**ecrease of c**O**gnitive decline, malnut**R**ition and sed**E**ntariness by elderly empowerment in lifestyle **M**anagement and social **I**nclusion) combined scientists from different disciplines to produce activities targeting

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health and wellbeing in elderly people. The increased costs of health and social care in elderly people can arise from poor nutrition, sedentariness, cognitive decline and social isolation [6]. A lifestyle intervention was delivered by DOREMI on a tablet computer with the aim to encourage active ageing by increasing socialization and physical activity, promoting cognitive function and improving diet [7]. The burden on healthcare systems could then be reduced by encouraging participants to be autonomous with the program delivered by a tablet computer [8]. Participants can be motivated to continue with the program via gamification [9-11] – the use of age-appropriate design elements to increase activity and participation.

This paper describes one element of the DOREMI project [12]: the design, development and implementation of cognitive games for a specific group of elderly people with mild cognitive impairment. Health related games have been produced previously [13] but this project was novel in that individuals with profiles the same as the intended users were involved in the design and development. The theoretical approach of this project was one rooted in that of positive psychology and psychological wellbeing [14] which is to improve individual's lives. In order for people to engage in the task the games had to be designed in a way that was relevant to the participant with an appropriate level of difficulty. Successful implementation would result in participants continuing with the task because of high self-efficacy [15]. Participants would reach a state called "Flow", a term from wellbeing theory [16] where they would be self-motivated and make positive health choices [17].

There has been considerable debate on the effectiveness of computerized cognitive games on producing any change in cognitive function. For example, one systematic review of research with unimpaired elderly adults found that the use of computerized training was more effective than that of traditional paper-and-pencil cognitive training [18]. Other systematic reviews in cognitively healthy adults concluded that the experimental design was important in determining the outcome [19-20]. One of the most recent and extensive reviews on "brain-training" concluded that interventions did improve performance but there was not generalization across cognitive domains [21]. There have been some systematic reviews of training with people either at risk of dementia or elderly adults with mild cognitive impairment [22-23]. These studies suggested there might be moderate positive effects. Overall, many of these papers recommended there should be further research.

There were two main aims to this study: first to design age-appropriate cognitive games through a user-centered design that could be delivered via a tablet computer; and second to explore the experiences of elderly people with of this technology solution after a 47 day period. The preferences of individuals were first investigated through a series of iterative user-centered focus groups. Qualitative data were collected on the experiences of the participants through individual interviews. Our research questions were as follows:- 1. What components of a cognitive game are preferred by elderly adults and how can these people be used to help in the design of cognitive games? 2. What are the experiences of elderly people playing cognitive games on a tablet computer over a 47 day period?

2. Methods

2.1. Development of cognitive games

An iterative user-centered design process was used in three focus groups to develop the cognitive games. Participants had normal cognition or mild cognitive impairment as assessed by the mini mental state examination (MMSE) [24] or the Montreal Cognitive Assessment (MoCA) [25]. In the first focus group there were nine people (5 male; mean age=77.0, SD=7.47; mean MMSE=29.3, SD=1.00). This group found out about the exposure to technology of individuals and ideas for cognitive games. In the second focus group there were five people (1 male; mean age=74.6, SD=5.46; mean MoCA=22.8, SD=1.64). This group tested initial games and received feedback on user experience. There were four people in the third focus group (1 male; mean age=78.5, SD=1.91; mean MoCA=22.0, SD=2.45). This group tested games that had been modified following suggestions from the first group and obtained more participant input. The groups were facilitated by two psychologists with each session lasting 50 to 70 minutes. The recordings were transcribed and analyzed thematically.

2.2. Testing of cognitive games

Following the final development of the cognitive games the experiences of older people playing these games was explored over an extended period. Participants aged 65-80 years old with mild cognitive impairment were recruited to be part of the study. All participants were living alone. There were 25 participants (3 male; mean age=75.0, SD 4.28; mean MoCA 24.2, SD=1.71).

Participants had a training period over 16 days when they received advice on how to use the tablet computer and engagement with the games was recorded remotely. There then followed a period of 47 days during which these participants followed the DOREMI protocol which included playing cognitive games.

2.3. Post-Intervention Participant Interviews

The experiences of participants in the project were explored through individual interviews lasting an average of 35 minutes. The interview schedule was designed to elicit specific and detailed responses. Interviews were transcribed verbatim and analyzed using thematic analysis which allowed for participant common themes to be identified. An inductive approach used so that the identified themes were data driven. Thematic analysis steps were followed as previously detailed [26] involving the reading and re-reading of the transcripts, followed by the generation of codes. Participant responses were then classified according to these codes, after which codes were collapsed to form themes.

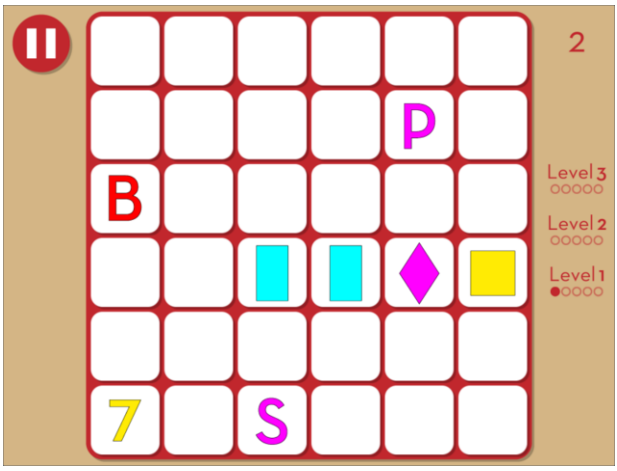

Figure 1. "Find it" cognitive game. In this example participants are asked to touch all light blue rectangles.

3. Results

3.1. Cognitive games development

Six of the nine participants in the first focus group had some computer literacy with participants reporting using computers for online banking, shopping, social networking and Skype. Participants liked playing games such as puzzles, card games and trivia games and reported they did this to maintain their cognitive health. Three participants had manual dexterity problems and requested a design that was age-appropriate. Computer technology was viewed by the group as a useful way of passing the time when unable to complete normal activities due to bad health. Additionally, participants felt that games could offer some social interaction for elderly people who did not often leave the house.

Figure 2. "Match it" cognitive game. Participants are shown cards which turn over and then asked to remember the spatial position of pairs of tiles.

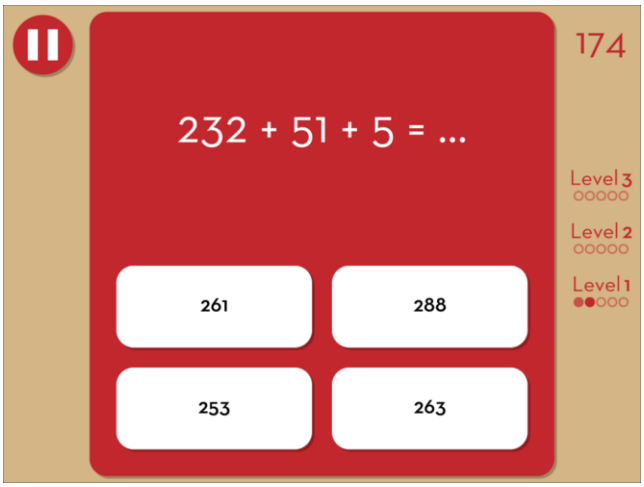

Figure 3. "Solve it" cognitive game. Participants are asked to indicate the solution to a mathematics problem by pressing on the correct answer.

The second focus group introduced participants to a prototype of a game where they were asked to find and press on objects presented on the screen. Participants reported they were able to follow the instructions well and could operate the tablet computer. Feedback was received on color selection with participants preferring bright colors.

In the third focus group two further games were introduced: one was a memory game where participants were shown pairs of cards on the screen which then turned over. The task of the participants was to remember the location of cards and select them in pairs. The other was a game on mathematical problems where answers were presented as multiple choice. Participants found the mental arithmetic challenging but liked this game. They commented that the symbol they would use for divide would be "÷" rather than "/" which is more commonly used now.

Following participant feedback four games were finalized: Find it—where participants looked for and touched screen elements as fast as possible with this game assessing language, memory and executive function (see Figure 1); Match it—a card pairing game where participants selected pairs of objects with this game designed to assess memory, attention and spatial layout (see Figure 2); Solve it—a mathematical game where participants solved problems by multiple choice which tested calculation (see Figure 3); and Complete it—where participants filled in the missing photograph pieces by dragging, dropping and if necessary rotating elements with this game testing spatial attention and memory (see Figure 4).

3.2. Evaluation of the cognitive games

Participants successfully completed the 47-day period over which they played the cognitive games by themselves and experienced the four different games.

Thematic analysis of the participant interviews after the period of playing games revealed a number of themes. Participants spoke positively about the cognitive games *"Ooh, I like them!"* (participant E01) and the overall experience *"I'm glad I had the experience"* (participant E01) and *"It's been good, I've enjoyed them"* (participant E06). There were comments that the games had been beneficial *"Well, I think it's done me*

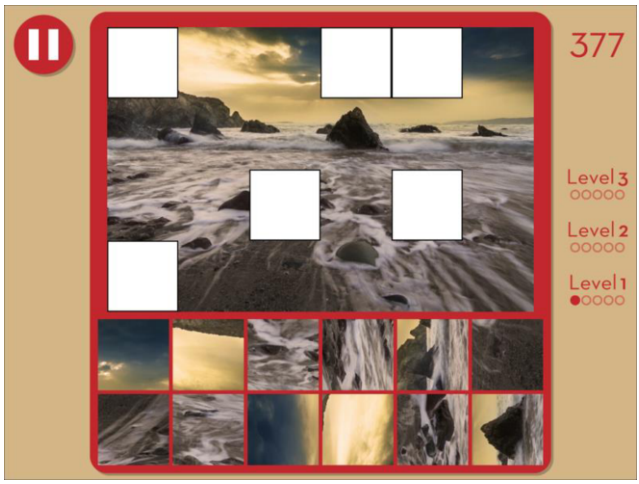

Figure 4. "Complete it" cognitive game. Participants are asked to complete a picture on the top of the screen by dragging across (and rotating if necessary) the missing parts from the bottom.

good" (participant E01), "*it broadens your mind*" (participant E02) and *"You're never too old to learn"* (participant E05). In terms of the different games "Find it" was liked "*I enjoyed that the best*" (participant E02) along with "Solve it" "*the maths were good*" (participant E02) "*the maths games was good*" (participant E05) in this case because of the link to a former career. The game "Match it" received good reports *"That one I quite liked"* (participant E08). On the other hand, "Complete it" was liked less "*I found it boring*" (participant E02).

4. Discussion

Through an iterative user-centered design a set of four cognitive games were devised for elderly people with mild cognitive impairment. This approach has been applied previously for health, education and for elderly people [27-28]. The usability of software on tablet computers with elderly people needs to be considered carefully because of changes in motor performance [29] and vision [30] with age. Therefore, controls need to be of an appropriate size with high contrast elements. Furthermore, the language used in instructions on games needs to be age-appropriate.

Qualitative results from the intervention suggested that participants felt positive about the cognitive games and there were reports that some participants felt the games had benefitted them. Cognitive games have been used preciously in studies attempting to enhance cognition in elderly people [18-23]. There have been mixed reviews of the effectiveness of games to change cognition. For example, one large systematic review [21] suggested that although games can improve performance on the trained task there is less evidence that interventions improve performance on closely related tasks. For any brain training task to be effective there needs to be generalization. Future developments could include the use of games similar to those that have been devised in this study and giving them to elderly people over an extended period of time in a controlled study (such as 6 months or more) and monitoring whether they produce any long lasting general cognitive changes.

Psychological wellbeing is a complex construct, particularly for elderly people and contains several components that interact with each other [31]. During the initial focus groups, the participants said that an important factor for maintaining health and wellbeing during old age was to keep their brains active along with regular exercise, social interaction, and a healthy diet. Certainly, the confidence that participants had with using technology improved during the time they used the games and this confidence in technology together with the experience of playing the cognitive games can enhance overall self-esteem [32] and promote active ageing.

Acknowledgments

This study is part of the EU Framework 7 DOREMI project, Grant agreement - 611650 http://www.doremi-fp7.eu/

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