Incorporating Cognitive Training with Elderly People's Everyday Use of Smartphones

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Abstract: The ageing population is growing rapidly, and the risk of cognitive decline among this populace is alarming. Dementia patients represent one of the most significant groups among individuals experiencing cognitive decline. Despite having pharmacological medications available to support dementia patients, non-pharmacological interventions can be a better approach, considering the cost and undesired side effects. Mobile cognitive training applications (apps) have been introduced to elderly individuals, but adoption rates have not been high. One possible reason for this can be that they do not perceive such apps as useful. These apps are standalone apps that do not take users' real-life tasks into consideration. Hence, in this study, we aim to integrate cognitive training exercises with elderly's everyday use of smartphones. First, we gathered user requirements by conducting literature review, app research and an interview with an elderly person. We then conducted four iterations of prototyping and evaluations, where feedback from participants in the evaluations was used to improve the prototypes developed in next iteration. Through the entire process, we generated some lessons learned that are applicable for designing such apps. Future work includes further development of this app to make it fully functional, and testing it in a longitudinal study.

1 INTRODUCTION

The demographic change has led to a growing number of the ageing populace. As indicated by the World Health Organization (WHO), by 2050, the world's elderly population aged 65 years and above will be doubled, with an estimated total of 2 billion people (WHO, 2023). This growth in numbers is accompanied by a significant increase in the number of people with dementia, with age being the strongest recognized risk factor for this disease (WHO, 2017). Dementia encompasses a set of symptoms related to a decline in memory, reasoning, and other thinking skills (WHO, 2017). Various types of dementia exist, but Alzheimer's Disease (AD) accounts for 60 to 80% of cases overall (Prince et al., 2016).

Although it is not a type of dementia, mild cognitive impairment (MCI) is a syndrome deemed a precursor to dementia (Jongsiriyanyong & Limpawattana, 2018; Petersen et al., 2018). MCI is a cognitive decline that is more extensive than expected in normal ageing but less severe than dementia (Jongsiriyanyong & Limpawattana, 2018; Langa & Levine, 2014). Clinically, healthy elderly individuals could have some progressive decline in terms of their cognitive functions, such as processing speed abilities and memory. The further extensive decline in cognitive domains could be related to MCI. Having MCI is an alarming indicator of dementia and indicates a high risk of development of dementia and subsequently to more severe AD (Gauthier et al., 2006; Petersen et al., 2018).

There are pharmacological medications available to support dementia patients. Nevertheless, the effect

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of the available pharmacological medications is not curative, but they may aid in alleviating symptoms of dementia (Groot et al., 2016; Smith & Argentina, 2020). Additionally, these medications have undesirable side effects on patients; thus, finding alternative approaches for controlling the progression of dementia is crucial (Zhang et al., 2021).

Non-pharmacological interventions, such as cognitive interventions, could provide a healthier and less costly alternative to pharmacological interventions. The adoption of appropriate cognitive training, also known as brain training or mind training (Zhang et al., 2021), can activate the brain compensation mechanisms of the elderly and keep their cognitive level high (Fabbri et al., 2019; Zhang et al., 2018). Various research has provided evidence regarding the effectiveness of cognitive training exercises in improving elderly's cognitive performance and slowing the progression of dementia (Husseini et al., 2016) and AD(Bonnechère et al., 2021; Fabbri et al., 2019). Cognitive training exercises stimulate multiple cognitive domains which include memory, reasoning, and information processing speed (Bonnechère et al., 2021; Zhang et al., 2018). Examples of cognitive training exercises include jigsaw puzzles, Sudokus, and crosswords. A good support tool for cognitive training exercises in aging are smartphone applications (apps) (Bonnechère et al., 2021). Hereinafter in this article, "cognitive training apps" refers to smartphone apps that provide cognitive training exercises for elderly populace.

An app's success is determined by its engagement among the intended users, and one of the main factors influencing app engagement is its usefulness. (Thorpe et al., 2016). Usefulness concerns whether the system provides functionalities/features that align with and fulfill users' typical "real-life" tasks using that system (Thorpe et al., 2016; Yingta et al., 2021). A real-life task is a task that matches an activity or action that would occur in real-life use. For example, common real-life tasks concerning smartphone functions are related to management of messages (sending/receiving), calls (making/receiving), and photos (taking/sharing) (Petrovcic et al., 2018). Thereby, to implement a successful system, from the perspective of usefulness, designers should consider the users' real-life tasks and design a system that can empower them to perform these tasks.

Regardless of the potential benefits of the cognitive training apps as an alternative for pharmacological medications, there is a challenge with the usefulness of these available apps; they often are not designed to integrate practising cognitive training exercises with performing typical real-life tasks using smartphones (Bonnechère et al., 2021; Thorpe et al., 2016). For example, in some of the current apps, when performing a cognitive training exercise involving puzzles, the user's task is to rearrange the tiles back to their original shape. Even though this exercise stimulates various cognitive skills, the user is unable to associate the completion of the exercise with a typical smartphone function, such as making a call, or an app that is regularly used on a smartphone, like YouTube.

Elderly people from various demographic backgrounds possess different ways of using a smartphone. In Norway, elderly people do use smartphones regularly; 93% of elderly individuals aged 65 to 74, and 75% of those between 75 and 79 years old use phones with Internet (SSB, 2023). Accordingly, our objective is to propose a design concept to fabricate an app that incorporates practising cognitive training exercises with the elderly everyday use of smartphones. To the best of our knowledge, no study has yet attempted to integrate cognitive training exercises with regular use of smartphones among the elderly individuals.

2 METHODOLOGY

In this study, we adopted a user-centered design (UCD) (Karat, 1996) approach to ensure that the needs and preferences of elderly people were considered throughout the entire process. According to MacKenzie (2012), two requirements must be met to apply the experiential results to individuals who were not tested: (1) the participants must be members of the targeted population; and (2) a sufficient number of participants must be tested. In light of this, a total of nine elderly, which is a valid sample size for a problem discovery study, participated in the study (Macefield, 2009).

Participants were recruited through convenience sampling, which means they were invited to participate for the study due to their easy accessibility (Sedgwick, 2013). The criteria for inclusion were being above the age of 65 (according to the definition of an elderly person by WHO (2023), and the retirement age in Norway (NAV, 2023)), being cognitively healthy and using a smartphone. The app was targeted to be used by elderly individuals for cognitive training purposes with a focus on prevention rather than treatment.

Prior to participating in the study, participants were first briefed about the project. They were then asked to give their consent by signing a consent form. All participants were met physically in person at their homes, except for one (he preferred to meet somewhere else), in order to create the most natural setting for using the app. The entire process took around an hour for each participant.

2.1 User requirements gathering

Using literature search and app research, relevant studies and existing mobile apps focusing on cognitive training were identified. Three main areas were carefully considered during this stage, i.e., types of cognitive exercise, the elderly's everyday use of smartphones, and user engagement which includes rewards.

Developed on the findings from literature search and app research, we conducted an interview with an elderly individual using a semi-structured interview guide. During this interview, since we were interested in integrating elderly individuals' use of smartphones with training cognitive exercises, we first asked questions about the interviewee's smartphone usage. Questions such as "What are your favourite apps", "How often do you use social media apps/ messenger services/ internet browser?" and "Have you ever used any cognitive training app?" were asked. We then presented her designs of some existing cognitive training apps and sought her opinions about them.

2.2 Iterations of prototyping and evaluation

Based on the user requirements, we created the first prototype. As UCD requires an iterative process, we conducted a total of four iterations of prototyping and evaluation. For evaluations, usability testing was conducted with two elderly individuals in each iteration. Similar to the interview in user requirement gathering, all participants were first asked about their smartphone usage. They were then presented with the prototypes and instructed to use them.

During the testing, we encouraged the participants to think aloud. We observed the participants' interaction with the prototypes. To gain a better understanding of how we could provide a better user experience of our prototypes, questions concerning the design choice were asked. Examples of these questions include: "What do you think about the design/ colours/ layout/ size of icons?", "What do you think about getting rewards after doing the exercises?", "What do you think about the recap of your performances?" and "What kind of skill/ ability would you like to work on?".

After every testing, the results were analysed to identify improvements required to make for the next iteration's prototype. All prototypes were created using Figma.

Table 1: Participants' profile.

	Age	Gender	Smartphone use	Most used apps	Often play games on smartphone	Age-related decline	Favourite type of cognitive training exercise	Experience with cognitive training exercise
P1	70	F	Daily	Facebook, YouTube	No	No	N/A*	No
P2	68	M	Daily	Instant messaging (IM), Facebook	Yes	No	Problem-solving with numbers	No
P3	70	M	Two to three times a week	Vipps (payment), Games	No	No	Problem-solving with numbers	No
P4	83	F	Daily	IM, Facebook	No	Vision	Focus training using sorting	No
P5	76	F	Daily	IM, Facebook	Yes	No	Focus training using sorting	No
P6	71	M	Daily	Spotify	No	Vision	Problem-solving with numbers	Yes
P7	69	F	Daily	News, Weather	No	No	Focus training using sorting	No
P8	72	M	Daily	IM, Facebook	No	Vision	Problem-solving with numbers	No
P9	67	F	Daily	YouTube, social media	No	No	Focus training using sorting	No

*Participated in user-requirement study, hence did not evaluate different types of cognitive training exercise.

3 RESULTS

Table 1 summarizes the participants' profiles, which include demographic background, smartphone usage, and their favourite type of cognitive training exercise revealed after conducting evaluations with them. They used their smartphone every day, except P3. He only used it two to three times a week because he preferred to use a laptop. In terms of experience of using a cognitive training app before, P6 was the only participant who had experience. He played an app named Lumosity app before. Despite not having experience with a cognitive training app, the other participants were aware of the existence of such app. P1 even expressed her willingness to try. In each iteration, all participants tried out two different types of cognitive training exercises. Although the participants were able to identify their favourite type of exercise, both types received almost similar responses.

3.1 User requirement gathering

After conducting literature review and app research, we chose the Skillz app (TriangleLabs, 2018) and Peak (PopReach, 2023) as both claimed to have a suitable design for an elderly user. Peak was also used in a study assessing the effectiveness of cognitive mobile games in "real-life" use among elderly people (Bonnechère et al., 2021), which means elderly used this app independently and without specific guidelines on training frequency. Not only that Peak was used in "real-life" scenarios, Bonnechère et al. (2021) also reported individuals of all ages demonstrated improved cognitive performance, such as increased scores and processing speed, after training with the games in Peak.

In terms of types of exercises, we identified two main categories, i.e., problem-solving and focus training. The former involves exercises that challenge users to find solutions, such as arranging numbers in ascending or descending order. The latter refers to exercises that require users to utilize their focus and concentration skills. For instance, identifying and sorting the same object.

We had P1 tested both Skillz and Peak. One major finding is that the menu and instructions did not appear intuitive to her. She was confused most of the time when attempting to do the exercise. Both apps had similar exercises, but with different designs. We took advantage of this opportunity to compare both designs and asked her to choose her preference. For instance, in the focus training type of exercise when users had to choose and sort images (Fig. 1), P1 preferred the design from Peak, because it was more intuitive for her to click on the arrows right beside the image.

In terms of incorporating cognitive training app into everyday use of smartphones, P1 expressed the need to have a "skip" button. The suggestions to perform cognitive training exercises should always come after she has completed her intended actions. However, this also depends on the original app she was using. If it was a "less important" app like YouTube, she would not mind being suggested to perform cognitive training exercises even before she started watching anything on YouTube. Regarding user engagement, she was interested in having rewards to motivate her. Additionally, feedback to show the progress after each exercise was also appreciated. Other than that, she also provided feedback on the colours and shapes of elements for the exercise design, such as having simple colours (not overly striking and colourful).

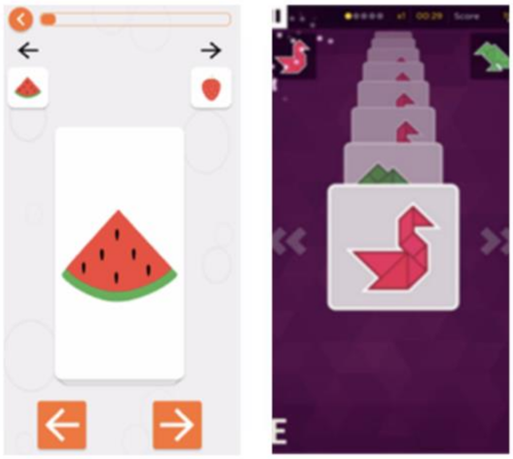

Figure 1: Focus training exercise (Skillz on the left and Peak on the right).

3.2 First iteration

In the prototype for the first iteration, we first attempted to implement the feature of incorporating elderly's everyday use of smartphones. We incorporated the cognitive training app with a text message app and YouTube. As illustrated in Fig. 2, from left to right: the user completed sending a text message, was then asked to perform a cognitive training exercise, and instructed to do a problem-solving exercise that required tapping the numbers on the screen in ascending order.

Based on the findings from user requirements gathering, we created two prototypes: one for problem-solving with number sorting (Fig 2) and one for focus training, where users needed to categorize objects. We improved the design by providing clearer and shorter instructions to the users. We also included a skip button for their convenience. Lastly, when they have completed the exercise, the app will display the status of exercise completion and their scores. The colours used in the app were kept simple.

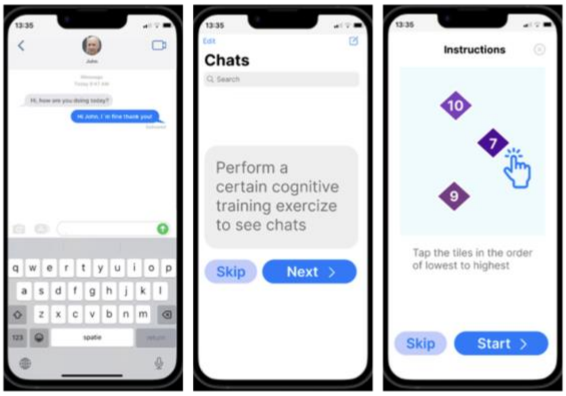

Figure 2: Incorporating cognitive training exercise in text message app.

P2 and P3 participated in the usability testing in this iteration. Both had experience in playing games on smartphones. Overall, they liked the design of the prototype. The colours and sizes of elements in the exercises were deemed suitable. In terms of usability, both of them completed the exercises without much issue, except for the fact that they did not notice the "start" button (see Fig. 2, rightmost) and they clicked on the object instead of the arrow (same design as in Skillz app in Fig 1).

Regarding rewards, both expressed an interest in receiving vouchers as rewards, and they wanted more animations when receiving rewards. For P3, he would be willing to do more cognitive training exercises if they were recommended to him and recognized as beneficial for his health. Both P2 and P3 agreed with P1 regarding the appropriate timing for suggesting to perform cognitive training exercises, i.e., after they have completed the intended tasks.

3.3 Second iteration

To address the usability issue of not noticing the "start" button, the instruction "press start to play" was added (see Fig. 3, leftmost). Animations were also incorporated around the score (see Fig. 3, middle). To avoid the confusion of clicking on arrows instead of exercise objects, we removed the arrows (see Fig.3, rightmost). Furthermore, we developed a new exercise that required users to pair two words with the same or similar meaning. In addition, we also added higher difficulty levels for the same set of exercises.

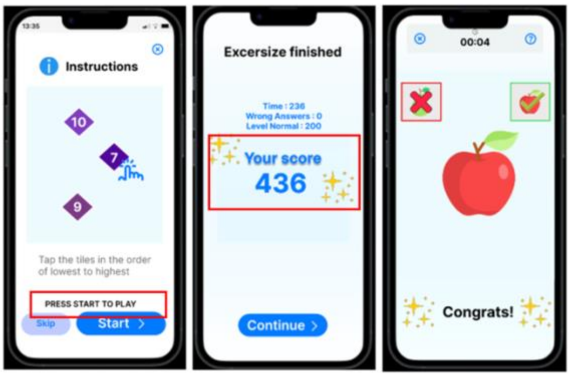

Figure 3: Changes made to improve the prototype in second iteration.

P4 and P5 were involved in the usability testing during this iteration. Same as in the previous iteration, both testers had issues understanding where and when to start the exercise. They overlooked the "start" button. The removal of arrows in the prototype of this iteration resulted in better usability. However, P4 faced a slight issue with the colours not effectively differentiating between right and wrong answers when the answers were revealed. Unlike the other earlier participants, both P4 and P5 did not find monetary rewards like vouchers motivating. For P4, she was happy with seeing words like "Congratulations!" when she completed the exercise, while for P5, it would be more engaging for her if a doctor recommended these exercises.

3.4 Third iteration

Therefore, we made the "start" button bigger by removing the "skip" button on the instruction page and kept it exclusively on the page when users were offered to perform cognitive training exercise) (see Fig. 4, leftmost). The bigger "start" button had an animation so that users could know better where and when to start the exercise. To skip the exercise, users were required to click on the cross button, located in the top right corner of the pop-up box.

We also implemented an improved design that emphasized on informing users when getting the correct answers (see Fig. 4, middle). In the previous iterations, users had to end the exercise when they made a mistake. In this iteration, we introduced a design that provided them the option to either end the exercise, or make a reattempt (see Fig.4, rightmost).

Lastly, as illustrated in Fig 5, we implemented additional new designs for receiving rewards based on all the feedback we had received from previous iterations. By presenting these new designs to the new testers, we hoped to gain further insights on rewards or results that could enhance user engagement. These new designs included displaying scores, presenting playcoins that can be converted to monetary vouchers, showing attained levels, comparing results to historical data, and displaying newly earned badges.

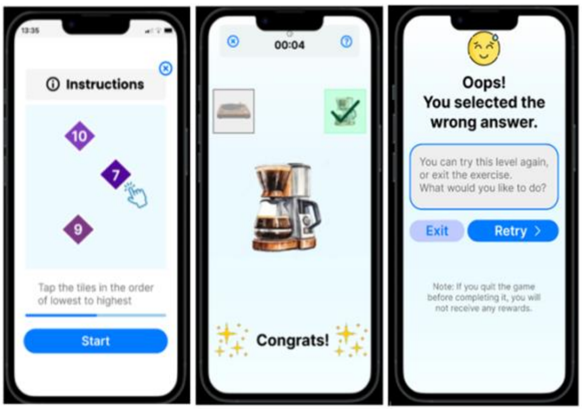

Figure 4: Changes made to improve the prototype in third iteration.

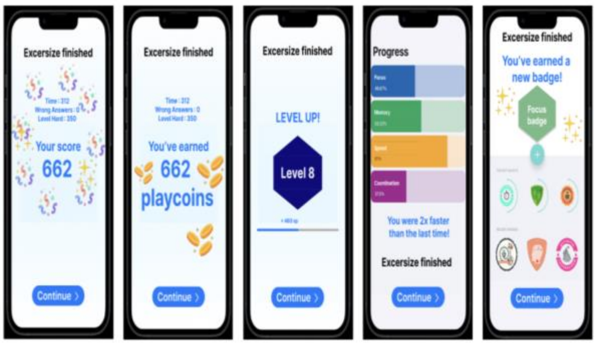

Figure 5: Designs for rewards.

In this iteration, P6 and P7 took part in the usability testing. Despite having implemented all the changes to make the exercise starting point clearer, both testers still had issues understanding where to start. They mistakenly thought they could begin right away at the instruction page. Other than that, they managed to complete the exercise without encountering many usability issues. Regarding rewards, both liked most of the proposed designs, with no specific preferences. Unlike P5, P6 preferred if the advice, or general information about performing a cognitive training was given by a researcher or an expert, instead from a doctor.

3.5 Fourth iteration

Figure 6: The page that prompts users to perform a cognitive training exercise (left) and the instruction page (right).

In the final iteration, as illustrated in Fig. 6, we modified the instruction page by completely removing the "start" button from that page. When users were asked to play the exercise, they were offered either to skip or agree to do that. If they would like to skip the exercise, they would click on the "skip" button, or the cross button in the top right corner. On the instruction page, the exercise started automatically after instructions were displayed. This was the only major change in this iteration, and testers P8 and P9 had no issue understanding this design. We purposely asked both of them to skip the exercise as part of the testing tasks, and they managed to complete this task by clicking on the "skip" button. Overall, both testers were able to interact with the cognitive training app without experiencing any usability issues. They liked the app and were positive to try it when it was fully developed.

4 DISCUSSION

In this study, we adopted a UCD approach, gathered user requirements through literature review and app research, and conducted four iterations of prototyping and evaluations. Throughout the process, we continuously improved the prototype and identified essential elements for designing an app that integrates elderly's everyday smartphone use with cognitive training. The results appear promising, as all participants expressed openness to using this app. Based on our findings, we have generated some lessons learned for designing a cognitive training app for elderly individuals. This list of lessons learned is presented on Box 1.

Box 1: Lessons learned.

1. To engage elderly individuals, user interface design is more important than types of cognitive training exercises.
2. Make the interactions in exercises natural and relatable to the real world.
3. Emphasize sensitive/important user interface elements to enhance their visibility.
4. Ensure logical flow in the app.
5. "Assuring" interactions do not always work for elderly individuals as they might trust the interactions to be simpler.
6. Keep elderly individuals motivated throughout the entire process, i.e., before, during and after performing cognitive training exercises.

4.1 Drivers of user engagement

The four iterations of prototyping and evaluation involved two different types of cognitive training exercises: problem-solving and focus training. Participants' feedback revealed that exercise preference was not based on the type of exercise itself but rather on how the exercise was designed, specifically, the user interface (UI) design. Despite the participants' ability to pinpoint their preferred type of exercise, both types obtained nearly indistinguishable responses from all participants. Thus, the users' engagement with exercises is dependent on the presence of a user-friendly design. This finding is in good agreement with the findings of Jamieson et al. (2022) and Lilholt et al. (2015), which indicated that the users, including elderly individuals (Zhu et al., 2022), engage with exercises that have an intuitive and easy-to-understand UI design.

From the findings, we are able to identify two drivers essential for promoting their engagement with the cognitive exercise app. These drivers are based on two design principles, i.e., "match between system and real world", and "recognition rather than recall". According to the relevant evaluation studies (Kaur & Chen, 2022; Lilholt et al., 2015), these two design principles play a significant role in determining the user's acceptance of the examined health systems.

According to Nielsen (1994), the "match between system and real world" design principle suggests that the design should utilize language and concepts that are familiar to users in their daily life routines. In the second iteration, the exercise was modified by removing arrows (refer to Fig. 3, rightmost) as it was deemed more natural for participants to click on an item rather than an arrow. In addition, the participants' feedback highlighted the importance of following this principle to improve user experience and overall engagement. Research shows that users preferred a clear connection between the exercises in the app and their potential positive impacts, as well as actual contributions to their mental well-being. In this study, participants expressed the opinion that they would perceive cognitive training exercises app more engaging if the recommendations, including the potential benefits, were provided by someone who typically offers such guidance in the real world, such as a physician, researcher, or other expert.

Currently, we have this design by incorporating reward feedback from experts. To further leverage this valuable insight, future app design should consider integrating a feature that enables for the seamless communication of expert recommendations directly within the app interface. This could involve incorporating brief messages, notifications, or even interactive content from authoritative figures, providing users with personalized insights and guidance. Consequently, it would enhance the overall user experience and foster greater user engagement with the cognitive training app.

The second principle is "recognition rather than recall". Nielsen (1994) describes this principle as minimizing the user's need to remember information by ensuring UI elements are visible. In line with this principle, during the early iterations (first and second) participants faced some usability-related challenges, such as recognizing the "start" button, and distinguishing colours between correct and wrong answers. In the later iterations (third and fourth), redesigning the start button and subtle elements with more noticeable sizes and colours, along with supporting animations, effectively addressed these recognition issues in the initial designs. This redesign concept aligns with the recommendations by Inostroza et al. (2016), who emphasize the importance of prominently placing sensitive/ important UI elements to reduce the users' cognitive load and improve their ability to recognize those elements in smartphone UI.

Implementing the principles of "match between system and real world" and "recognition rather than recall" provides an enhanced user experience by mitigating cognitive load, which in turn improves user engagement with mobile apps. The findings of Salman et al. (2018) and Petrovčič et al. (2018), which demonstrate the positive impact of implementing these two principles on elderly user engagement with smartphones, are in good agreement with our interpretation of the findings. First, applying the "match between system and real world" principle helps users feel more comfortable and self-assured when using an app that replicates their perception of the real world. This leads to faster learning curves and a greater chance of sustained user engagement with mobile apps. Second, "recognition rather than recall" makes the mobile app more intuitive and user-friendly by reducing the requirement for users to remember particular UI elements or information. This approach promotes a smooth user experience, which lowers frustration and encourages continued engagement. Both outcomes are particularly more important to achieve, especially when considering elderly individuals who are using an unfamiliar app; they are more susceptible to demotivation, making it crucial to ensure their user experience (Bong & Chen, 2015).

In conformance with the above discussion, app designers should take into consideration the requirements and needs of elderly users when designing an engaging mobile app. However, meeting requirements that satisfy all elderly individuals can be a challenging task. For instance, some participants preferred simple colours, while others favoured active animations. Similarly, there were different opinions on how to represent rewards, whether through playcoins or without them. These challenges are to be expected when conducting research involving elderly individuals using a mobile health app (Liu et al., 2021; Matthew-Maich et al., 2016).

4.2 Other design elements

One usability issue that we encountered in multiple iterations was related to the “start” button. Most participants overlooked the “start” button and had the expectation that the exercise would begin right away. One possible explanation is that our initial design may not have provided a clear logical flow. The participants did not expect that they had to manually start the exercise after agreeing to perform cognitive training exercises. Such an “assuring” interaction might not be necessary for elderly individuals. This can be seen as an “over-trusting” behaviour, which is consistent with that of Zhong et al. (2020) who reported a similar behaviour among their participants when interacting with the “start” button on a microwave. In their study, participants demonstrated a tendency of "over-trusting" the functionality of the "start" button on the microwave, mistakenly assuming that pressing it directly would be sufficient for operation. They were not anticipating the need for any other "additional" interactions. Additionally, there may be too many texts being displayed in the same screen (see Fig. 3, leftmost).

When it comes to skipping performing cognitive training exercises, we observed that both P8 and P9 chose the “skip” button instead of the cross symbol in the top-right corner. The design featuring both buttons was only implemented in the fourth iteration. Therefore, we were only able to test them once with two participants. We acknowledged that this lesson learned is based on a very small sample size. Besides addressing the usability issue with the “start” button, we implemented this design to provide users multiple options for declining the offer to perform cognitive training exercises, by incorporating the universal design principle “flexibility in use” (Story et al., 1998), as well as Nielsen (1994)’s heuristic “flexibility and efficiency of use”. It was not surprising that P8 and P9 preferred the "skip" button over the cross symbol, as we were aware that the visibility of the cross button was comparatively lower. Nonetheless, studies have also demonstrated that elderly individuals have a better understanding of buttons with text rather than those with symbols or images (Bong & Chen, 2015; Gatsou et al., 2011).

In addition, we have also identified some suitable approaches for integrating cognitive training exercises with elderly’s everyday use of smartphones. All participants in our study would prefer to receive the prompts to perform cognitive training exercises after they have completed the intended tasks on their smartphones. However, participants who spend more time on entertainment activities such as watching YouTube, playing games, and browsing Facebook, expressed no objection to receiving the suggestions even before starting to use those apps. This can be due to elderly perceive performing cognitive training exercises on smartphones more important than engaging in entertainment activities. When investigating the acceptance of technology among elderly people in Hong Kong, Chen and Chan (2014) identified other factors that influenced elderly people’s technology acceptance such as cognitive ability and self-reported health conditions. This suggests that elderly people might perceive the use of technology for health-related purposes to be more important than engaging in entertaining activities. However, one important thing is that the option to decline the offers to perform cognitive training exercises can never be overlooked, as the offers shall serve as reminders that encourage them to perform cognitive training exercises regularly.

5 CONCLUSIONS

In this study, we aim to propose a design concept for creating a mobile app that primarily targets the elderly population; this app would encourage them to perform cognitive training exercises when they are using common smartphone functions. Through four iterations of prototyping and evaluations, we have gained valuable insights on designing an effective cognitive training app for elderly individuals. These findings have significant implications for researchers and mobile app designers, as they can benefit from the lessons learned generated in this study.

This study is at its initial stages of inquiry, where we have gathered user requirements and proposed the design concept for creating this mobile app. Therefore, one of the main limitations is that we have yet to evaluate whether this app can effectively encourage elderly smartphone users to perform cognitive training exercises over a longer period of time. Another essential element for this app that we did not manage to cover in this study, is about how often these suggestions asking elderly smartphone users to perform cognitive training exercises should be prompted. Although elderly individuals can choose to skip when being asked, it is important to ensure the frequency of prompting suggestions does not irritate them.

Research bias is a recognized challenge, and in this study, it may be particularly noticeable. The first interview for user requirement gathering and all evaluations except with P8 and P9 were conducted by a group of students enrolled in the European Project Semester course. Although this observation is subjective, they reported that Norwegian participants who evaluated the prototypes with them were very polite and friendly. They might have provided biased answers to favour the students. We were able to identify usability issues by observing how the participants interacted with the prototype. However, in terms of design elements such as colours and rewards after completing an exercise, there was nothing for us to observe.

Lastly, other limitations of this study include a small sample size and relatively homogeneous participants, predominantly representing the ethnic Norwegian population. Despite our awareness of the rule of thumb for conducting usability evaluations, we had to consider factors such as feasibility concerns (both in terms of recruiting participants and conducting evaluations with them) and this study being at its initial stage of inquiry (Caine, 2016). Therefore, we made the decision to have two participants in each iteration for this UCD approach.

As part of our future research plan, we intend to conduct further testing and evaluation of the most recent version of the prototype. This forthcoming evaluation will engage a minimum of 15 participants, a sample size deemed adequate for generating statistically significant findings, in multiple rounds of app testing iterations. The execution of such a prospective investigation will serve to mitigate a limitation identified in the current study, namely the insufficient availability of participants for engaging in iterative evaluations of prototype versions. Subsequent versions of the app, informed by the outcomes of this planned study, hold promise for enhancing our ability to reach a comprehensive and statistically substantiated determination regarding the extent to which revised prototype versions address participants' concerns and ultimately improve their user experience.

We hope to further develop the mobile app and have it fully functional. Future studies should consider conducting a longitudinal study to investigate how elderly individuals engage with and benefit from the app over an extended period. A larger sample size should also be targeted. In addition, we should engage researchers with expertise in brain function, cognitive psychology, or related fields to collaborate. This multidisciplinary approach will provide valuable insights concerning the app's effectiveness in training elderly individuals' cognitive abilities.

Building on this multidisciplinary collaboration, we aim to have the app used and tested by patients with MCI. Although the app is not specifically designed for them, engaging in cognitive training exercises could provide some level of cognitive stimulation, potentially helping to slow the progression of cognitive decline. Importantly, it should be noted that the design, i.e., usability and functionality, of such an app for individuals with MCI would likely be different. Therefore, it will require evaluations with different settings through further research and user testing. Last but not least, by utilizing advancements in machine learning and artificial intelligence, we see potential in incorporating a personalised system in the app. This would adapt the UI and the game logic/mechanism to better suit specific groups of users and/or patients.

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