

Lean Rehabilitative-Predictive Recommender Games for Seniors with Mild Cognitive Impairment: A Case Study

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Abstract. The number of dementia seniors is increasing. It is important to maintain their quality of life as much as possible and reach the masses. However, there are not that many personalized recommender systems for dementia seniors. Hence, this study aims to develop simple fun games for seniors with mild cognitive impairment (the stage before dementia) and their caregivers, which would be simple, fun, and rehabilitative. Designed based on the Montreal Cognitive Assessment test (MOCA) and the Mini Mental State Examination (MMSE), our games assess users' game plays, and recommend suitable difficulty levels based on two initial calibrations. The first calibration is for the memory game and the second calibration is for the fishing practice concentration game. The caregiver can also adjust the difficulty level manually. In the future, based on gameplay data, the system will be able to predict seniors' condition, and follow-up with advice from practitioners. User testing highlight interesting correlations between/among intra-Technology Acceptance Model (TAM), intra-User Experience (UX) and inter-TAM-UX constructs.

Keywords: Rehabilitative · Games · Lean · Assessment · Recommender · Mild cognitive impairment

1 Introduction

Throughout the world, millions of people suffer from dementia. According to the World Health Organization (WHO), as of 2019, there are 50 million dementia patients [1]. Dementia affects not only the individual but also their families and the society. The cost of handling dementia globally is estimated to be $818 billion per year [2]. Although there is encouraging progress in the medical field, the intricacies of the disease make it difficult to pinpoint the causes [3].

1.1 Problem to Be Addressed

While dementia is generally not curable at this point of time [4], many research and professional bodies have tried to possibly delay the progress of dementia in a patient.

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We note that there is a lack of recommender-enhanced mobile-based games for dementia patients in the market, which automatically customize the level of difficulty to the player, or would enable the senior/the caregiver, to choose the level of difficulty.

1.2 Objectives

We aim to train and improve the cognitive abilities of individuals with mild cognitive impairment, to delay progress into dementia. We hope to do so, through simple, yet fun rehabilitative games. Designed based on the Mini Mental State Examination (MMSE) [5] test, and to a certain extent, the Montreal Cognitive Assessment (MOCA) [6] test, *MindRegen*, consists of two mini-games, which are the Matching game (addressing attention and memory) and the Fishing game (addressing attention and motor skills). Rehabilitation and calibration are enabled by tracking the seniors' game play, and assessing and adjusting the game's level of difficulty to the seniors' current level of ability. We hope the gameplay data can also be used to predict seniors' eventual ability.

2 Related Work

2.1 Dementia

Dementia is defined as a disease that can cause progressive decline in a person's cognitive abilities. It affects both learning and reasoning abilities to the point that it disrupts the person's daily activities. There are several types of dementia, including Alzheimer's disease, Lewy dementia, Cerebro-vascular dementia, Fronto-temporal dementia, Parkinson's disease, Hippocampal sclerosis and mixed dementia. Among all the types of dementia, Alzheimer's disease is by far the most common (60–70%) followed by Vascular and Lewy body dementia [2, 7, 8].

2.2 Mini Mental State Examination (MMSE) and Montreal Cognitive Assessment (MOCA)

There are many versions to the Mini Mental State Examination (MMSE) [5] test. However, the common assessments include spatial orientation, object recognition/recall, attention and language. Similar to the MMSE, the MOCA [6] focuses on visual-spatial, recall, attention/concentration, and abstract reasoning. The difference lies in the addition of time and place orientation.

[9] have experimented with affordance design, for cognitive access, with seniors with the Alzheimer's Disease Foundation of Malaysia (ADFM). Design is based on the four MMSE constructs and prior discoveries/insights from the creative industries on semiotics, lean sustainable design, and three types of cognition [10]. Among the activities, seniors piece together shapes, as part of a leisure activity. The placement of the shapes reflect object recognition and visual orientation abilities. The heart shape symbolizes the seniors' main concern. Other shapes are interpreted in relation to it.

The use of semiotics in [9] is supported by [11]. [11] recognize the use of models and semiotics-based artifacts for improving communication and for identifying and

modelling elicited requirements. Their study uses semiotics to elicit non-functional requirements, i.e., for privacy. It is a novel bridge between Art and Science.

Pursuant from [9, 12]'s meta-analysis, abstracts from prior inclusive design systems. These are designed based on the MMSE. However, user testing involves active aging seniors, who are hand-phone users, not MCI seniors. Findings indicate that germane load in [13]'s Cognitive Load Theory, is confirmed as a generative design factor, which can motivate self-regulation and tradeoff intrinsic and extraneous cognitive loads. [9, 12] are rehabilitative, and predictive.

2.3 Games for Dementia

2.3.1 Big Brain Academy

Big Brain Academy (BBA) contains a variety of puzzle games. In the "Think" category, players are challenged to solve *logical* questions. For the "Memorize" category, players have to utilize their *recall* and *memorization* abilities. The "Analyze" category provides the players with puzzles that require *reasoning* whereas the "Compute" category involves *Math* tests. The last category "Identify" aims to train *visualization.*

All of them allow 60 s for a player to complete the game. When a player gets the wrong answer, BBA will lower the difficulty level and deduct points and the timer for the player. BBA can be played in three different modes: Test Mode, Practice mode and versus mode. At the end of the game, BBA will show the player's performance in terms of their weaknesses and strengths [14]. A study [15] indicates that seniors playing BBA report a decrease in stress levels and is calmer in mind.

2.3.2 CogniFit

CogniFit, an interactive mental game application that contains more than 20 games, aids cognitive skills stimulation through personalized daily training. It trains cognitive abilities in different aspects, such as *memory, concentration, attention, mental arithmetic, executive functions, reasoning, planning, mental agility, coordination.* It also shows detailed statistics to track the user's progress and performance [16]. The technology used to develop the game is the Cognitive Assessment and Individualized Training System (ITS). ITS is a real-time application that configures every user's training experience, by using advanced algorithms on information provided by assessments on the user. ITS constantly monitors the cognitive level of the user in real time to develop proper adjustments. It then provides each user with a distinct assessment with suitable number of tasks and levels of difficulty. This will provide the most optimal training experience to every user. Apart from that, the Cognitive Assessment test is used to determine the cognitive ability of a user by comparing it with performance from demographic peers with age and gender as the primary variables.

2.3.3 MindMate

MindMate (MM) is a mobile application, which caters to people with Alzheimer's disease or dementia. It aims to reduce the deterioration of the disease by encouraging seniors with dementia to have a holistic lifestyle. MM also promotes reminiscence therapy in

improving cognitive abilities and quality of life for the elderly [17]. It provides a digital platform for brain games, nutrition, exercise advisories and social interaction. The games available in MM are classified based on four core cognitive areas, which include Problem Solving, Speed, Memory and Attention.

A Finnish intervention [18] found that aside from improvements in cognitive functions, participants' overall health improves. The research [19] also finds that the MIND (Mediterranean-DASH Intervention for Neurodegenerative Delay) diet helps to slow down dementia by 53%.

2.3.4 WiiFit

WiiFit, is designed by Hiroshi Matsunaga for the Nintendo Wii console. It offers a variety of exercising choices, such as Yoga, Strength Training, Aerobics and Balance Games. The Wii Balance Board allows the user to stand on top of it, while doing the exercises. The user needs to imitate the postures on-screen while a virtual personal trainer provides feedback. The *WiiFit* is able to improve balance and gait, important in preventing falls [20], as well as balance and walking speed [21].

3 Methodology

We have applied the waterfall methodology. The requirements for the game are gathered from literature review on games aimed at improving the condition of patients with dementia. The review covers how seniors with dementia would interact with a certain game and how recommendations are developed for them. These requirements are then included in a survey form. We next ask the training coordinator in a Malaysian Alzheimer's Association for her opinion on the survey (second part of requirements gathering), to obtain her consent, prior to distributing the game and survey online.

The game engine, *Godot,* simplifies all the physics of the character and the platforms. The programming language GDScript, is a high-level, programming language. It uses a syntax like Python (blocks are indent-based, and many keywords are similar). It is optimized for, and tightly integrated with the *Godot* Engine, allowing great flexibility for content creation and integration.

User testing is via Google survey, with the Alzheimers' Disease Foundation of Malaysia's (ADFM) caregivers, MCI seniors. It is the same foundation as that in [9]'s and initially, [12]'s. The differences are different caregivers and seniors (some seniors have passed away), the past study's commentator/vettor is the head nurse but for this study, the training coordinator, past is physical materials but for this, totally digital.

4 Systems Design and Development

4.1 Mechanisms

There are three mechanisms: a) assessment, b) rehabilitation and c) prediction. The predictive mechanism is to predict the user's next level of ability based on the current gameplay. These three mechanisms are also used by [22–24]. Furthermore, users can

choose the level of difficulty for any game. By default, a recommender system will calibrate to enable seniors and their caregivers to play the game at a level which they wish. The difficulty level can be manually adjusted if the caregiver thinks it is not suitable, by selecting other difficulty levels in the difficulty selection screen or by skipping the calibration phase.

Other design considerations are the device (tablet/Web-based/executable file), comfort while playing (whether seated/standing), separation of motor and cognitive skills training, suitable duration [25], short and simple instructions, different levels of difficulty (adjusted to error rate of less than 5% and a reaction time of less than 5 s [26] or successful completion of three consecutive tasks without mistake, or successful completion of 80% of the game over six sessions [27]), and feedback [28].

4.2 Game Flow Overview and User Interface

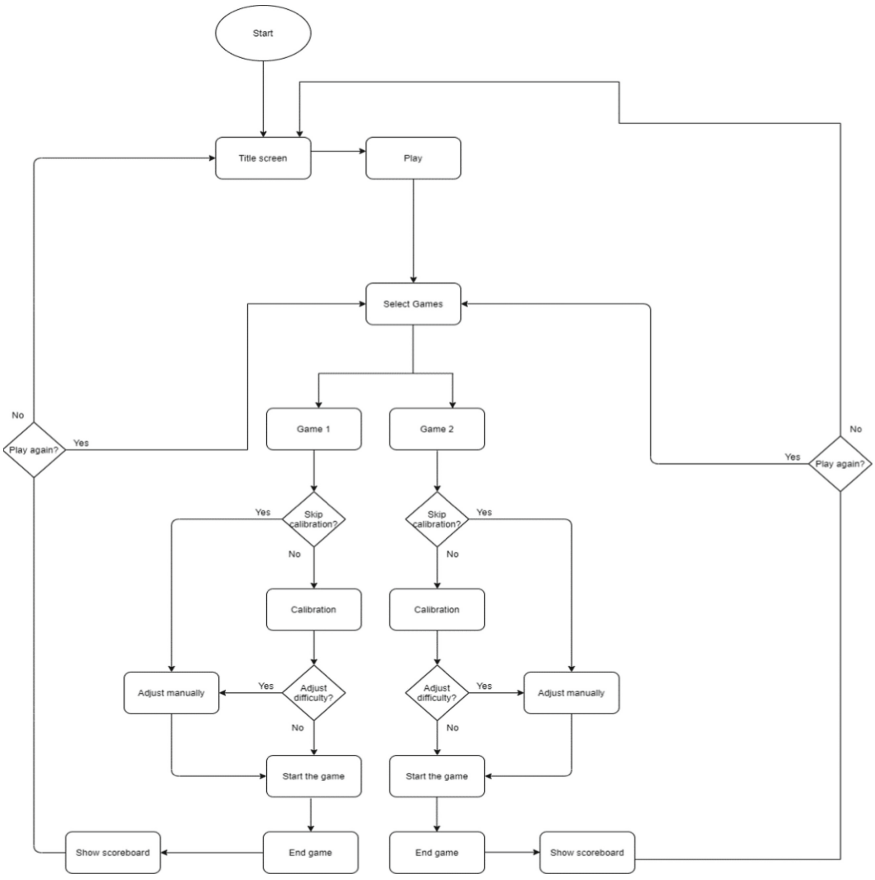

Fig. 1. Game overview flow

An overview of the game flow is presented in Fig. 1. The user interface and human-computer interaction are designed partly based on [29]'s design principles, partly based on non-functional requirements, i.e., portability, effectiveness, efficiency and reliability, and ultimately, fun.

4.3 Game 1's Flowchart and Functional Requirements (to Train Memory Skills)

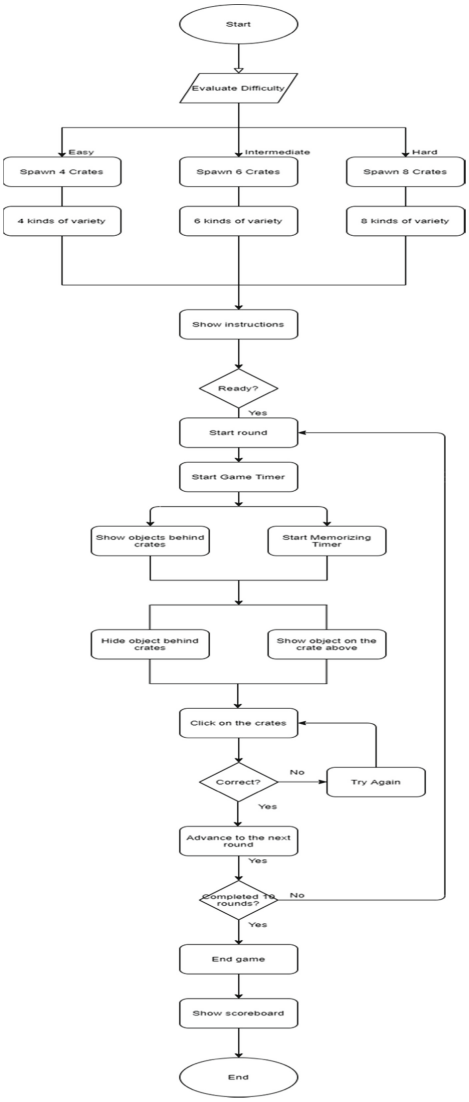

Fig. 2. Game system flow for game 1: matching cards (calibration 1), followed by recommender, based on score and time taken thresholds

The flowchart, and user interfaces are presented in Fig. 2. There are various non-functional requirements, but to us, the most important are convenience, portability, and reliability. Some of Game 1's functional requirements are shown in Table 1.

Table 1. Some functional requirements for game 1 (memory game)

The features inside the game shall be distinguishable and recognizable	The game shall implement large objects with contrasting colours
The difficulty of the game shall have the ability to be manually adjusted	The difficulty of the game can be adjusted by the caregivers if needed
The game shall not take a long time to play	Playing one round of the game shall not exceed 4 min
The game shall be diverse in terms of difficulty (Game 1)	Different difficulty levels will trigger different number of platforms and object variety, e.g. 4 Easy, 9 Intermediate, 16 Difficult or 2 Easy, 4 Intermediate, 6 Hard

4.4 Confirmation of Design (User Requirements)

A survey consisting of five questions are distributed to caregivers of the Alzheimer's Foundation via an online Google Form, to gather and confirm requirements identified from the above literature review and our proposed design. All questions are measured on a Likert scale of 1 to 5, with 1 being very unlikely and 5 very likely.

The first question (Fig. 3) inquires to what extent users would like to set the difficulty level by themselves, and to have the option of choosing which game they would like to play. The results indicate that majority of the users like this function.

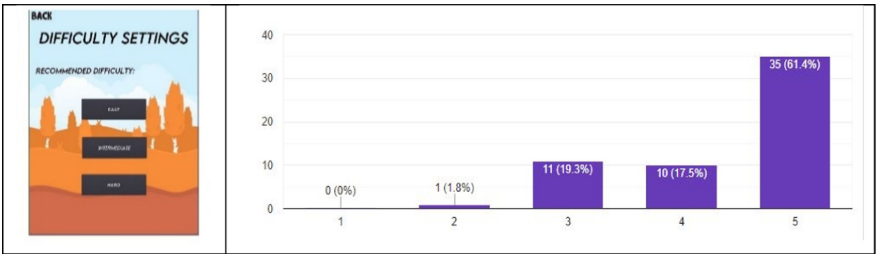

Fig. 3. Degree of preference for availability of difficulty settings and options

The second question (Fig. 4 aims to determine whether the seniors would like the system, to automatically recommend a difficulty level for the user, based on his/her performance. The results indicate that it is positively-perceived.

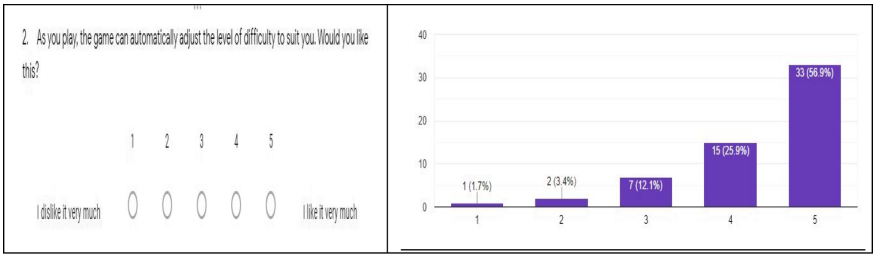

Fig. 4. Preference for automatic adjustment/recommendation of digitadifficulty level

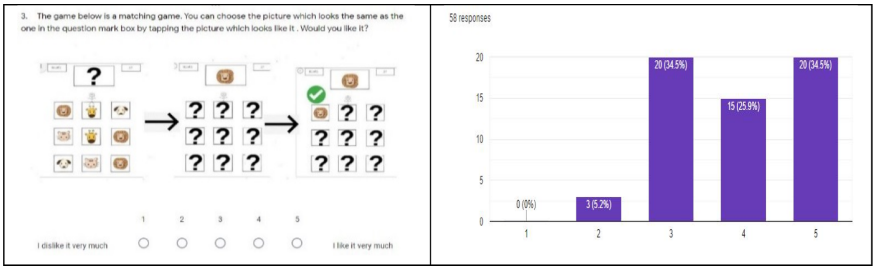

Fig. 5. Degree of preference for the memory game

The third question (Fig. 5 aims to determine whether the users like the gameplay of the first game. This game aims to improve the user's memory skills. More than 80% of the users like this game.

The fourth question (Fig. 6 aims to determine whether users like the gameplay of the second game (Fishing Practice). This game aims to improve the user's concentration and reaction speed. Findings indicate that this game is quite well-perceived, though it is not as popular as the first game.

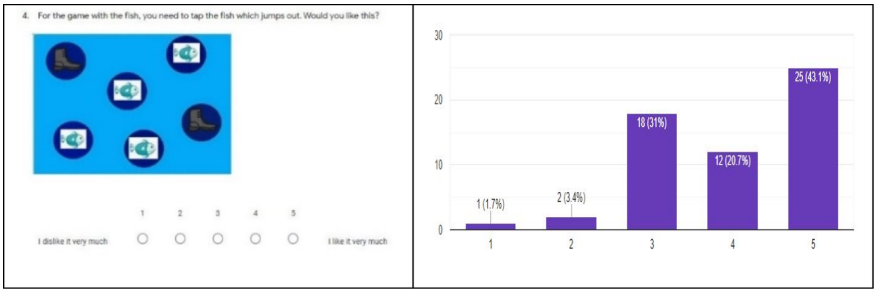

Fig. 6. Degree of preference for the fishing practice (attention and reaction speed)

The final question (Fig. 7) aims to determine whether users would like a scoreboard, which displays their performance after they end the game. The results are mixed, with

4 out of 30 respondents disliking it. This may probably be due to the worry of losing motivation, if they get poor results or lose privacy. However, most like the scoreboard.

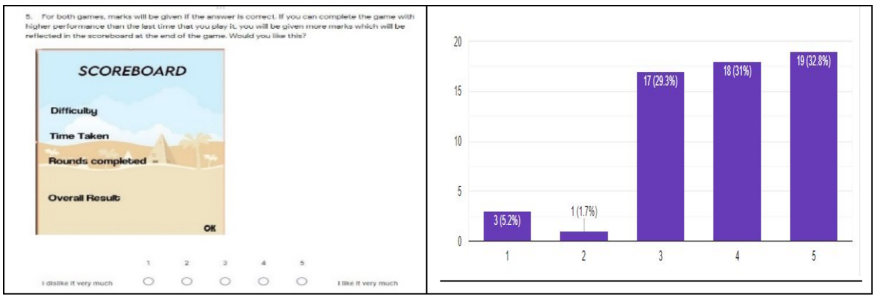

Fig. 7. Degree of preference for scoreboard

4.5 Refinements Based on Confirmation of User Requirements

Based on the confirmation of requirements above, the games, with the following interfaces (Figs. 8, 9 and 10) are finalized for user testing.



Fig. 8: Main page (left), game selection (middle), manual difficulty selection (right)

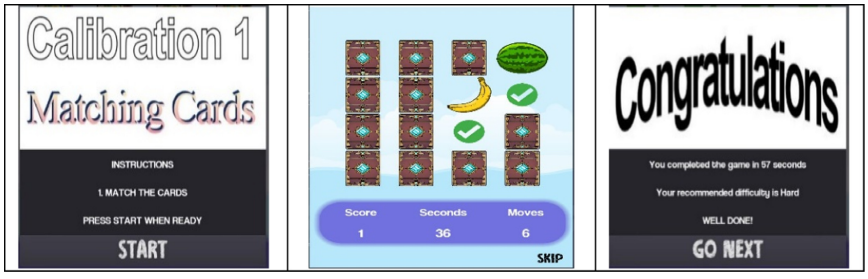

Fig. 9. Calibration test 1: matching cards (memory)

The games begin with 2 calibrations. The first calibration (Fig. 9) will recommend the level of difficulty for game 1, i.e., memory crates, and the second calibration (Fig. 10) will recommend the level of difficulty for game 2, i.e., fishing practice.

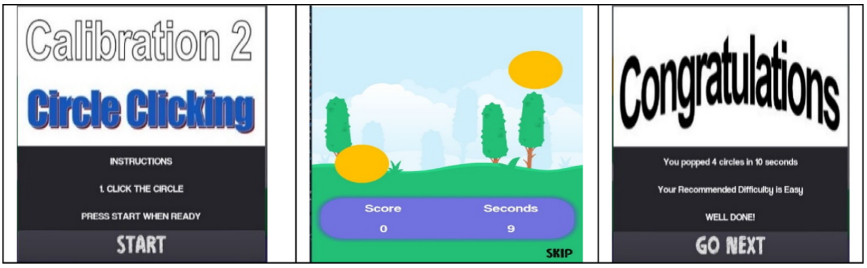

Fig. 10. Calibration test 2: popping the circles (attention and spatial ability)

Game 1's instructions page and the game itself are presented in Fig. 11.

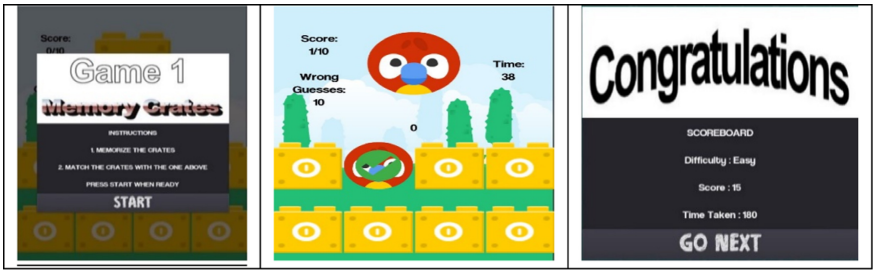

Fig. 11. Game 1 (memory crates), aimed at improving memory

Game 2's instructions game page and the game itself, are presented in Fig. 12.

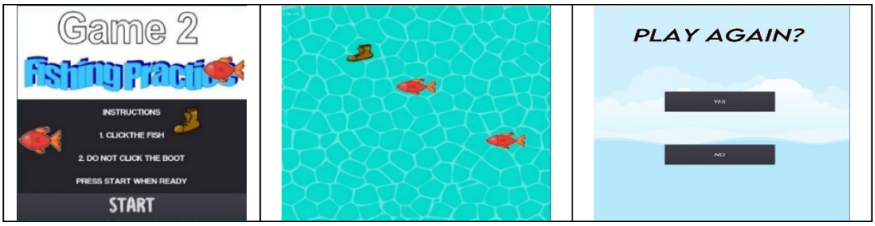

Fig. 12. Game 2 (fishing practice), aimed at improving attention and spatial orientation

5 User Testing

User testing is carried out end of May 2021. It is totally virtual, due to stringent movement control order procedures in the country. A questionnaire, consisting of 21 questions, is

developed, integrating constructs from [30, 31]'s Technological Acceptance Models (TAM) 1, 2, and 3 and [32]'s User Experience (UX) questionnaire.

Questions 1–3 evaluates ease of use, questions 4–12 usefulness, and questions 13–14 the excitement and motivation the games create. Perceptions towards the recommender and difficulty levels fall under usefulness. Questions 15–16 evaluates the dependability/reliability of the games in terms of the ability of the game to run without problems. Question 17 assesses whether the games could capture the interest of the users, question 18 the efficiency of the games and question 19 the attractiveness of the games. Lastly, Question 20–21 assess whether the users are interested to continue playing the game in the future. Questions 1–12 and 20–21 are based on the TAM 1, 2, and 3, while questions 13–19 are based on the UX questionnaire.

We receive thirty caregivers'/seniors' responses to our Google survey. Figure 13 illustrates the cumulative score for each question. Figure 14 shows the average scores by TAM and UX grouping. The graph shows a high score of 4.4 for ease-of-use, indicating that the game can be easily managed by the seniors. Similarly, usefulness and intention to use in the future score an average of 4.2 each. Although attractiveness scores 3.8, the respondents find the games stimulating (4.05). We need to improve with more visually appealing designs.

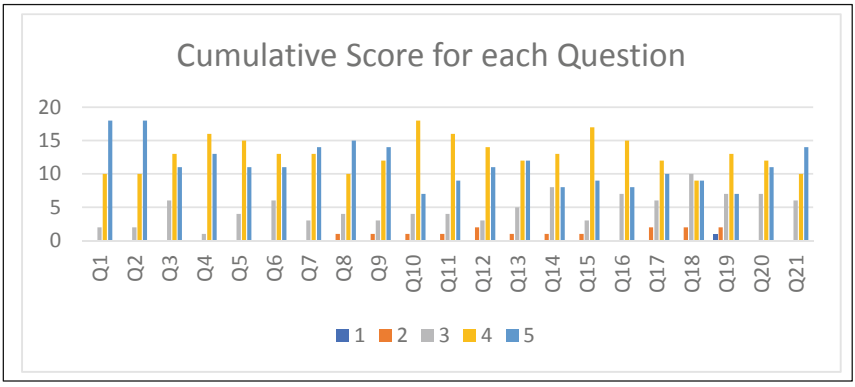

Fig. 13. Cumulative score for each question

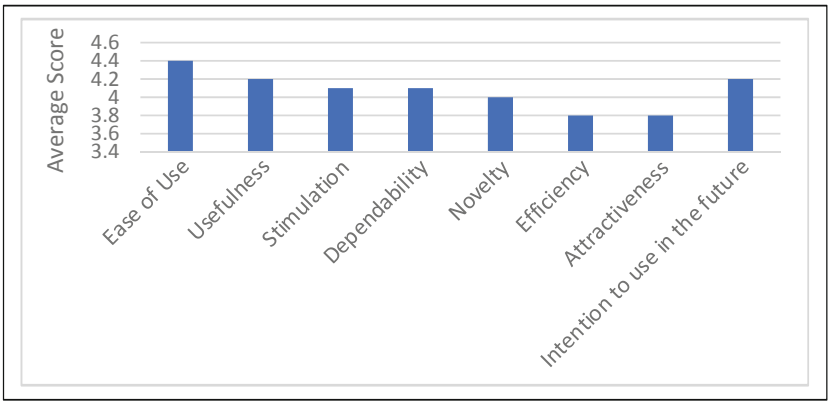

Fig. 14. Average scores by TAM and UX grouping

Next, Pearson correlation for intra-TAM, intra-UX and inter-TAM-UX constructs are investigated. Some of the correlations investigated are Q1 (ease-of-use)-Q7 (usefulness), Q13 (stimulation)-Q15 (dependability), Q17 (novelty)-Q18 (efficiency), Q19 (attractiveness)-Q20 (intention to use in the future). Outcomes are presented in Figs. 15, 16, 17, 18, 19, 20 below.

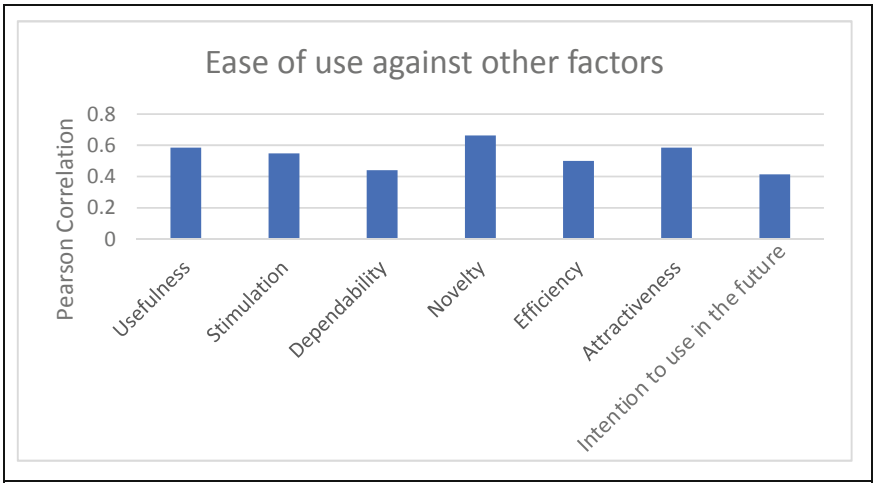

Fig. 15. Ease of use against other factors

These figures indicate that stimulation, followed by novelty and attractiveness (Fig. 22) are the three most important design factors to these seniors. Furthermore, attractiveness is most highly correlated with novelty (Fig. 21). Novelty in turn is equally highly correlated with stimulation and attractiveness, followed by ease of use and intention to use in the future (Figs. 17 and 19).

Moreover, perception towards the recommender's dynamic adjustment of the difficulty level receives an average score of 4.5 (Q4) and the reasonableness of the generated difficulty level for each game (Q5), receives an average score of 4.2. Degree of skewness for Q4 and Q5 are −0.19, and −0.30 respectively.

Surprisingly, the averages for the questions on clarity with regards to the functions of buttons, the Fishing game for improving concentration, the Fishing game for improving recognition and the scoreboard at the end of the game, are 4.5, 4.3, 4.3 and 4.1 respectively, and are skewed −0.96, −0.95, −0.98, −0.90 respectively. These are encouraging findings. Surprisingly, they also confirm the findings in [9, 12], though with different modality and over time.

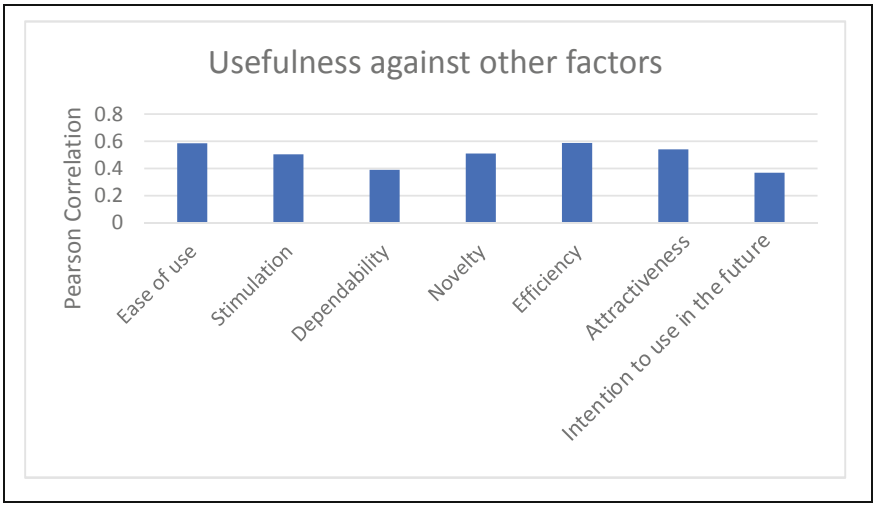

Fig. 16. Usefulness against other factors

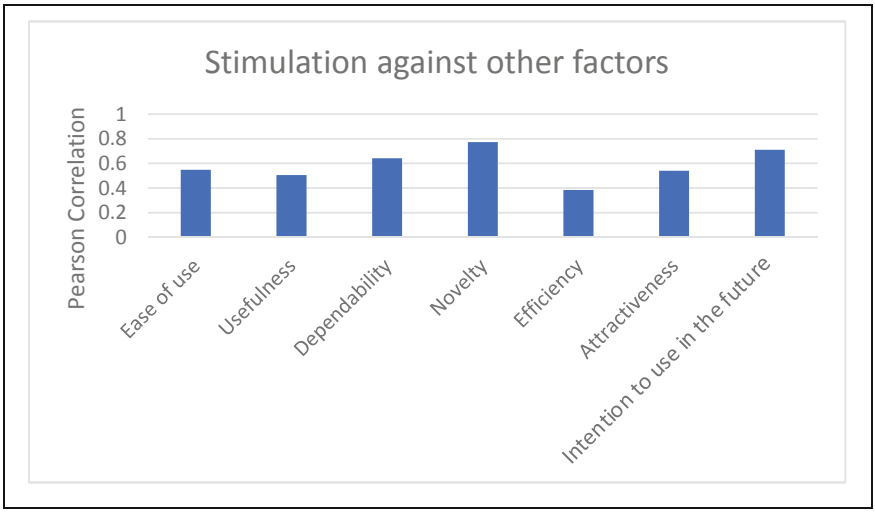

Fig. 17. Stimulation against other factors

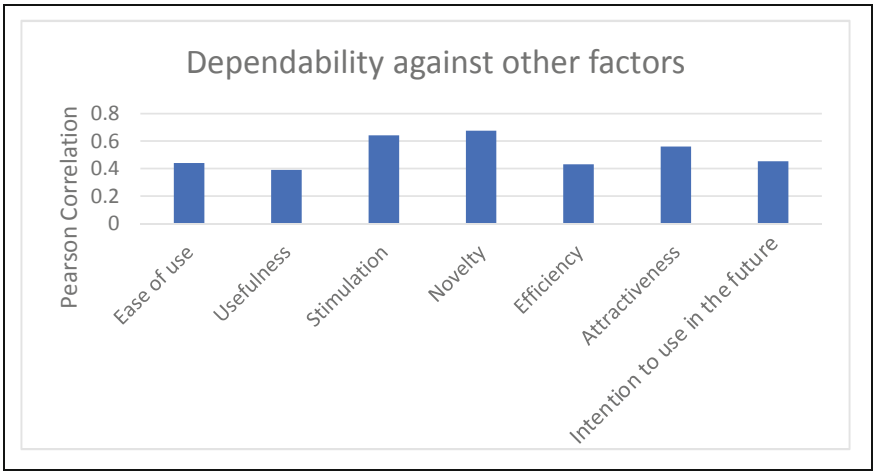

Fig. 18. Dependability against other factors

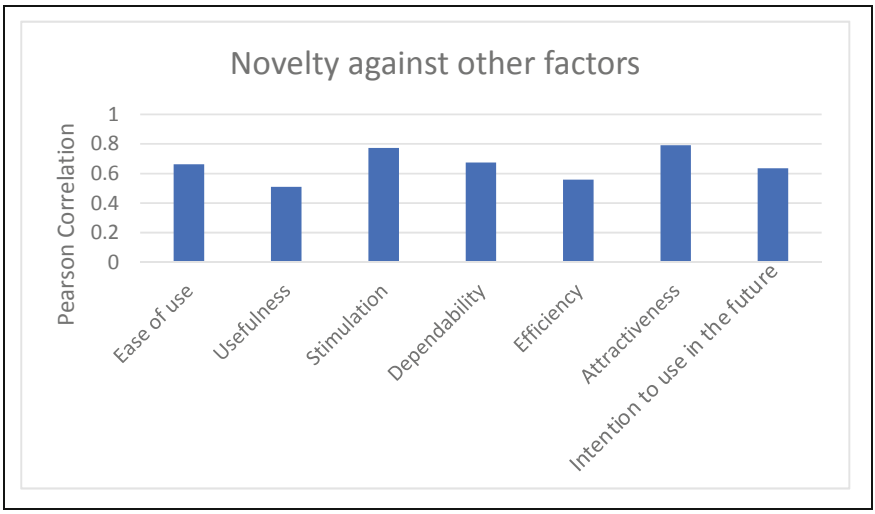

Fig. 19. Efficiency against other factors

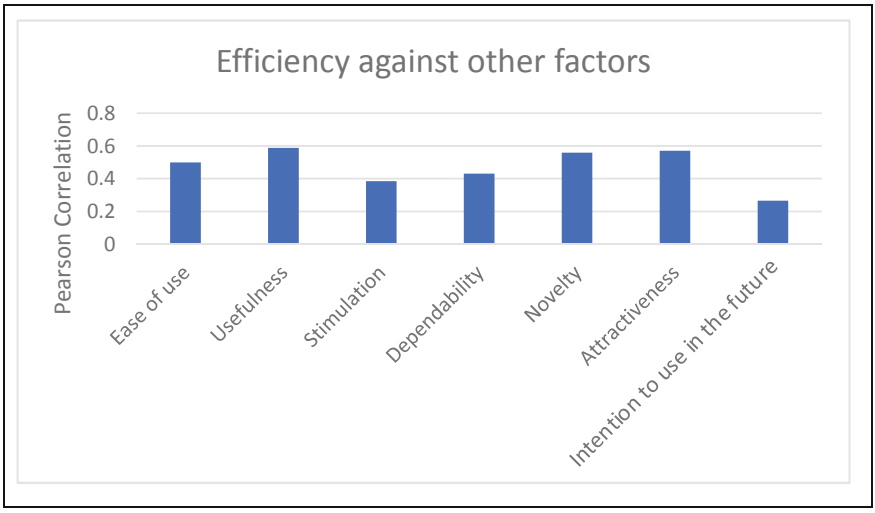

Fig. 20. Efficiency against other factors

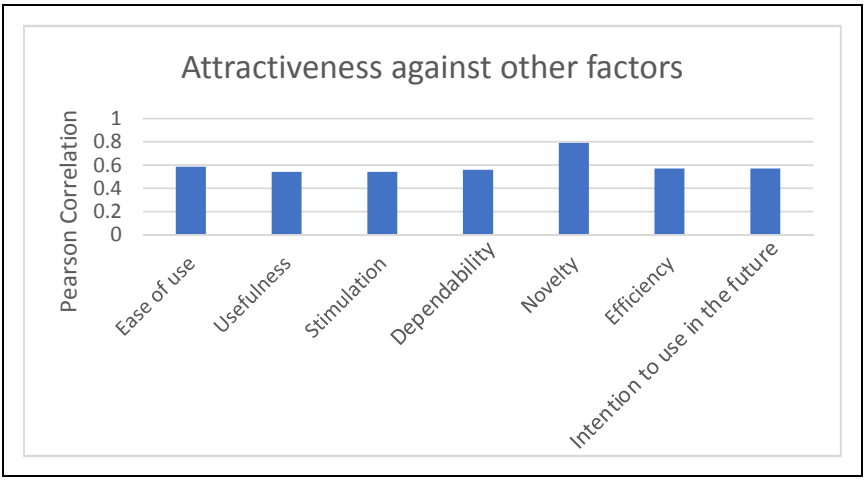

Fig. 21. Attractiveness against other factors

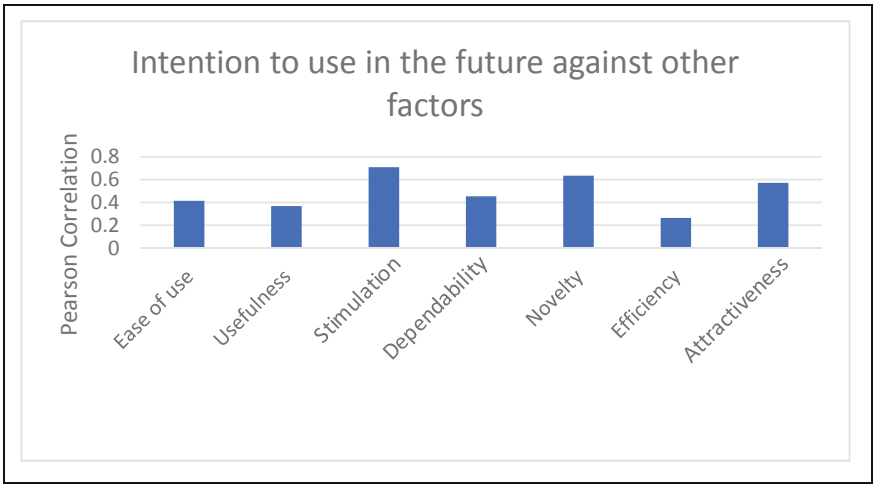

Fig. 22. Intention to use in the future against other factors

6 Conclusions

We have developed games, each with its own calibration cycles. Findings indicate that it is possible to extend these games to MCI seniors at home, where they can play with their caregivers. Due to the small sample size, findings are not generalizable. In the future, if we have funding, data may be captured and shared with doctors, (with family consent), for further interventions. We hope there would be positive improvements, similar to medically-grounded brain training randomized trials in the US, UK, EU.

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