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Development and evaluation of cognitive game application for Filipino elderlies: A Design - Based Research

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Abstract

Many types of research exposed those games have been pointed out as training interventions to remediate cognitive decline among elderlies. In this study, the game apps were casual games that covered the cognitive domains: affect attention, executive functioning, memory, language, and visuospatial function. The participants tested the game which is in real-world scenarios with different variables. Various components of the design were refined by the developer using Design-Based Research composed of two cycles. It involves: ((I) Evaluating whether the game environment was accepted with the structure of cognitive training and exploring suggestions for its redesign to improve the usability; and (II) Designing and testing the game app to verify and refine its context and usability. Using Davis's Technology Acceptance Model (TAM) questionnaire, the fifteen elderly participants agreed on its usefulness and ease of use. They showed a positive attitude and intentions toward using it. However, evaluation from the game developers proposed some more enhancements on an interface, interaction, and feedback mechanisms. This study suggests that the game app's efficacy as a cognitive enhancer may be tested on a larger scale and more prolonged period.

Keywords— cognitive decline, cognitive domains, cognitive game app, Design-Based Research (DBR), elderlies

Introduction

The population of the world is aging today. Executive director of the Asia Pacific Risk Center, Wolfram Hedrich, said that the Asia-Pacific Region is aging faster than any other region. The Philippines is contributing to that phenomenon. The country's 60-year-old population is projected to grow by 4.2 percent, while it is estimated that the 80-year-old and older people will increase by 0.4 percent from 2010 to 2030 (Help Age Global Network 2017b). A report of the Philippine Institute for Development Studies (PIDS) in 2018 found that this country is already heading to becoming an aging society. While it is growing gradually, it is estimated that by 2032, the elderly, or those aged 65 and older, will constitute at least 7 percent of the total population. By 2069 it will have become an "aging society," with at least 14 percent of the people. Although an aging population is a sign of increased growth, it also requires more resources and facilities to meet their needs, particularly their rising mental health needs (Weng et al., 2019).

As evidenced by Neurochemical theory, Localized theory, and Process theory, cognitive aging has gained prominence as domain-specific, age-related cognitive changes that affect importance, executive functioning, memory, language, and visuospatial function at a minimum. In general terms, the effect of biological aging is a decline in both physical and cognitive functioning (Clouston et al., 2013). The World Health Organization (WHO) has thus encouraged healthy aging as a global priority. Foster and Walker (2015) identified active aging intending to promote the right of older people to remain safe (reducing health and social care costs), staying longer in jobs (reducing pension costs), while still engaging in community and political life. Participants addressed the recommendations in their 2015 conference on how to preserve the memory, ability, and physical function of elderlies promote their social involvement and

emphasize the skills and expertise they should possess (Lu et al., 2017).

One way to support the elderly is to undertake research, but the sad reality revealed by Villegas (2014) is that aging in our country remains a highly under-theoretical topic. In 1996, the National Institutes of Health (NIH) was founded in the University of the Philippines Manila, the only government institution that focuses on aging, to tackle this problem. It aims to contribute to the national development and improvement of the Filipinos' quality of life as they age. It will create infinite possibilities for its value-added existence through scientific study, training and education, and specialized services with the aged Filipino. Their groundbreaking work was published in 2006 with the monograph "Maximizing the Quality of Life of the Elderly Through Better Health ." In one of its articles, one written by Dr. Shelley de la Vega, entitled "Research Issues on the Improvement of the Quality of Life of Filipino Older Persons," surveyed that the most significant percentage of senior citizens (elderlies) was found in Southern Tagalog (Region IV) with a contribution of 14.2 percent to the total, and mostly women. Her research also showed that older people correlated improved quality of life with the area of physical health. They recommended prevalence and longitudinal studies on morbidity and mortality, functional status, and disability, emphasizing major geriatric syndromes such as dementia and delirium to validate this result.

Dominguez et al. (2014) conducted a study. They found that dementia may not be detected as some people still consider cognitive decline part of normal aging. Older people are excused from demanding mental activities and access to timely diagnosis is limited. Another study conducted by Ten Brinker et al. (2018) found that no curative pharmaceutical therapy currently exists for cognitive impairment and dementia; thus, they emphasized that it is essential to identify strategies that promote healthy cognitive aging and minimize cognitive decline. One of which is using technological devices, which is now part of their daily lives.

With the development of technology, elderlies have been allowed to interact very quickly, primarily through devices such as mobile phones. The use of this type of unit, also by them, is increasing in particular. Many studies revealed that technological devices could enhance their well-being and health conditions. It was also found to have strengthened their functional abilities as they play digital games. Jung et al. (2009) found that engaging in this type of game impacts the emotional and physical well-being of the elderly in nursing homes. These games can delay the loss of memory and cognitive impairment and even enhance cognitive skills that are deteriorating due to the phase of aging. Many commercially accessible gaming products, on the other hand, are not appropriate for elderlies (Gerling K.M et al., 2012). An organized approach to digital game design for therapeutic applications and serious games is needed. In addition to developing therapeutic apps and serious games, this Rarely group has academic work on an audience based on age-related changes and deficits (Nap, H.H., 2009). Thus, on these premises that this study was conducted.

Objectives

This study was conducted primarily to evaluate the develop cognitive game application for Filipino elderlies. Specifically, it determined the following on the game app: (1) The level of acceptability in terms of its contexts: (a) perceived usefulness, (b) perceived ease of use, (c) attitude towards using, and (d) intentions to use; (2) Usability heuristics as perceived by elderlies and game developers; and (3) Comments, suggestions, and recommendations from the participants to enhance the game applications.

Materials and Methods

This study employed the Design-Based Research (DBR) used by u, M. H., Lin, W., & Yueh, H. P. (2017). It was adapted from Barab and Squire (2009) in its approach to the relatively recent idea of creating cognitive training games for elderlies. The emphasis of the study was the evolution of a digital game through iterative processes as a design artifact to assess both the theoretical and functional consequences of the games.

Research Design

The cognitive training game created in this study was described as a casual game. In complex real-life settings involving several variables, the game was investigated, and different design aspects were optimized using DBR. Two cycles of design were adopted and are shown in Figure 1.

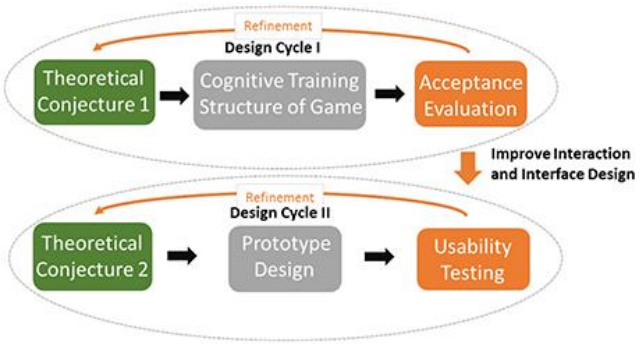


Figure 1. Design-Based Research (DBR) Model

Source: Adapted from Barab and Squire (2004)

The two iterations made successful refinements in style, interpretation, review, and redesign. The **first iteration** concentrated on determining whether the game environment agreed with the cognitive training framework suggested in **Figure 1** and addressed suggestions for enhancing its usability following its redesign.

The **second iteration** focused on designing and testing the structure and function of the game application to verify and improve the meaning and usability of the game. An acceptance assessment and usability testing were carried out in the homes of selected elderlies to obtain the data in genuine use contexts.

Participant Recruitment

There are two groups of participants in this study: the elderly and game developers/I.T. experts. Each participant had to fill up an informed consent form before being given a questionnaire. The said form contains complete information about the study's goal, research process, data collection, potential risk, and compensation.

Fifteen 15) elderlies performed heuristic evaluations of the mobile cognitive game application. They were chosen through purposive and convenience sampling. All of them were retired government employees and had their mobile phones. Five of them were males, and the rests were females.

Five (5) game developers/I.T. experts participated in evaluating the game application. They were identified to have developed their casual games before.

Data Collection Procedures

The following steps in Figure 2 on the next page were undertaken in collecting data for this study:

Figure 2. Data Collection Procedure

Interview of the Cognitive Training Structure for the Game App

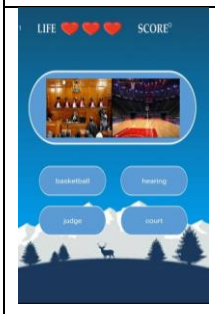
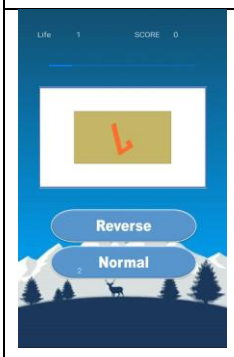
Theoretical foundations of aging cognition and technology were examined and organized into design guidelines to create this cognitive training game application. Based on the literature review provided in Figure 1, the cognitive training framework of the game was first proposed. The researcher conducted a semi-structured interview with three medical doctors of rural health units in the province to solicit their experiences of encounters with those with mild dementia. The interview guidelines covered four aspects: (1) What are the everyday life and physical and mental statuses of elderlies you have encountered in the rural health unit/facility you are working in? (2) What are cognitive training activities these elderlies participate in in your community? (3) Do these elders use gadgets/devices in playing games, and what is their technological ability? (4) Is a cognitive training game design for elderlies important? Why or why not? The results of these questions were recorded, encoded, and integrated into the mobile game application development.

Game Selection

According to their goals and characteristics, there is a wide range of games grouped by genres. Genres encourage the creation of games so that existing components can be reused and improved. However, in this study, only the brain and puzzle genres of the mini-games were focused on.

The following are the cognitive game apps developed:

Cognitive Game Apps

Name	**Cognitive Domains**	**Descriptions**
 Match Me	memory and attention	This game aims to develop the memory and attention of the elderly. You can get the point if you match the two pics correctly upon pressing them consecutively. Both pics will close whenever you unmatched them, and the matching continues. Recording of many tries can be found on the upper left portion of the gadgets' screen. It can be played in 2 x 2, 2 x 3, or 3 x 4.
 Mi Homo	Memory, language and visuo-spatial function	There are lots of words of the exact spelling but with different meanings. They are called "homonyms." So in this game, two images will be flashed, and the player will select the homonym for it. Whenever the correct name is pressed, a corresponding point will be given. The total attributes for this game is 5.
 Gyre	Memory, language and visuo-spatial and executive functions	This is a rotation game. The player needs much familiarization with the alphabet (capital and small letters and of how they have been positioned. You need proper identification of whether these letters are in reversed or normal positioning. It must be done quickly since the time limit for each game is 5 seconds. Each correct answer has corresponding 5 points.

	Memory, language and visuo-spatial and executive functions	This game requires much focus and attention because it can be played in 10 seconds only. You must have memorized the colors so that you can match them quickly to their names. For every correct identification, 5 points will be given. Whenever, your score got the highest, you will be considered as the top ranked.

Acceptance Evaluation

Elderlies performed an acceptance assessment to determine whether or not the framework of the game's cognitive training was suitable for elderlies. These elderlies were asked to perform heuristic evaluations of the game applications installed in their phones using the Technology Acceptance Model Questionnaire by Davis (2004).

Formative Evaluation and Usability Testing

The elderlies did the formative assessment by answering the Usability Heuristics Questionnaire developed by Santos, Luana Giovani N. O., et al. (2017). The evaluation centered on the specific features of the games and their experience while playing the game.

The game developers/I.T. experts also assessed the heuristics for user interface design formulated by Jakob Nielsen. Because they are broad rules of thumb rather than precise usability requirements, they are referred to as "heuristics." It is composed of ten (10) principles that should be met so that the design will be considered usable.

Results and Discussion

Tables 1 through 3 can be found on the following pages to summarize the study results.

Table 1. Acceptability evaluation of mobile game app for the elderlies

Game App Contexts	**Weighted Mean**	**Descriptive Interpretation**
A. Perceived Usefulness		
Playing the game app…		
1. helps boost my memory	4.67	VH
2. enhances the performance of my daily task	4.80	VH
3. motivates me to finish tasks quickly	4.67	VH
4. makes me catch up on directives/ instructions	4.27	H
Over-all Usefulness	***4.60***	***Very High Agreement***

Table 1. Acceptability evaluation of mobile game app for the elderlies…

Game App Contexts	Weighted Mean	Descriptive Interpretation
B. Perceived Ease of Use		
Playing the game app makes it easy in …		
1. becoming skillful at using other gadgets and devices.	4.33	VH
2. applying the techno skills in performing daily tasks	4.33	VH
3. understanding instructions and directions.	4.47	VH
4. making decisions more flexible and optional.	4.67	VH
Over-all Ease of Use	***4.45***	***High Agreement***
C. Attitude Toward Using		
Playing the game app is …		V
1. good	4.40	H
2. favorable	4.60	VH
3. a positive influence for me	4.67	VH
4. valuable to use	4.53	VH
5. trendy	4.40	H
Over-all Attitude	***4.52***	***Very High Positivity***
D. Intention to Use		
I tend to use the game app to…		
1. apply the strategies learned in my daily tasks.	4.73	VH
2. try to challenge me to get a perfect score.	4.73	VH
3. boost my interest in performing speedy tasks.	4.80	VH
4. intense my desire in playing.	4.80	VH
5. provide multi-approaches in dealing with problems encountered.	4.80	VH
Over-all Intent	***4.77***	***Very High Positivity***

Legend:

Weighted Mean (WM) **Descriptive Interpretations(DI)**

4.51 – 5.00	Strongly Agree (SA)	Very High Agreement/Positivity (VH)
3.51 – 4.50	Partially Agree (PA)	High Acceptability/Positivity (H)
2.51 – 3.50	Neither Agree Nor Disagree (NAND)	Neither High Nor Low Acceptability/Positivity (NHNL)
1.51 – 2.50	Partially Disagree (PDA)	Low Acceptability/Positivity (L)
1.00 – 1.50	Strongly Disagree (SDA)	Very Low Acceptability/Positivity (VL)

How high the elder participants accept the mobile game app was presented in Table 1. It should be noted that the utility of the game app with a weighted average of 4.60 has been widely accepted, and its ease of use is highly accepted. They significantly believed that it enhances the performance of their daily tasks (4.80) and helps them decide on a more flexible and optional manner (4.67). Moreover, their attitude towards using and intention to use it received very high positivity, 4.52 and 4.77, respectively. They also experienced that this game has a positive influence on them that they are very willing to play again and again. This result justifies those elderlies are very glad to play the game app due to their cognitive training benefits.

Table 2a. Usability heuristics for the evaluation of mobile game app for the elderlies

(n = 15 elderly participants)

Heuristics The games'…	**Weighted Mean**	**Descriptive Interpretation**
1. controls are precise, customizable, and physically comfortable; their respective response actions are immediate.	4.73	VHA
2. the main objective was presented to me since the beginning of the game.	4.67	VHA
3. visual representations can be easily understood by me.	4.67	VHA
4. aesthetics of the screen is pleasing, with visible content, enabling the identification and understanding of its components.	4.60	VHA
5. sessions/matches allow quick start.	4.60	VHA
6. graphics and soundtrack catch my interest.	4.47	HA
7. challenge can be adjusted according to my skill, and is not repetitive nor boring.	4.40	HA
8. layout and menus are intuitive and organized to keep my focus on the game.	4.40	HA
9. allow me to develop skills needed in the future.	4.20	HA

As a player, I … 10. am rewarded for my achievements clearly and immediately. 11. find a tutorial/help to get familiar with the game. 12. save the current state from resuming the game later. 13. can quickly obtain information about everything around me, including my score. 14. can customize the audio and the video of the game according to their needs.	4.49 4.48 4.45 4.44 4.43	VHA HA HA HA HA
Over-all Acceptability	***4.51***	***Very High***

Legend:

Weighted Mean (WM)	**Descriptive Interpretations (DI)**	
4.51 – 5.00	Strongly Agree (SA)	Very High Acceptability (VHA)
3.51 – 4.50	Partially Agree (PA)	High Acceptability (HA)
2.51 – 3.50	Neither Agree Nor Disagree (NAND)	Neither High Nor Low Acceptability (NHNLA)
1.51 – 2.50	Partially Disagree (PDA)	Low Acceptability (LA)
1.00 – 1.50	Strongly Disagree (SDA)	Very Low Acceptability (VLA)

The elderly participants were able to familiarize themselves on the features of the game app as evidence by their acceptability ratings of high to very high (4.20 - 4.73). The following indicators are the notable ones (See Table 2a): game controls are clear, customizable and physically comfortable (4.73), main objective was presented to them since the beginning of the game and visual representations can be easily understood (4.67); aesthetics of the screen is good, with a visible content, enabling the identification and understanding of its components and sessions/matches allow quick start (4.60). The rests of the features were highly accepted. This result indicates that the elderlies acknowledged the very high usability of the game app.

Table 2b. Usability heuristics for the evaluation of mobile game app for the elderlies

(n = 5 game developers)

Heuristics	**Weighted Mean**	**Descriptive Interpretation**
1. Aesthetic and minimalist design - Information that is irrelevant or only occasionally required should not be included in dialogues. In a discourse, each additional unit of	4.60	High

information competes with the relevant information units, lowering their relative prominence.		
2. Match between system and the real world - The system should speak the players' Instead of using system-oriented terms, utilize words, ideas, and concepts recognizable to the user. Follow real-world norms to present data in a logical and natural sequence.	4.40	High
3. Recognition rather than recall - Minimize the player's memory load by making objects, actions, and options visible. The player should not have to remember information from one part of the dialogue to another. Instructions for using the system should be visible or easily retrievable whenever appropriate.	4.20	High
4. 4. User control and freedom - Players frequently, system functions are chosen by mistake, necessitating the use of a designated "emergency escape" to quit the unwanted state without having to go through an extensive discussion. Support undo and redo.	4.00	High
5. 5. Visibility of system status - The system should always keep players informed about what is going on through appropriate feedback within a reasonable time.	4.00	High
6. Flexibility and efficiency of use - Accelerators — unseen by the novice player — may frequently speed up the interaction for the expert user, allowing the system to accommodate both beginner and experienced users. . Allow players to tailor frequent actions.	4.00	High
7. Consistency and standards - Players should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.	3.80	High
8. Error prevention - Even better than good error messages is a careful design that precludes the occurrence of a problem in the first place either remove error-prone conditions or check for them and give users a confirmation choice before allowing them to proceed to commit to the action.	3.80	High
9. Help players in error detection, diagnosis, and recovery - Error messages should be written in simple English (no codes), clearly state the problem, and offer a helpful remedy.	3.80	High
10. Help and documentation	3.40	Neither High Nor

- Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be accessible to search, focused on the player's task, make a list of clear steps to be followed, and keep it manageable.		Low
Over-all Usability	***4.00***	***High Usability***

Legend:

Weighted Mean (WM)	**Descriptive Interpretations (DI)**	
4.51 – 5.00	Strongly Agree (SA)	Very High Usability (VH)
3.51 – 4.50	Partially Agree (PA)	High Usability (H)
2.51 – 3.50	Neither Agree Nor Disagree (NAND)	Neither High Nor Low Usability (NHNL)
1.51 – 2.50	Partially Disagree (PDA)	Low Usability (L)
1.00 – 1.50	Strongly Disagree (SDA)	Very Low Usability (VL)

Table 2b presents the usability heuristics of the mobile game app as evaluated by the game developers. Though the overall evaluation falls under high usability (4.00), there are still components to be looked into. Specifically, help and documentation (3.40) are necessary whenever they find difficulty playing the games. Next is consistency and standards. Since players looked into patterns, there is a need to give clues whenever malfunctioning exists. This result justifies that the game developers perceived the game app as highly usability. This is consistent with the result of the study of Adcock et al. (2020) that the training game showed to positively influence physical and cognitive functions. They also emphasized that some aspects of the exergame prototype can and should be improved.

Table 3. Comments/suggestions of the participants regarding the game app

Elderlies	**Game Developer**
1. Very help and easy to play game app. 2. There is a need to embed the directions on how to play and win in the game.	*Some more enhancements on interface, interaction and feedback mechanism*

Conclusions and Recommendations

The following conclusions are drawn in light of the findings:

1. The elderly participants were able to familiarize themselves with the features of the game app and are very much willing to play it due to its impact on cognitive functioning.
2. The elderly participants and game developers acknowledged the very high usability of the game app.

Based on conclusions and suggestions of the participants, the following recommendations are now offered:

1. The use and play of the developed game app are highly encouraged among elderlies who can use mobile phones upon considering the suggestions: some more enhancements on an interface, interaction, and feedback mechanism.

2. Testing the effectiveness of the game app to cognitive functioning is highly recommended.

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