Developing Serious Games to Promote Cognitive Abilities for the Elderly

Hongmei Chi[1] and Edward Agama
Department of Computer & Information Sciences
Florida A&M University
Tallahassee, FL 32307, USA
[1]hongmei.chi@famu.edu

Zornitza Genova Prodanoff
School of Computing
University of North Florida
Jacksonville, FL 32224, USA
zprodano@unf.edu

Abstract—**This paper presents the design of a computerized serious game suite called the "Smart Thinker", which is used to enhance core cognitive skills. The focus is specifically on memory and attention skills. Smart Thinker empowers older adults to exercise their brains and achieve their maximum cognitive performance. To achieve this objective, a thorough study was completed on 59 older adults who were randomly separated as participants of a controlled group or an intervention group. The 20 participants within the controlled group did not play Smart Thinker and were not surveyed. The Mini Mental State Examination (MMSE) was administered to both groups at the beginning and ending of the six week period. The measuring tool was administered under the guidance of licensed clinical social workers of the Alzheimer's Project and was used to determine whether Smart Thinker had an effect on the participants' cognitive functioning. This game research revealed a significant improvement in the cognitive skills of the intervention group who used Smart Thinker Game compared to the controlled group who did not play Smart Thinker.**

Keywords— *Serious Game, Cognitive Skills, Alzheimer's disease, Dementia, Smart Thinker.*

I. Introduction

Cognitive impairment is when a person has trouble remembering, learning new things, concentrating, or making decisions that affect his or her everyday life [1]. According to a publication funded by the Centers for Disease Control and Prevention, an estimated 5.1 million Americans, aged 65 years or older may currently have Alzheimer's disease. Alzheimer's is the most well-known form of cognitive impairment and this estimation may rise to 13.2 million by 2050 [2]. This terminal, progressive brain disorder unfortunately has no known cause or cure [3]. Alzheimer's is on the rise throughout the world and it is shocking to know that each day, thousands of American families are forever changed by this disease. Worldwide, nearly 44 million people are believed to be living with Alzheimer's disease or dementia, and that number is projected to increase to 76 million by 2030 [4]. The impact of these cognitive disorders on the older population such as memory loss, decreased activity and poor judgement are alarming as the consequences are difficulty to manage and imply that effective interventions aimed at the older population would be beneficial. Most of the research done in the realm of Human–Computer Interaction (HCI) is performed on young people [5]; nevertheless, with the upsurge of cognitive impairments in older adults, it is imperative for researchers to put a greater focus on older adults and their cognitive health needs.

Recent studies have started to investigate the effectiveness of serious games in people with cognitive impairment, such as Alzheimer's disease and other related disorders [6]. As a brief introduction, serious games are defined as computer or video games designed for a primary purpose other than pure entertainment and have more "serious" purposes [7]. Research studies have demonstrated the increase of cognitive skills, reaction times, self-esteem, and a sense of well-being in the elderly when playing computer games. In a personal health article posted in the New York Times, Dr. Ronald C. Petersen, a neurologist at the Mayo Clinic College of Medicine, provided several possible ways to preserve cognitive functioning, such as taking certain medications, reducing stress, and decreasing cardiovascular risk. Most enlightening was his statement that although "some cognitive rehabilitation exercises, like computer games to enhance focus, may be helpful with cognitive impairments, but there have been few good studies to demonstrate such benefit [8]." For this reason, Smart Thinker is undoubtedly a needed instrument to the rapidly expanding older population as this research demonstrates its prodigious benefits as a suite of serious games to improve cognitive skills of older adults.

Though the concern of cognitive impairment is being addressed with exergames such as iDance [9], and brain training games such as Lumosity (https://www.lumosity.com/), there is also a great need for Smart Thinker because it aims for ways to prevent cognitive impairment. It accomplishes this goal at no cost to the older adults unlike other serious/brain games which have purchase fees or subscription requirements. A preliminary survey, conducted during this research, revealed that older adults face challenges using serious games such as purchase costs, the rigorous nature of starting online games, game device complexity, skill level requirements, and privacy concerns where players are required to provide personal identifiable information such as credit card information among others. Taking steps to address this issue will ultimately have a positive impact on older adults in our families and communities. This research, therefore, intends to develop a computerized serious game suite that mitigates against cost, complexity, privacy concerns, and start up procedures targeted to older adults. This suite is designed to be easily accessible with no cost to the players. Furthermore, it is being developed

with a simple design interface that is engaging and enjoyable while simultaneously enhancing older adult memory and attention skills. Cognitive impairment can affect all age groups, but because aging is a major risk factor of cognitive impairment, the concentration of this study is directed towards older adults who are 55 years of age or older.

This paper is organized as follows. Section II presents an overview of related studies that examined the relationship between previously proposed mHealth apps on cognitive decline in adults. The proposed by this study game application is introduced in Section III. It is based on the on-line Smart Thinker suite of serious games. The methodology used and the game implementation details are described in Section IV. The final two sections provide an overview of the study results and conclusions, respectively.

II. Related Work

A literature review of mental health problems and needs was an essential part of this research in order to ascertain more details regarding health conditions that are linked to a decline in cognitive abilities for older adults. Equally important was the need to gain more knowledge about what methods are used to resolve this issue. According to the Centers for Disease Control and Prevention (CDC) and the National Association of Chronic Disease Directors (NACDD), it is estimated that 20% of people age 55 years or older experience some type of mental health concern [3]. The most common conditions include anxiety, severe cognitive impairment, and mood disorders. With mental health problems on the rise, it is imperative that continual research and design of serious games and tools are available to stimulate psychological well-being and satisfactory adjustment to the ordinary demands of life for older adults worldwide. This effort has been sought out by Ada Kwan who conducted a thorough research entitled *mHealth Solutions for Mental Health and Aging and Illnesses in the Aging Process* which reveals that mHealth Solutions intervention can help with cognitive health, mental health, monitor moods, promote healthier behaviors associated with better mental health, develop awareness about what to expect during mental health care and treatment, and provide adults access to interventions without traveling to trained professionals [10]. Kwan found that for mental health issues in aging, all of these barriers are further surrounded by cognitive decline and other factors; however, they have implemented several strategies to fulfill their research, including cognitive fitness technologies, such as thinking games, with assessment and tracking components.

Lumosity is an online brain training and neuroscience research company that offers a brain training program consisting of more than 40 games in the areas of memory, attention, flexibility, speed of processing, and problem solving [11]. To begin playing their games, a user has to select all aspects of memory, attention, speed, flexibility and problem solving that a user wants to improve. The user then has to create an account with a name, password, email and date of birth. The user is also required to provide bio-data relating to gender, educational level and job. Additionally, a user has to provide answers to questions such as (1) what time of day are you most productive? (2) How often do you exercise? (3) How much sleep do you usually get each night? and (4) What other devices would you like to do Lumosity training on?

Just as Lumosity, ***BrainHQ*** also offers online brain fitness from Posit Science that performs cognitive training exercises for processing speed, attention and memory among others [12]. Users are required to sign up and decide how to train by selecting categories of training as it relates to the various cognitive skills. Users are allowed to try a few games for free, but to continue, a user has to subscribe with a payment plan. BrainHQ uses a dual metric of stars (1-5) and percentile rank to track user performance.

Dakim is a "brain fitness program," that is able to address the kind of mental tasks that have been demonstrated to play a role in preventing Alzheimer's and related symptoms. Dakim is mainly designed to improve attention and concentration and offers its users a set of games and puzzles designed to help exercise their brains [7]. UCLA researchers have found that older adults who regularly used a brain-fitness program on a computer demonstrated significantly improved memory and language skills.

III. Smart Thinker Games

This research provides a significant solution to resolve problems faced by older adult game players and to empower them to meet their cognitive enhancement needs.

Table 1: Games and Cognitive Descriptions

Games	Cognitive Description	Cognitive Skill
High-Low	This is a math puzzle game that requires users to decide whether a number is greater or less than previously displaced number. A player needs to be constantly attentive to recall the immediate previously displayed number.	Attention
Color Game	This is a color game that displays a grid of colors that appears on a background color. A player must constantly be attentive to keep up with matching grid colors that are similar to the background color due to the constantly changing background color.	Attention
RPS	This is a popular fun game that uses objects such as Rock, Paper, or Scissor. The player follows the rules to determine which object wins in each round.	Memory
Find Me	This is a sentence game that requires players to constantly remember displayed sentences and their object locations in each round.	Memory

Our solution is framed as the design and implementation of Smart Thinker, a free web-based suite of serious games designed for older adults with a simple interface to support their cognitive enrichment needs.

The proposed game application includes Color Game, High-Low (number game), Rock Paper Scissors (picture game), and Find-Me (word game). Cognitive functions influenced by Smart Thinker are attention and memory as discussed next.

Table 1 above describes Smart Thinker games and their respective cognitive descriptions. Other inherent cognitive skills to which Smart Thinker could provide benefit include brain speed and judgement and decision making; however, these other skillsets are not the focus of this research.

This research project does not suggest that playing the game once or twice guarantees cognitive enhancement. Game players are encouraged to repeatedly play these games which, through repetitive usage, would inherently enhance core cognitive functioning. Smart Thinker also provides motivation to its players through rewards for high scores to maintain interest.

Smart Thinker game framework consists of four layers: participant access to Smart Thinker, cognitive skills selection, games, and feedback. In the first layer, the participants initially register or login into Smart Thinker using appropriate credentials defined by rules.

The second layer allows participants to choose which cognitive skills to enhance. The third layer allows participants to select games that correspond to cognitive skill areas. The fourth layer provides necessary feedback to Smart Thinker players in the form of scores.

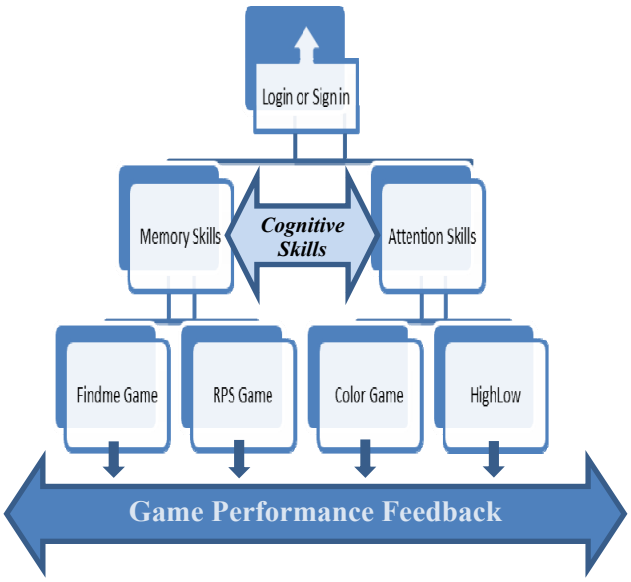

Figure 1 – Overview of the Proposed Game Framework

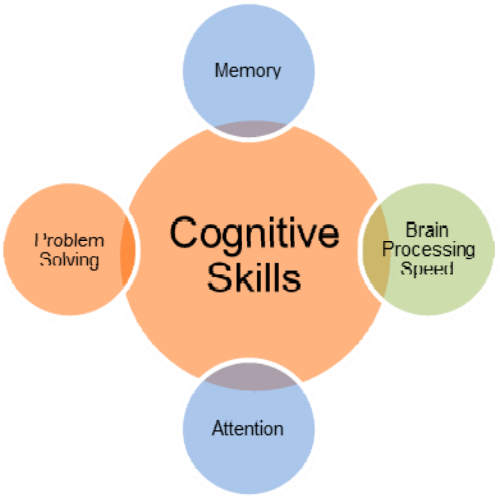

Figure 2 – Example of Cognitive Skills

Figure 1 demonstrates the overview of the game framework and consists of four layers. These layers explain the sequential processes involved as players interact with the game platform.

A. Cognitive Skills

Cognitive skills are essential in our approach to everyday life. This research focuses on enhancing two important cognitive skills among older people; short-term memory and attention skills. Cognitive skills are the mental capabilities that allow people to process the information received from their five senses [13]. These skills which include reasoning, awareness, perception, knowledge, intuition and judgment are needed for a person to be able to think, talk, learn or read. They are what gives a person the ability to recall things from memory, analyze, concentrate and draw association from various pieces of information. One source indicated that as people age, they are tempted to withdraw from social interaction, giving them less opportunities to engage in matters important to them. Nonetheless, there are still daily activities that older adults can do to help keep their minds active and alert such as playing games, making crafts, and solving puzzles. These are essential to engaging the brain and improving cognitive skills and memory [14]. Figure 2 describes a few examples of cognitive skills.

B. Participant Recruitment

This research recruited older adults, age 55 and older, through flyers placed on notice boards at Tallahassee Senior Center and Jake Gaiters Community Center. Potential participants consented to be part of the research and were asked to complete preliminary paper questionnaires to qualify their participation. The preliminary questionnaire contributed largely to the selection and design of Smart Thinker. Out of a total of 54 older adults who completed the questionnaire, 42 were approved to participate. Approval was denied to subjects

below age 55 or who did not want to be contacted for research participation. The 42 subject sample size consisted of 42.6% males and 57.4% females. Qualified preliminary study participants were later contacted to be part of further research after Smart Thinker games were fully functional. The qualified participants and further recruited subjects consisted of 59 older adults who were randomly placed into two groups namely: Control group and Intervention group.

The *Control group* consisted of 20 participants who did not play Smart Thinker games at all but participated in both pre and post Mini Mental State Examination (MMSE) assessments.

The *Intervention group* consisted of 39 participants who were administered a standard cognitive assessment tool, MMSE under the guidance of qualified licensed clinical social workers from the Alzheimer's Project. This pre-assessment qualified them to the next stage of gameplay for six weeks. Each participant played Smart Thinker four times a week and ten minutes per game. Participants in the intervention group were again administered the MMSE tool as a post assessment. Some participants from this group also completed a survey about their game user experience.

IV. Methodology and Game Implementation

The development of Smart Thinker was realized on Windows 8 machine using technologies best known for web development such as HTML, CSS and JavaScript. Although the game was developed using JavaScript, it operates using Phaser engine.

A free software tool, written in PHP, called phpMyAdmin, is intended to handle the administration of MySQL over the Web. It can perform various tasks such as creating, modifying or deleting databases, tables, fields or rows. It can also execute SQL statements or manage users and permissions [11]. Smart Thinker's back end manages the user login system and the game data. The user login system enables sessions and uses both PHP and MySQL in order to maintain user records and their individual gaming history. This provides the front end with quantitative data of game performance for its players.

A. Procedures

The Procedures for this study consists of seven parts:

An Institutional Review Board (IRB) Approval: To conduct research involving human subjects; an IRB committee has to review and approve the research to ensure that the research is conducted in accordance with all federal, institutional, and ethical guidelines [15].

Literature Review and Preliminary Assessment: This research began with preliminary investigation and literature review of current serious games for the elderly without specific application in mind. The review continues with an assessment of existing games and technological devices used among the elderly for games. Research participation is voluntary and participants comprise of adults age 55 and above who were recruited and randomly placed in two groups: an intervention group and a control group. A preliminary investigation was conducted to assess older adult gameplay patterns and how useful games contribute to enhancing cognitive skills. The preliminary investigation also reviewed current games that seniors play and ascertained online games that could positively influence their interest and enhance their memory and attention skills.

Game Design and Development: The researcher analyzed the results from a literature review and the preliminary assessment and based off these results, proposed the design and development for the Smart Thinker framework with the objective of enhancing cognitive skills via a fun game.

Usability Testing: This was a key step in the successful design and development of new applications, ensuring the intended users are able to interact easily during game play.

Pre-Assessment: Literature review stresses that an important aspect in the evaluation of serious games, like other educational tools, is user performance assessment [15]. To evaluate Smart Thinker game framework and its impact on participant cognitive skills, this research used standard cognitive assessment tool Mini Mental State Examination (MMSE) for pre-screening qualified participants. Pre-surveys about previous game experience and expectations of Smart Thinker were also evaluated. The control group participants participated in the pre-screening but not the pre-surveys.

Pre-Survey: The research used a pre-survey to learn about game experience, computer usage and perceived views of Smart Thinker as it related to assigned importance.

Gameplay: The Intervention Group participants played the Smart Thinker game suite for six weeks at the Tallahassee Senior Center.

Post-Assessment: Post-screenings were conducted among all qualified participants however, post-surveys about game effectiveness and user experience were conducted only among the Intervention Group participants. Pre and post assessments present a holistic view of how well the game contributes to the elderly experience. Result Analysis: This research procedure concludes with analysis of findings from screening, game and survey results in form of tables and graphs.

Post-Survey: The post-survey gained Intervention participant opinions about the game effectiveness, user experiences and satisfaction levels.

Result Analysis: This research analyzed the screening data, game data, and surveys to evaluate the effectiveness of the Smart Thinker contribution to enhancing cognitive skills (such as memory and attention skills). The data also evaluated the satisfaction derived from the games.

B. Mini Mental State Examination (MMSE):

MMSE is an assessment tool originally developed as a screening test to distinguish 'organic' from 'non-organic' (e.g. schizophrenia) cognitive disorders [2]. However, in recent years, it has become a screening tool for observing the progression of dementia and delirium. MMSE can be used to systematically and thoroughly assess mental status. It is an 11-question measure that tests five areas of cognitive function: orientation, registration, attention and calculation, recall, and language. The maximum score is 30. A score of 23 or lower is indicative of cognitive impairment. The MMSE takes only 5-10 minutes to administer and is therefore practical to use repeatedly and routinely. For instance, this tool was applied in

a game user interface (UI) to add functions promoting dementia prevention and identify the degree of susceptibility to this disease [1]. This tool is targeted to assess cognitive impairment with older, community dwelling, hospitalized and institutionalized adults. The MMSE was used as a cognitive assessment tool during the research of Smart Thinker.

C. *Gameplay metrics*

This research gathered specific information regarding game types using questionnaires and informal meetings. The objective was to better understand elderly gamification needs, define preferences for technological devices and games, and identify potential barriers to game usage in order to implement games that meet elderly needs. These derived suitable games for our population cut across game challenges that involve math puzzles, pictures, colors and words. The assessment meetings with participants revealed technological devices on which elderly are most comfortable playing games such as web-based games suitable for desktop computers with which they are already familiar.

Gameplay metrics are probably the most important metric when evaluating game design and user experience because it refers to variables related to user behavior and describes how people actually play games. These metrics are useful for design implementation and analysis. Smart Thinker game made use of simple interactions with the game interface using mouse clicking and the use of upper and lower control keys on a standard keyboard. As these interactions are performed, the interface reacts to changes such as number change, mode change and color change. Point and click and arrow keys are the fundamental control metrics implemented in the games. These metrics are implemented in the games as follows.

Color Change: This metric determines which selection a player has to make during the play for color game.

Mode Change: This metric determines which selection a player has to make as the RPS game switches modes.

Number Change: Players have to constantly make selection decisions using upper and lower keys as numbers randomly change on the game interface during game play.

Sentence Change Display: Players have to constantly make selection decisions using upper and lower keys as sentences randomly change on the game interface during game play.

D. *Interactional Approach for Smart Thinker*

Smart Thinker games consider a working model for user interaction and various subtasks involved with the player's cognitive skills. Table 2 illustrates the name of the game, the user interaction with the game interface, and the activities involved with the gameplay. The prototype design began with paper-and-pencil prototypes to sketch the architecture of the game. These prototypes were used as a guide to implement the development of the online version. The game application is developed using web technologies and Phaser library hosted by OpenShift server, enabling the games to be easily accessible using supported web browsers [16].

TABLE 2: INTERACTIONAL APPROACH FOR SMART THINKER

Games	Game interface	Activities
High-Low	Cursor Control: Upper key and Lower key	A player uses the upper key on a computer keyboard for a greater number and lower key for a lower number
RPS	Point and click	Player must select the hand that wins against the displayed hand or loses to the displayed hand respectively
Color	Point and click	Player must select as many colors in the grid that match the background color of the displayed grid
Find-Me	Point and click	Player must select the best alternative answer that fits sentence description of item location.

Smart Thinker Games use web accessibility that allows older adults to enjoy playing games on the computer with an internet connection in an effort to account for the needs of adults, age 55 and above. Smart Thinker features a familiar game interface designed to be simple and friendly by guiding players through a demonstration on how to play the game**.**

Past and current research and publications show that ageing adults tend to exhibit signs related to cognitive or mental illness which includes confusion, disorientation, problems with concentration or decision-making and memory loss, especially with short-term memory [5]. Several types of activities exists however, that can help maintain and advance the cognitive skills of adults age 55 and above. Some of them involve mind-challenging and everyday activities such as playing games, making crafts and solving puzzles. Popular games and puzzles for seniors include: Dominoes, Checkers, Chess, Card games, Scrabble, Bingo, Jigsaw puzzles, Crossword, Word search, Sudoku and Crypto quotes. This project considered developing four essential games that are targeted to engage older adults to enhance their cognitive skills

E. *Smart Thinker*

So far, there are four games in Smart Thinker. Figure 3 shows the interface for each Smart Thinker game. These games are carefully considered based on discussions and preliminary surveys conducted with research participants.

High-Low Game is a math puzzle type game to keep the mind sharp. Many warning signs which indicate mental health concern and one of these is trouble with handling finances or working with numbers [5]. High-low game strengthens analytical and memory power through the use of integers. To

be successful with this game, players must keep track by remembering immediate previously displayed integers to make a winning decision with currently displayed numbers on a screen. When a displayed integer is greater than its previously displayed integer, then a player will make a correct decision by tapping the upper key on the keyboard. The reverse is true for a smaller integer in current display mode against its previously displayed integer that is greater. It takes about 5-10 minutes to complete this game.

The RPS game is designed to display rock, paper, or scissors at each round. During a win mode, the player is expected to choose an object that beats the other displayed objects. In loss mode, the player is expected to choose the object that loses to the displayed hand object. Arrows are used in this game to distinguish between the switching modes. RPS game displays three hand objects in a row against another hand object to be compared with. There is an arrow pointing either upward or downward depending on the mode.

Visual distinction in colors is becoming more difficult among older adults. This game is designed to help strengthen aging adult ability to identify color differences. The ability to quickly select colors that match the randomly displayed background in a timely manner is essential to winning the game. In the color game, a grid of colors appears in front of a colored background. Users must pick or select as many colors that match the background of the displayed grid.

Smart Thinker's Find-Me game is a sentence or word puzzle game that requires players to constantly remember previously displayed sentences and their object locations in each round. The game requires players to answer questions based on those sentences by selecting the best answer from alternatives that describe the location of an object in a sentence. The Find-Me game consists of five levels and is designed to strengthen a player's short term memory using sentences and asking questions based on the sentences.

Figure 3 – Smart Thinker Games

V. Study Results

The qualified participants and further recruited subjects consisted of 59 older adults who were randomly placed into two groups namely: Control group and Intervention group. This section presents screening results, game data and the use of statistical tools to compute tables and graphs to show 59 participants gameplay performance. The Mini Mental State Examination (MMSE) was administered to both groups at the beginning and ending of the six week period. This research used two Independent variables namely: Intervention and Controlled Groups where there was no relationship between the subjects in each group.

All four games have been played by intervention group participants. Number of playtimes per each game: Overall, High-low game had the highest count of 281 playtimes whereas Color game recorded 264 playtimes. RPS game had 237 playtimes against find-me game recording 203 playtimes.

Participants from the intervention group participated in the gameplay. 18% of the game participants were between the ages of 55-64; 55% of the game participants were between the ages of 65-74 and 27% of participants were more than 75 years old. Intervention group population constitutes people with diverse educational background. The educational distribution among the game participants are as following: 49% of the game participants completed a four year university, whereas the least with 10 % had doctorate titles. 25% and 17% constitute participants who had their Master's degree and high school certificates respectively. It is clearly shown in the graph that more than two-third of our participants are females constituting 79% whereas male participants constitute 21%.

To determine which research group had a better performance after the 6 weeks on general cognitive skills, pre and post MMSE screening data were computed for *t*-test analysis. The results show the group statistics and the independent sample test computed to determine which group performed better. Levene's test for equality of variances F-value is equal to 2.687 ($p = .107$) which is not statistically significant. This implies that the two groups may have equal variances. Based on the comparison of the two groups $t(57) = 4.985$ ($p<0.05$) implies that there is a significant difference between intervention and control groups. Intervention group participants from analysis ($M = 1.26$, $SD= 1.12$) performed better than control group ($M = -.15$, $SD = .81$) members implying that Smart Thinker significantly contributed to their post-cognitive performance task.

Intervention group and control group analyses for attention cognitive skills assessment were performed as part of the overall mental status assessment. Figure 4 represent a data graph from 21 participants in the control group and 39 participants from the intervention group using the MMSE assessment tool. These data are incorporated into our independent *t*-test analysis. Group and independent analysis was conducted to evaluate attention skills targeted by Smart Thinker attention skills games.

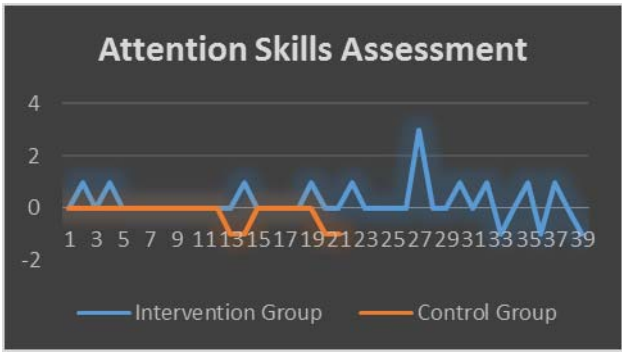

Figure 4 – Attention Skills Assessment Data

The graph presented in Figure 4 demonstrates that Smart Thinker has contributed to a great extend to the enhancement of memory and attention skills.

Table 3 shows the group statistics and the independent sample test computed to determine the level of attention cognitive skills enhancement between the two groups. Levene's test for equality of variances F value is equal to 2.676($p = .107$) which is not significant implies that the means of the two groups have an equal variances. Based on the comparison of the two groups $t(58) = 2.518$ ($p<0.05$) indicates that there is a significant difference between intervention and control groups in performance of attention skills related tasks. Intervention group participants from analysis ($M = 0.23$, $SD=.71$) performed better in enhancing Attention skills than control group ($M = -.15$, $SD = .81$) members.

Participants were asked to rate how helpful Smart Thinker was to their cognitive skills with "extremely helpful" been the highest and "not helpful" being the worst score. Participants were also asked how helpful Smart Thinker has been to their memory and attention cognitive skills. Over 80% of the people surveyed pointed out that Smart Thinker was extremely helpful to enhancing their memory and attention cognitive skills.

TABLE 3: STATISTICS AND INDEPENDENT *t*-TEST FOR ATTENTION SKILLS

Group Statistics

	Group2	N	Mean	Std. Deviation	Std. Error Mean
attention	1.00	39	.2308	.70567	.11300
	2.00	21	-.1905	.40237	.08781

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
attention	Equal variances assumed	2.676	.107	2.518	58	.015	.42125	.16731	.08634	.75615
	Equal variances not assumed			2.944	57.744	.005	.42125	.14310	.13477	.70772

This result is in sharp contrast to the mere 9% of participants who thought a priori (as indicated in the pre-survey) that the games will be extremely helpful. Specifically, a little over 45% of all participants mentioned that memory games were extremely helpful to their short term memory, such as remembering. On attention skills, a little over 63% pointed out that the games were extremely useful in helping them to focus better.

VI. CONCLUSIONS

Serious games have penetrated a range of disciplines and have been proven to be effective instruments for learning and training in the corresponding fields. With Smart Thinker, older adults can have continual enhancement of their memory and attention skills by playing Smart Thinker games accessible via web browsers. Feedback from participants demonstrates that Smart Thinker has the capability of enhancing cognitive skills while providing the elderly the chance to have fun through game play. Smart Thinker games are engaging, user-friendly, simple to understand, easy to play, cost free, and easily accessible on home computers with internet and browser access. Smart Thinker games also provide positive feedback to its users. Our assessment analysis shows that Smart Thinker significantly contributed to enhancing cognitive skills in general and largely enhanced attention skills. Result data also proved that games have the potential to improve memory skills in older adults. The findings of this study adds to a body of research exploring whether computerized serious games may help improve attention and memory and ultimately help protect older adults from cognitive decline associated with aging and Alzheimer's disease.

Future directions for this research include enhancing the game design interface, adding more challenging games, and allowing users to track real-time feedback on cognitive skill progress and scores. There is also a demand to make the game application more accessible to research groups for holistic demographics, more sociable for the game players, increased in optimization for mobile devices, and extended in application to other cognitive skills and other research subjects such as children's and young adults.

ACKNOWLEDGMENT

This work has been supported in part by the Florida Center for Cybersecurity. The opinions expressed in this paper do not necessarily reflect those of the funding agencies.

REFERENCES

[1] Alzheimers.net, "Alzheimer's Statistics," A Place for Mom, Inc. , 2015. [Online]. Available: http://www.alzheimers.net/resources/alzheimers-statistics/. [Accessed 1/24/2017].

[2] J. Banks, J. S. Carson, B. L. Nelson, and D. M. Nicol, Discrete-Event System Simulation. 3rd ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc., 2000.

[3] Alzheimer's Association, "2015 Alzheimer's Disease Facts and Figures," Alzheimer's Association, Chicago, 2015.

[4] Centers for Disease Control and Prevention, "Cognitive Impairment: A Call for Action Now!," 2 2011. [Online].

Available: www.cdc.gov/aging/healthybrain/index.htm. [Accessed 1/24/2017].

[5] BrightFocus Foundation, "BrightFocus Foundation: Cure in Mind, Cure in Sight," 19 06 2015. [Online]. Available: www.brightfocus.org. [Accessed 1/24/2017].

[6] A. Dickinson and J. P. S. Arnott, "Methods for human–computer interaction research with older people," Behaviour & Information Technology, vol. 26, no. 4, pp. 343-352, 2007.

[7] M. Cristina, P. G. U. P. Tiraboschi, C. A. Defanit and G. B. Frisoni, "Clinical trial design of serious gaming in mild cognitive impairment," Frontiers in Aging Neuroscience, vol. 7, pp. 1-4, 2015.

[8] Wikipedia, "Wikipedia, the free encyclopedia," Wikimedia Foundation, Inc., 26 06 2015. [Online]. Available: https://en.wikipedia.org/wiki/Serious_game#cite_note-1. [Accessed 1/24/2017].

[9] R. G. Sánchez, et. Al, "Value propositions for serious games in health and well-being." In International Conference on Serious Games Development and Applications, pp. 150-157. Springer Berlin Heidelberg, 2012.

[10] A. Kwan, "mHealth Solutions for Improving Mental Health and Illnesses in the Aging Process." White Paper Series on mHealth and Aging, mHealth Alliance, UN Foundation, 2013 [Online]. Available: http://hingx.info/Share/Attachment/1425/mHA-AgingPaper3_092713.pdf [Accessed 1/24/2017].

[11] M. Ayad, M. Taher, and A. Salem, "Real-time mobile cloud computing: A case study in face recognition." In Advanced Information Networking and Applications Workshops (WAINA), 2014 28th International Conference on, pp. 73-78, IEEE, 2014.

[12] Ronghua Mao, Changxiang Chen, and Dan Li "Intervention effect of BrainHQ visual training on depressive symptom in patients with post stroke depression." Chinese Journal of Behavioral Medicine and Brain Science, vol. 24, no. 12, pp. 1097-1099, 2015.

[13] Alzheimer's Association, "Alz.org Mild Cognitive Impairment," Alzheimer's Association, 2015. [Online]. Available: http://www.alz.org/dementia/mild-cognitive-impairment-mci.asp#diagnosis. [Accessed 1/24/2017].

[14] C. M. Bleakley, D. Charles, A. Porter-Armstrong, M.D. McNeill, S. M. McDonough, and B. McCormack, "Gaming for health a systematic review of the physical and cognitive effects of interactive computer games in older adults." Journal of Applied Gerontology, vol. 34, nop. 3, pp. 166-189, 2015

[15] R. McCall and L. Baillie. "Ethics, Privacy and Trust in Serious Games, "Handbook of Digital Games R. Nakatsu, P. Ciancarini, and M. Rauterberg (2015).

[16] Chi, Hongmei, Clement Allen, and Edward Jones, "Integrating Computing to STEM Curriculum via CodeBoard." In International Conference on Computational Science and Its Applications, pp. 512-529. Springer Internat. Publishing, 2016.