APPROVAL SHEET

Title of Dissertation: Computerized and Non-Computerized Approaches to Brain Games for Maintaining and Enhancing Mental Acuity in Healthy Older Adults: An Investigation of Performance Enhancement.

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Doctor of Philosophy, 2017

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ABSTRACT

Title of Document: Computerized and Non-Computerized Approaches to Brain Fitness Games for Maintaining and Enhancing Mental Acuity in Healthy Older Adults: An Investigation of Performance Enhancement.

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Brain fitness games refer to games that are specifically designed with the goal of maintaining and enhancing mental acuity. While these games may generally be designed for players of all ages, some are designed for specific populations such as kids, teens, adults, older adults (seniors), etc. In older adult populations, research has shown that the main cognitive abilities that change with aging include: perception, attention, memory, and other more specific processes such as decision-making. With the right design of games that uses motivation, goal and incentives, these games may provide a learning experience coupled with the 'fun' that comes with playing games. Although player and game characteristics are known to affect player gaming performance and outcomes, no study has researched healthy older adults and performance enhancement approaches to current brain fitness games available for such populations. The aim of this dissertation research study is to investigate player demographic factors (such as age, race, gender, educational background, technology savviness) and game platform (paper versus mobile/tablet) on game outcomes and player experience.

This dissertation research study investigates the research problem with a mixed method games user study by engaging participants with a commercially available game-set designed to maintain and enhance mental acuity in older adults. A cohort of older adults in the baby boomer generation is recruited to play the game and share their experience playing the game on both paper and electronic platforms. A randomized sampling method is used to place participants into groups that determine the order of platform (paper before electronic or vice versa) on which they play the games. During each study, data on the following criteria are collected: user demographics, platform type, user outcomes, and user subjective experiences shared.

Both descriptive and statistical analyses are used to deduce meaning from the quantitative data collected. With the qualitative data analyses, data transcription, and coding are used to form themes and meaning from the subjective responses. Implications of the findings and discussions of the study may contribute to furthering wide adoption and implementation of such game interventions for maintaining and enhancing mental acuity in older adult populations.

Keywords: Brain Fitness Games, Older Adults, Mental Acuity, Games User Research, Cognitive Performance Enhancement, Senior Communities, Boomer UX.

COMPUTERIZED AND NON-COMPUTERIZED APPROACHES TO BRAIN GAMES FOR MAINTAINING AND ENHANCING MENTAL ACUITY IN HEALTHY OLDER ADULTS: AN INVESTIGATION OF PERFORMANCE ENHANCEMENT.

By:

Gloria Abena Opoku-Boateng

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland Baltimore County (UMBC), in partial fulfillment
of the requirements for the degree of
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Dedication

to the Almighty God

…for giving me life and sustaining me through graduate school

to my Loving Family- Daniel, Sarah, Florence, and Francisca Opoku-Boateng

… for supporting and cheering me on even in times when I wanted to quit

to my Wonderful Husband – Reginald Osardu, MD

…for being the wind behind my soar, and being in a relationship (then) that required extra patience and prayers… I always returned to you empty after I had poured my heart and soul to finishing this dissertation

to my Advisor, Mentor, and Friend – Dr. Anthony Norcio

…for being my advocate, champion, and mentor; giving me a chance to prove myself, room to find my passion, and support to follow my instincts…making me stand taller because I stood on your shoulders these past years.

to my PROMISE AGEP mentors – Drs. Renetta Tull, Wendy Carter-Veal, Christine Grant, and Karsonya Wise Whitehead

…for showing and being to me, the present-day success stories of excellence in being a smart, resilient, successful strong black woman and yet having it all.

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"Surround yourself only with people who are going to take you higher" –*Oprah Winfrey*.

When I look back at all the help and support I have received over the past four 3+ years at UMBC, Oprah's quote above perfectly summarizes my experience. I could not have asked to be surrounded by people who could and were willing to help me on my journey to getting a PhD. Their significant help came in various ways and here are a few thank-you among the lot.

I would like to thank God for giving me life, and helping me finish this dissertation research. Special thank you to my husband, family, and friends who have been so supportive along the way. I am also grateful for a dissertation committee whose members (Drs. Norcio, Koru, Pan, Stuart, and Ludwig) are so flexible, patient, and interested in my work.

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Finally, many thanks to my research mentor and chair of my dissertation committee, Professor Anthony Norcio, PhD. You made it all happen!

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Contextual Definition[1] of Key Terms

Age-related Cognitive Decline – Some degree of decline in mental acuity as all humans age. This decline usually includes forgetfulness, decreased ability to maintain focus and decreased problem solving capacity.

Baby Boomers – The demographic group born during the post–World War II baby boom, approximately between the years 1946 and 1964. This includes people who are between 52 and 70 years old in 2016, per the U.S. Census Bureau.

Brain Fitness Games – Brain training programs (in the form of games or gamified technology) usually designed to train cognitive skills such as memory, attention and speed, and emotional intelligence.

Cognitive Abilities – Brain-based skills needed to carry out any task from the simplest to the most complex. These abilities have more to do with the mechanisms of how people learn, remember, problem-solve, and pay attention, rather than with any actual knowledge.

Cognitive Decline – The inability of the brain to work as well as it used to.

Cognitive Training – Involves completing a variety of computerized exercises specifically designed to improve cognitive functioning in areas such as sustained attention, thinking before acting, visual and auditory processing, listening, reading.

Game Platform – The console or system that a game is played on. In this context, the paper and electronic platforms are being considered.

[1] Student researcher's paraphrased definitions to better explain the context of use for these terms.

Experiment – A scientific procedure undertaken to make a discovery, test a hypothesis, or demonstrate a known fact.

Game Outcome – In game theory, an outcome is a situation which results from a combination of player's strategies. Every combination of strategies (one for each player) is an outcome of the game.

Gerontology – The scientific study of old age, the process of aging, and the problems of old people.

Brain Health – The ability to remember, learn, plan, concentrate and maintain a clear, active mind. It's also being able to draw on the strengths of your brain i.e. information management, logic, judgment, perspective and wisdom.

Serious Games – Video games designed for a primary purpose other than pure entertainment.

Games User Research – Games user research (sometimes called "user testing for games", "player research" or "Games User Experience") is a core part of game development, which helps games reach their design goals by observing and understanding players.

Mixed-Method Research Design – A methodology for conducting research that involves collecting, analyzing and integrating quantitative (e.g., experiments, surveys) and qualitative (e.g., focus groups, interviews) research.

Performance Enhancement – Mentally improving upon the way you currently perform. It doesn't necessarily mean that something is wrong or performing inappropriately rather to increase knowledge and skills to improve something currently done.

Population Demographics – Statistical data about the characteristics of a population, such as the age, gender and income of the people within the population.

User Experience – The overall experience of a person using a product such as a website or computer application, especially in terms of how easy or pleasing it is to use.

User Research – Research focusing on understanding user behaviors, needs, and motivations through observation techniques, task analysis, and other feedback methodologies.

User Study – Research studies focusing on the use of information. i.e. Information means (formats), networks (social, academic, workplace networks) or information providing systems (information retrieval systems, digital libraries, web search systems, intranets, etc.).

Chapter 1: Introduction

1.1. Background and Significance

As people age, changes in the brain structure and function lead to cognitive decline (Deary, et al., 2009; Salthouse, Atkinson, & Berish, 2003). Ample evidence show that alterations in brain structure and function are intimately tied to alterations in cognitive function (Glisky, 2007). Some changes that occur in the brain may directly or indirectly affect basic and higher level cognitive functionality (Person, et al., 2006). Working memory – the ability to keep multiple pieces of information in mind while acting on them – declines with age (Rypma, and D'Esposito, 2000). This means that the ability to inhibit extraneous information when attempting to focus attention may be impaired as well. Age-related cognitive decline is especially evident in tasks that require effortful brain processing relying on attention, inhibition, working memory, prospective memory, and episodic memory (Cabeza, et al., 2004).

As the United States (US) population matures over time, life expectancy has seen to rise with increasing numbers of the older adult population. Many older adults may start to experience health risks associated with ageing such as cognitive performance decline. This decline may start to threaten their independence and quality of life. Older adult populations experiencing cognitive decline may be categorized as; non-healthy older adults (those with co-morbidities such as dementia, Alzheimer's, depression etc.), and healthy older adults (those without co-morbidities and are experiencing cognitive decline only because of ageing). Approaches to mitigating these risks of cognitive decline which have shown positive outcomes include: cognitive and physical activity, social engagement, and therapeutic nutrition in optimizing cognitive aging (Williams and Kemper, 2010). More and more, we hear of successful and engaging stories of older adults who come together to play board games to stay active and social. Board games (or to use the broader term, tabletop games) refer to games that are normally played on a table or other flat surface, and can include card games, dice games and tile games, such as Scrabble. Games such as Bingo, Mah jongg, and Cards continue to rise in popularity among older adult players.

Recently, the use of computerized games as well as computerized online versions of board games have increased. These computerized games (especially electronic Bingo and Candy Crush) utilize gamification/gaming technology to increase engagement in players. Slowly these games are being turned into serious games that double the fun in game playing as health interventions. This dissertation focuses on computerized games that particularly help older adults maintain and enhance their mental acuity (Hall, et al., 2012; Basak, et al., 2008). Current approaches alongside other novel technological interventions have mostly focused on older adults with specific cognitive, speech and mental impairments. Thus, placing emphasis on rehabilitation and therapy roles of such approaches and interventions.

Older adult populations who do not experience major memory loss or memory dysfunction such as Alzheimer's do not have many brain fitness games specially designed to maintain and enhance their cognition. The irony here is that the need for such intervention remains as important to healthy older adult populations as those experiencing memory loss or other cognitive impairments (Reijnders, van Heugten, & van Boxtel, 2013). As people age, ways to keep the mind sharp becomes one of their major concerns (Seeman, et al., 2001; Lustig, et al., 2009). A brain health research study with older adults released in 2014 by the American Association of Retired Persons (AARP) found that older adults believed maintaining mental acuity (37%) is second only to a healthy heart (51%) in sustaining a healthy lifestyle. A London-based brain-training company (My-Cog) recently developed a three-part approach to keeping older people cognitively active and living at home (DeBaggio, et al., 2002). In this approach, the three parts are: 1) an online virtual assistant that helps people remember appointments and tasks, 2) a computerized “memory box” which includes photos of important people and places in the user’s life, as well as linking the participant to close friends and relatives who share those memories, and 3) The use of cognitive senior games to enhance motivation and user engagement during the intervention.

The significance of this research which investigates older adults and interventions to enhance and maintain mental acuity is that, maintaining and enhancing mental acuity in healthy older adults will continue to be as critical as enhancing and rehabilitating mental acuity in non-healthy older adults as life expectancy continues to rise. Using brain fitness games as interventions is a feasible approach which lacks proper games user research for wide adoption and implementation. Hence motivating a study that further investigate both computerized and non-computerized approaches to using games as an intervention for age-related cognitive decline.

1.2. Problem Statement

In older adult populations, the main cognitive abilities that change with aging include: perception, attention, memory, and other more specific processes such as decision-making (Rypma, & D’Esposito, 2000). With the right design of games that use motivation, goal and incentives, these games provide a learning experience coupled with the enjoyment that comes with playing games (De Carvalho, Sales, & Ishitani, 2012). Current technological advances and the need for age-related cognitive decline interventions provides the perfect timing for increased research in brain games in general; mostly for children, youth and adult populations (Colapinto, 2009; Singer, 2008; George & Whitehouse, 2011; Swan, Kido, & Ruckenstein, 2014; Zelinski, Dalton, & Smith, 2011).

The problem under investigation in the implementation and wide adoption of such brain games for healthy older adult populations. First, there seem to be a disconnect between the number of brain games designed specifically for healthy older adults and the crucial need of this population to engage in activities that maintain and enhance mental acuity. Second, there are a few games user research specifically done to test approaches to brain fitness games for older adults. This dissertation research addresses a specific challenge in the broader problem by investigating the effect of select user (or player) demographics and game platform (paper or electronic) on player experience and outcomes. Since gaming experience and gaming outcomes influence the adoption and use of such interventions, investigating the effect of select player demographic factors and game platform preference on outcomes gives insights on how to properly and widely implement and adopt brain games for mental acuity in healthy older adults.

1.3 Study Purpose

The goals of this dissertation are to 1) To investigate, the effect of select older adult demographic factors on outcomes of senior games that enhance mental acuity in older adults, and 2) To examine differences in player experience and game outcomes with game platform preference. To achieve these goals, the following objectives are stated:

- Selection of a brain fitness game designed specifically to enhance and maintain mental acuity in older adults.
- Recruitment of healthy older adults (baby boomer generation) for study.
- Moderation of all study sessions with older adults.
- Collection and analysis of data from sessions.
- Recording and reporting findings from research study.
- Discussion of implications of dissertation study.

1.4 Scope of Study

This study intersects three main research domains; gerontology research, games user research and serious games for age-related cognitive decline. The dissertation research however covers the following scope:

- Games Domain: Brain fitness games for maintain or enhancing mental acuity.
- Research Population: Healthy older adults born in the baby boomer generation.
- Gaming Platform: Single-player paper and electronic (mobile) platforms.

1.5 Research Questions

Research Question 1: What perspectives and subjective experience do older adults have on cognitive decline, brain fitness games, and brain health?

Research Question 2: Do population demographics such as gender, race, age, technological savviness and educational background influence gaming outcomes like speed, satisfaction, errors, and task completion?

Research Question 3: Does game platform type (paper versus electronic) influence game outcomes (speed, satisfaction, errors, and task completion) in healthy older adult players?

1.6 Chapter Summary

Chapter 1 introduces the research problem under consideration. In this short chapter, the background and motivation for this research remain this: as older adult populations, especially in America continues to grow, the effect of having a sizeable older adult population becomes exposed. Research on age-related cognitive decline which is the focus of this dissertation is embraced and addressed as an area that desperately needs technological interventions. On a broader scope, both computerized and non-computerized approaches are of interest. Three (3) research questions however are formulated to address the use of brain fitness games as interventions for age-related cognitive decline.

Chapter 2: Review of Literature

2.1 Older Adult Population and Cognitive Decline

The proportion of people aged 65 or older is the fastest growing age group worldwide (Fillenbaum, 2013). The World Health Organization (WHO) has estimated that the global population of older adults will grow by 223% by the year 2050. Which means an estimated number of about two billion older adults, of which 80% are expected to be living in developing countries (WHO, 2002). Due to the increasing time spent in old age and the high level of disability in older adults, there is an increasing need for residential aged care facilities, community care, and flexible care services (AIHW, 2012). Knight and Mellor, (2007) proposed that a combination of unfulfilling social activities and constant interactions with unfamiliar people can lead to the development of poor mental health in aged care residents.

Since age-related cognitive and brain declines can result in functional deterioration in many cognitive domains, dependency, and dementia, a major goal of aging research is to investigate methods that help to maintain brain health, cognition, independent living and wellbeing in older adults (US Department of Health and Human Services, 2011; Dukart, et al., 2011).

2.2 Preventing Cognitive Decline in Older Adults

Only a small number of research work show positive results on preventing age-related cognitive decline (Plassman et al., 2010). A review of research targeted at preventing cognitive decline in healthy older adults showed that most of these studies are small and have short follow-up periods (Naqvi, et al., 2013). None of the studies of pharmacologic agents found clinically or statistically significant benefits associated with their use. However more promising results were seen in some studies that assessed cognitive training for mitigating cognitive decline. More substantial research studies show ways to reduce or reverse cognitive decline in older adults (Williams, and Kemper, 2010; Jorm, 1994).

Cognitive training has been shown to somehow support long term memory performance and enhancement in both younger and older populations (Botirolli, Cavallini, & Vecchi, 2007). In a randomized control trial with about 102 older adult participants, it was found that cyber-cycling older adults achieved better cognitive functionality than traditional exercisers, for the same effort, suggesting that simultaneous cognitive and physical exercise has greater potential for preventing cognitive decline (Anderson-Hanley, et al., 2012).

Another study that analyzed the influence of a cognitive training program on participants with age-related memory loss, showed significant changes in the test group, demonstrating improved cognitive performance and quality of life perception (Fernandez-Prado, et al., 2011). Broader studies such as Martin, et. al., (2011)'s systematic literature review on the effect of cognitive training interventions on various domains of cognitive function (i.e. memory, executive function, attention and speed) in healthy older adults and in people with mild cognitive impairment also revealed the following; for healthy older adults, immediate and delayed verbal recall improved significantly through training compared to a no-treatment control condition. There were no findings on specific memory training effects for both healthy individuals and those with mild cognitive impairment.

With the evidence that cognitive interventions do lead to performance gains but none of the effects observed could be attributable specifically to cognitive training, there are suggestions of more standardized study protocols to maximize comparability of studies and to maximize the possibility of data pooling - also in other cognitive domains than memory (Colcombe, & Kramer, 2003). A training program targeting age-related cognitive decline also showed significant improvements in assessments directly related to the training tasks and significant generalization of improvements to nonrelated standardized neuropsychological measures of memory thus demonstrating that intensive, plasticity-engaging training can result in an enhancement of cognitive function in normal mature adults (Mahncke, et al., 2006).

A new way of cognitive training called the computerized cognitive training (CCT) is believed to be safe and can be inexpensive (Kueider, et al., 2012; Smith, et al., 2009; Klingberg, 2010). Studies have found that CCT programs can enhance cognition in healthy older adults (Gunther, et al., 2003; Melby-Lervag, and Hulme, 2013; Jaeggi, et al., 2011), discriminate responsive from nonresponsive cognitive domains (Zelinski, et al., 2011), and identify the most salient design factors (Howren, Vander Weg, & Wolinsky, 2014; Owen, et al., 2010; Mowszowski, Batchelor, & Naismith, 2010). Future studies later support the effectiveness and durability of the cognitive training interventions in improving targeted cognitive abilities (Anguera, & Gazzaley, 2015). Lampit, Hallock, & Valenzuela, (2014) also found that although CCT is modestly effective at improving cognitive performance in healthy older adults, its efficacy varies across cognitive domains and is largely determined by design choices. Cognitive function in older adults is related to independent living and need for care but few studies have addressed whether improving cognitive functions might have short- or long-term effects on activities related to living independently (Ball, et al., 2002; Waller, and Gilbody, 2009).

2.3 Approaches to Cognitive Training in Older Adults

Cognitive training tools are currently categorized into two: video games (Basak, et al., 2008; Anguera, et al., 2013; Drew, and Waters, 1986) and cognitive exercises (Hatfield, 1986; La Rue, 2010). In these training tools, factors such as fun, motivation and adaptability often differ across approaches and purpose of cognitive performance enhancement (Gonzalez-Ortega, et al., 2014; Karakostas, et al., 2014). Another group of cognitive training tools that are found online may provide significant benefit to cognition and function in older adults, with benefit favoring the reasoning package of social interaction and cognitive health (Corbett, et al., 2015; Walton, et al., 2015; Gordon, et al., 2013; Simpson, et al., 2012). Cognitive control is defined by a set of neural processes that allow us to interact with our complex environment in a goal-directed manner (Van Muijden, Band, & Hommel, 2012). By playing an adaptive training games version of NeuroRacer[2] in multitasking training mode, older adults (60 to 85 years old) reduce multitasking costs and gained cognitive control (Anguera et al., 2013). Thus, cognitive training in older adults can result in performance benefits that extended to untrained cognitive control abilities.

In a control and intervention group of older adult participants, Wii bowling, which provides a user-friendly platform for older adults to use video games and incorporates both social and competitive aspects in the game play, was used as an intervention to

[2] A video game that trains cognitive control.

extensively investigated the social aspects of game technology with older adults (Chester, et al., 2015). The game proved to be an effective, fun, economical, and easy to use intervention which when properly scheduled as an activity for older adults living in care, may benefit their mental health. A randomized control trial with older adults using a commercially available brain game package (Lumosity) on a series of age-declined cognitive functions and subjective wellbeing, showed significant improvements in the trained group, and no variation in the control group, in processing speed (choice reaction time), attention (reduction of distraction and increase of alertness), immediate and delayed visual recognition memory, as well as a trend to improve in affection and assertiveness (Ballesteros, et al., 2014).

Although an important goal of cognitive training is to slow or reverse these age-related declines, research opinion is divided in the literature regarding whether cognitive training can engender transfer to a variety of cognitive skills in older adults. In a study, which trained older adults through a battery of cognitive tasks, including tasks of executive control and visuospatial skills, were assessed before, during, and after video-game training (Basak, et al., 2008). The trainees improved significantly in the measures of game performance as well as in executive control functions, such as task switching, working memory, visual short-term memory, and reasoning.

2.4 Game Platform Comparison on Performance Outcomes

As technology becomes pervasive and assessable, the comparison of paper versus electronic platforms becomes more necessary and worth revisiting. While questions regarding paper versus electronic platform surrounding accessibility, costs, storage, quality, and flexibility clearly supports electronic format/platforms, other questions surrounding issues like; the value of either format, the ease of use of either format, the comprehension of information on either format, the experience and satisfaction from using either format, etc., remain fuzzy and subjective.

At the core of paper versus electronic platform/format arguments in game design and implementation lie the issues of whether board games are better than video games[3]. Although board games and electronic games may seem to compete on relevancy and effectiveness, most electronic games were created from board games and vice versa. The reasons for such conversions usually vary by designer, player and gaming needs (e.g. collaboration in board games (Zagal, and Rick, 2014)). Recently, most of these games have been computerized for one or more of the following reasons: to reach more populations, cut down cost, increase the availability of such games, expand its use beyond just leisure and/or fun (Matorin, and McNamara, 1996). Some companies have created very true-to-life computerized versions of board games which are free to download and play.[4,5,6,7]

To gain the benefits of both computerized and non-computerized game platforms, some researchers are exploring the space between board games and video games. Mandryk, and Maranan, (2002) created a hybrid game that leverages the advantages of both physical and digital media by using a custom sensor interface to promote physical interaction around the shared public display while the un-oriented tabletop display encourages players to focus on each other rather than on the interface to the game. The

[3] Kain, 2012: Are board games better than video games?
[4] Games Company.
[5] Board Game Arena.
[6] Hasbro Monopoly Digital Games.
[7] Big Fish Online Board and Card Games.

hybrid board/video game has the potential to enhance natural and enjoyable recreational interaction between friends. Björk, et al., (2001) also explored how computer games can be designed to maintain some of the social aspects of traditional game play, by moving computational game elements into the physical world by constructing a mobile multiplayer game, Pirates! Conclusions from user testing Pirates indicate that the game can be deployed in a social setting where co-located people play together to promote social interaction between players and non-players alike. Some patents have also been filed for games that possess both electronic and board game characteristics (Itkis, 1984; Chan, 1992; Gilboa, 1998; Odom, 2003). Although no scientific research has been conducted to investigate the effect on paper versus electronic platforms on games outcomes, general concerns and lengthy discussion on this issue suggest a need for such investigation.

2.5 Brain Fitness Initiatives for Older Adults

Over the past few years, brain health and cognitive fitness has become a major focus especially in older adults. Although most initiatives for brain health focuses on therapeutic and rehabilitative measures for older adults, a significant number have focused also on cognitive enhancements and acuity in healthy older adults. With the proliferation of a new marketplace of "brain fitness" technology products (ranging from video games to computer software to mobile phone apps and hand-held devices), came a broader concern for brain health and fitness. This concern goes beyond the reductionism of the commercial brain fitness marketplace and asks how our most proximate relationships and local communities can play a role in supporting cognitive and psychosocial well-being (George, & Whitehouse, 2011).

In 2005, both the Center for Disease Control and Prevention (CDC) and the Alzheimer’s Association formed the Healthy Brain Initiative (HBI) to strategize the address of cognitive health in the U.S. In 2007, a 70-page document was released on how the HBI would best bring public health perspectives to the promotion of cognitive health (Alzheimer's Association, & Centers for Disease Control and Prevention (2013); Cherry, & Reed, 2007). The document provides a roadmap to maintaining cognitive health in especially in older adults. Assisted by the National Institute on Aging and the Administration on Aging, the current state of knowledge regarding the promotion and protection of cognitive health was examined, important knowledge gaps were identified, and the unique role and contributions of public health was defined. About six (6) years down the line, the federally funded National Alzheimer's Project Act of 2011 was in place. This project which called for a coordinated, national strategic plan, on the HBI resulted in a new Road Map (Ansello, 2014).

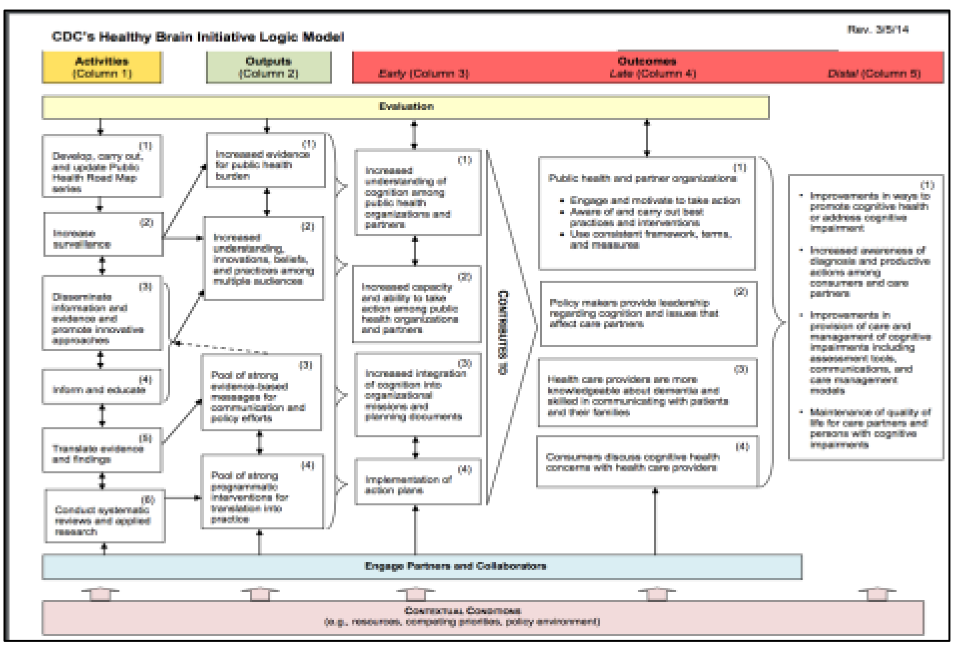


Figure 1: Alzheimer’s Association and Centers for Disease Control and Prevention (2013). ‘*The Healthy Brain Initiative Logic Model*’.

The Cleveland Clinic’s Healthy Brains is also an initiative that focuses on brain health and recommends resources available for older adults to learn more about maintaining a healthy brain. This initiative is house in Cleveland Clinic’s Lou Ruvo Center for Brain Health. This center also provides information about brain diseases, treatments, clinical trials. The Clinic also offers a brain health self-assessment.

The University of Florida (UF) and the Village Launch Program is an initiative that evolved out of a partnership between The University of Florida and The Village retirement community in Gainesville, FL. This partnership offers a research program dedicated to maximizing brain health in older adults. Vitality Mind provides residents of The Village and the community with free cognitive assessments and interventions that are designed to improve mental functioning, mood and the ability to independently perform everyday tasks in individuals age 60 and older. Other brain health interventions arising from this partnership and program include mindfulness meditation, computer training and physical exercise — all of which have separately been shown to improve older adults’ brain health in prior studies.

Finally, Easter Seals also provides information, resources and programs for healthy aging to caregivers, adults with chronic conditions, and veterans to help them overcome challenges and pursue their life goals. Their motivation for providing such support is that so long as the brain regenerates cells throughout a person’s life, people who have strokes or traumatic brain injuries can continue to improve for years afterwards. Many activities and lifestyle choices affect brain health of older adults, including physical activity, socialization, and the pursuit of stimulating interests. Easter Seals promotes brain health through: Health and wellness programs like Health Matters and Refresh!

Life Re-Energized©, Ongoing learning and skill-building experiences, Engaging and stimulating person-centered activities, Programs addressing early memory loss and other cognitive impairments. They also strongly encourage healthy older adults to also take steps to improve attention and memory as brain health science advances has made it possible for individuals to take greater control of brain health.

There are other smaller, lesser known efforts that are made towards brain fitness and healthy brains especially for older adults (healthy and unhealthy). For example, the Association of State and Territorial Health Officials (ASTHO) President recently[8] threw a challenge on healthy aging. The challenge was directed towards promoting the health of older adults by collaborating across sectors. This challenge aims to galvanize support for state health officials, their public health teams, state and local experts in aging and a broad network of partners, to implement evidence-based strategies for increasing the number of older adults who are living well in our communities. Promoting healthy aging requires collaboration across a range of disciplines and fields. The President's Challenge platform reflects a comprehensive approach, highlighted in the National Prevention Strategy, and emphasizes on data/surveillance and caregiving.

Whereas most of these small initiatives and efforts are in alignment with the Healthy Brain Initiative, others are implemented on their own roadmaps and strategies (McGill, 2015). Till now, the best motivation for cognitive training and brain fitness has come from individual or small group efforts.

[8] In 2015

2.6 Designing Brain Fitness Games for Older Adults.

When designing social games for elderly, a tangible play that keeps the guessing element in a game is very critical in keeping older adults immersed in the play (Al Mamud et al., 2010). Another design factor usually considered in games for older adults is intergenerational play. Research has shown that one of the key aspects of overcoming loneliness amongst older adults is the fostering of relationships between older persons and grandchildren (Rice, et al., 2013). Intergenerational activities may spark conversations on similar interest topics, and activities leading to happiness and a feeling of belongingness between different age groups. Thus, in gaming technologies for elderly, utilizing a design factor that bridges gaps across physical and social distances may be critical.

The following factors also contribute to a novel design of intergenerational games: 1. Support: There are mental model and digital affordances that vary by generations (Vanden Abeele, et al., 2010). 2. Customization: Game play challenges may need to be modified for each generation to keep it fun (Khoo, et al., 2009). 3. Type of game play: Knowing whether the goal of the game is cooperation or competitive (Al Mahmud, et al., 2010). Research also shows that younger players are over-competitive in playing games and that distracts older players from engaging in intergenerational games (Nap, et al., 2009). Other design considerations involve older adults understanding digital games (Chiong, et al., 2009), rehabilitation (Gerling, et al., 2012) versus physical coordination (Alankus, et al., 2010).

The design factors of social games may lead to a successful design of serious games for healthy older adults. And some researchers recommend the explorations of role differentiation and interdependence; gameplay assistance; focal points; physical engagement; and instructional support. In most cases the designers' good intentions justify incoherence and insufficiencies in their design. In addition, serious games are mainly assessed in terms of the quality of their content, not in terms of their intention-based design. For example, Schilbach et al., (2013), defend a “second-person neuroscience” perspective that focuses on the neural basis of social cognition during live, ongoing interactions between individuals.

The design of a tablet-based gaming platform for seniors that could promotes their quality-of-life and well-being by incorporating cognitive training mechanisms concluded that these games should target cognitive stimulation (Vasconcelos, et al., 2012). Game principles that needs to be adopted to create an enjoyable and engaging game experience for older adults, whilst ensuring that the purpose of the game, encouraging upper limb mobility ensure that opportunities for action that the game afforded were adapted to players' need (Awad, Ferguson, & Craig, 2014). To analyze and structure a game's formal conceptual design, its elements, and their relation to each other based on the game's purpose is a constructive first step in assessing serious games. Mitgutsch, and Alvarado, (2012) came up with the framework below.

Figure 2: Serious Game Design Assessment Framework (Mitgutsch, & Alvarado, 2012)

2.7 Assessing, Adopting and Implementing Brain Games for Older Adults

The lack of assessment tools to analyze serious games and insufficient knowledge on their impact on players not only is a barrier to adoption but also a recurring critique in the field of game and healthcare. Although initial empirical studies on serious games usage deliver discussable results, numerous questions remain unacknowledged (Gariepy, Chang, & Platt, 2013; Buitenweg, Murre, & Ridderinkhof, 2012). Questions regarding the quality of their formal conceptual design in relation to their purpose mostly stay uncharted (Awad, Furgerson, & Craig, 2014; Ijsselsteijn, et al., 2007). Subjective questions on goals, focus and benefits of games to older adults also remain unstructured (Nijholt, and Gurkok, 2013).

A study was done on a series of focus group studies carried out at the Sonic Arts Research Centre, Queen's University Belfast, Northern Ireland, to identify the key motivational factors influencing seniors' engagement with mobile brain training technology to inform the design of a brain training tool which is acceptable / enjoyable to target users (O'Brien, 2011). Findings show 237 motivational comments made up 19 motivational factors and 123 de-motivational comments made up 15 de-motivational factors. See table 1 for summary.

Motivation	Count	%
Challenge	59	24.9%
Usefulness	40	16.9%
Familiarity	30	12.7%
Entertainment	21	8.9%
Relaxation	17	7.2%
Achievement	15	6.3%
Ease of use	14	5.9%
Other (<5%)	41	17.3%
Total	237	100.0%

De-Motivation	Count	%
Usability issues	34	27.6%
Poor communication	19	15.4%
Too fast	15	12.2%
Difficult	8	6.5%
Social isolation	8	6.5%
Time consuming	7	5.7%
Other (<5%)	32	26.0
Total	123	100.0%

Table 1: Ranking of motivational and de-motivational factors (O'Brien, 2011)

The study concluded that generally, after the first hour or so of play, older adults are most motivated to engage with mobile brain training game technology when it's perceived as providing a good challenge, of some practical benefit and is in some way familiar. On the other hand, older adults see usability issues, poor communication from the game and games that are inappropriately timed, i.e. too fast, as barriers to engagement.

A novel strategy to the implementation of serious games for brain fitness especially in older adult populations is seen in Ahn, et al., (2014)'s "*Design of A Kiosk Type Healthcare Robot System for Older People in Private and Public Places*". In their research, the authors explored ways to design medical kiosks with special focus on targeting older adults. The conceptual model behind the design (see figure 3 below) reflects implementation in both private spaces as well as public spaces; both common environments in which older adults are likely to find themselves.

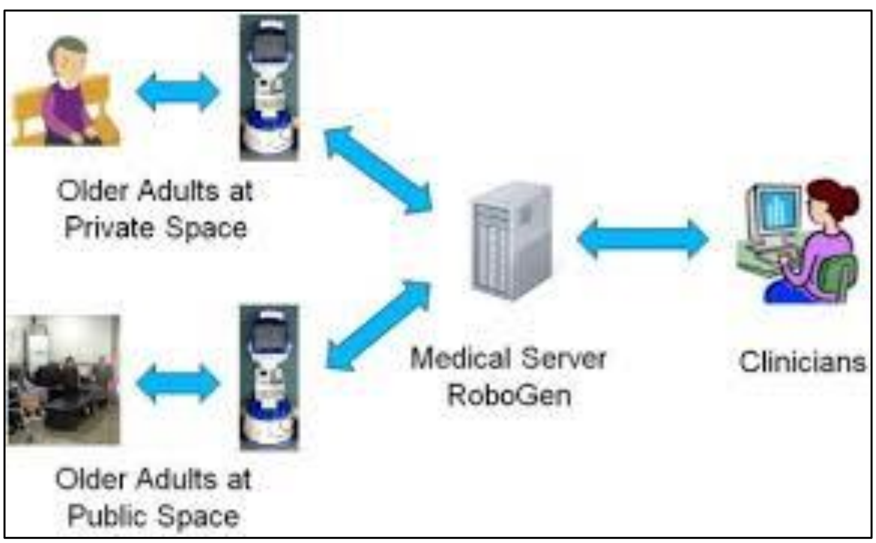


Figure 3: Private & public places experiment scenarios Model. (Ahn, et al., 2014)

The growing older adult demographic and the reality of age-related cognitive decline ensure continued interest in the adoption and implementation of programs and interventions which promote cognitive health (Vasconcelos, 2012). With regards to healthy older adults living in senior retirement communities, an interview with a brain fitness director revealed a recent trend of greater focus on residents' brain fitness. Many resident communities are starting to make concerted efforts to adopt and promote a brain-healthy lifestyle among residents.

2.8 Older Adult Adoption and Use of Technology

Per the Pew Research Center findings[9] on the state of technology use among older adults, several barriers that may hinder older adults from adopting new technologies include physical challenges, attitudes on benefits, and difficulty in learning the technology. These challenges however seem virtual once older adults join online communities or start using the technology. Among older adults (65 and older), analysis of data from the 2011 National Health and Aging Trends study shows that the lower likelihood of technology use was associated with vision and memory limitations. Even with older adults who have no disabilities, technology use varied by sociodemographic status and activity-limiting impairments (Gell, et al., 2015).

While the most promising research agenda for new technology for older adults may be adopting and implementing these technologies for training and enhancing cognitive abilities, the reasons for slow adoption especially by such populations may still be difficult to summarize. Brain games for enhancing mental acuity in older adults have not always received the support needed to project a wide adoption (Van Pelt, 2011). About two years ago, nearly 70 scientists issued a statement about their skepticism of

[9] Older Adults and Technology Use, Pew Research Center, April 2014

computer-based brain games and its claim to enhance mental acuity in older adults (Parker-Stanford, 2014). The reasons to this expression of skepticisms stemmed from a combination of the following points; 1. That there is no one-size-fits-all when it comes to brain performance and hence playing a game to train the brain does not imply a general, all-round deeper improvement in mental acuity, 2. That brain game companies have ulterior motives of profit and not healthcare and patient safety, 3. That lifestyle changes may provide a better effect on brain fitness than computer games. Over time, research has shown the fact that brain fitness games do enhance and maintain mental acuity in older adults. Even in healthy older adults; those who have no disabilities or cognitive impairments. The training and enabling of older adults to adopt and use technology however is a long-term goal which should be strategized by guided actions to provide better performance outcomes (Hickman, Rogers, and Fisk, 2007).

In retirement communities, a study found that most residents who used computers and other technology were younger, with more education, fewer functional impairment and more social resources (Carpenter, & Buday, 2007). The same study also found that barriers to use of technology among residents in a retirement community included cost, lack of interest, ergonomic impairments, and complexity of technology. Another study by White & Weatherall (2010), also found that older adults' involvement and use of technology were linked to the personal usefulness, direct experience and personal ownership of technology. They also illustrated how involvement and use of technology by older adults follows a cyclic pattern that reinforces continued use and involvement. Research on the adoption of new technology by older adults also show that attitudes and abilities of such seniors are the most predictive factors. Hence normative age-related changes can and should be considered in designing new technology for older adults (Charness, & Boot, 2009).

2.9 Chapter Summary

In this chapter, related literature is reviewed. This review was done to paint a broader picture of what the research problem is, why this dissertation is addressing the problem and more importantly, show how the research domain surrounding the dissertation theme affects and/or influences the research solution. An initial review was done on older adult populations in America and the resurfacing of commodities and other cognitive changes that occur because of ageing. It was found that although age-related cognitive decline cannot be prevented or cured, there are ways that have been tested by research to mitigate or slow down the process. There are many more theories surrounding approaches to addressing and reducing cognitive decline as well. Cognitive training, one of the oldest and most research approach, was reviewed to understand the process, methods and outcomes of such interventions. The literature also looked at research on brain fitness games that are available either or both electronic and paper platform. Generally, studies that test or evaluate the use of these games by older adults have clinical outcome evaluation metrics. Only a handful of research have had user testing or usability as their focus during these studies. Current initiatives surrounding and supporting older adults brain health and fitness were also reviewed. Finally, the review covered research on designing games for older adult populations, the use of technology by older adults, and the assessment, adoption and implementation of such brain fitness games for older adults.

Chapter 3: Methodology

3.1. Methods Overview

This dissertation study uses a mixed-method games user research methodology. The methodology selection is influenced by both the overarching research problem and the research questions under study for this dissertation. In this mixed-method games user research study, the goal is to investigate older adult performance enhancement through analyses of gaming playing field data. Benchmark usability testing research metrics and design comparison user testing methodologies influences the design of the methodology section of this research study. Participants who meet the criteria of the study were recruited using both the convenience and snowball sampling technique. Each participant went through a ~60-minute user session where they interact and play a 4-set brain fitness game specifically designed to maintain and enhance age-related cognitive decline in older adults. Each session begins with an initial discussion on participant's perspectives on brain health, cognitive decline, and brain fitness games. During each session, participant demographic data as well as game outcome data are collected. Each session typically ends with final comments from participants, and a follow-up thank you email from researcher to participant. Follow-up thank you notes include a link to download the free brain game from iTunes. Both descriptive and statistical analysis were used to deduce meaning out of the quantitative data collected, while qualitative data coding and analysis is used to form themes and meaning from the subjective responses. In-depth findings, discussions and conclusions are shared in the subsequent chapters of this dissertation. It should be noted that: 1) A pilot study with 4 participants preceded the main experiment. 2) A randomized sampling method was used to place participants into groups that determine which game platform (paper before electronic or vice versa) they start with.

3.1. Objectives

This study has the following three objectives: 1. To understand older adults' perspectives on brain health and cognitive decline and their experience with brain fitness games. 2. To investigate if selected user demographics influence player gaming outcomes in brain fitness games for older adults, and 3. To investigate if game platform preference (electronic versus paper) influences player gaming outcomes.

3.2. Game Selection

The brain game selected for the user sessions in this study is 'Senior Games'. Senior Games- '*Exercise your mind while having fun*'- is a mobile app that is available for download on both mobile and tablet platforms. This game is designed and developed by Lisbon Labs in Portugal. Lisbon Labs also create all sorts of gaming experiences for different age groups. Based on rigorous brain fitness and cognitive decline research by Lisbon Labs, this game is intended to keep the mind fit with its 8-set simple games (Matching, Speed, Memory, Perception, Calculus, Awareness, Recognition, Focus). The goal here is to keep older adult users alert and entertained. Perhaps the most influential factor that contributed to using this game in the study is the fact that most of the games can easily be printed out and played on paper platforms.

Figure 4: *Senior Games* Brain Game Interface (Lisbon Labs, *Senior Games* App, ©2016).

3.3. <u>Study Design</u>

The design of this dissertation study has the following parts: participant recruitment, study protocol, data variables, collection, and analysis, and evaluation outcomes.

3.3.1 Participant Recruitment

<u>Process:</u> Both convenience sampling and snowball recruiting technique is used to recruit participants. With convenience sampling technique, the researcher directly reaches out to potential participants for the study. With snowball sampling, the researcher asks participants which fit the selection criteria to recommend other participants who may be ideal for the study. Both sampling methods is chosen for several reasons.

First, non-random sampling tactics such as these are useful for researching small populations who may be marginalized or difficult to access. In this case whereas older adult populations may be large, access to this population is somehow difficult. Snowball sampling also helps access participants with multiple eligibility requirement. Finally, sampling tactics were selected to build trust and empower research participants during study sessions.

Recruitment fliers were also posted around the UMBC campus and the northern Baltimore community to recruit other participants who will typically not be found in a senior center. See appendix A for recruitment flier. Interested participants were contacted by researcher via phone or email for additional screening. See appendix B for recruitment emails. In the introductory email, the researcher briefs potential participants on study procedures. Once a person meets preliminary participant study criteria and still shows interest in being a participant, the researcher sends another email with scheduling information. All scheduling is done at the convenience of participants. Sample consent forms are sometimes sent to participants for review prior to session date. See appendix C for adult participant consent form.

- <u>Criteria</u>: Participants who were considered for this study meet the following demographic criteria:
    1. Must be born in the baby boomer generation. (i.e. should be between 52 - 70 years old as of December 2016).
    2. Must not have any hearing, speech, vision, motor or cognitive impairments that prevents them from playing the game or answering the follow-up questions.
    3. Must be fluent in speaking and reading English.

4. Must have prior experience with games.
5. Must be able to manipulate touch screens with gestures such as swipe, scroll, pinch, tap, double tap, flick etc.
6. Must be willing to go through the consenting process as well as the entire session.

- Sample Selection & Sample Size: For a games user research, such as this, a sample size of about 63 - 80 participants are sufficient to achieve adequate representation across the demographic categories and platform comparison. From the research questions, two main games user study analysis will be done on the data: 1) A benchmark usability test (emphasis on metrics) and 2) Design comparison study.

While a benchmark usability study also involves problem identification, it emphasizes assessing the usability of an experience. In this case, the usability of the gaming experience. From this benchmark usability testing, metrics being tested are: effectiveness (Errors, Completion Rates), Efficiency (Time on task), and User satisfaction (Post-test comments). The variability (binary) of the metrics plays a role in determining sample size. All factors being considered, with a sample size of 63 – 93, there is a margin of error of +/- 10 -12% for a 95% level of confidence[10].

A design comparison study on the other hand allows researcher to know which design participants think is better or perform better on. Hence the sample size needed is a function of how small a difference a researcher hopes to detect (if one exists). Again, binary metrics are used to set the sample size. A within-subjects study such as this dissertation study, require less than 93 participants (less than 25% of the between-

[10] Nielsen/Norman Group: Determining sample sizes for UX studies (2008).

subjects sample size) to achieve a 12% difference detection with 90% confidence and 80% power.

In all, factors that went into selecting the sample size for the study are:

1. Type of test are you conducting. Whether benchmark testing or design comparison
2. The Confidence Level: This is how confident you need to be that the population parameter will fall within your margin of error. It is usually set to 95% by convention, but 90% or 85% are fine for industrial applications.
3. The metrics being collected and amount of variability in the metric(s)—as measured by the standard deviation.
4. Between or Within Subjects: If users attempt tasks on both design alternatives you remove the variability between participants and it allows you to detect smaller differences with smaller sample sizes (within-subjects).
5. How large of a difference you want to detect: Large differences with a smaller sample size but need a large sample size to detect small differences.
6. Power: How confident you want to be that if a difference does exist, you'll be able to detect it. By convention this is set to 80%.

For the qualitative sampling, the choice to interview eighteen (18) participants was motivated by both practical and analytical reasons as well as considerations which are recommended in qualitative research (Baker & Edwards, 2012). Eighteen participants represent about 22% of the participants recruited for the gaming sessions. Practically speaking, a larger sample for the qualitative interviews would not have been prudent since most major themes start to get redundant after about 15 interviews. Additionally, 18 interviews are enough to provide the breadth of insights for this study; ultimately gaining an in-depth understanding of a variety of user experiences. The figure below shows a visual representation of the participant recruitment inclusion/exclusion criteria.

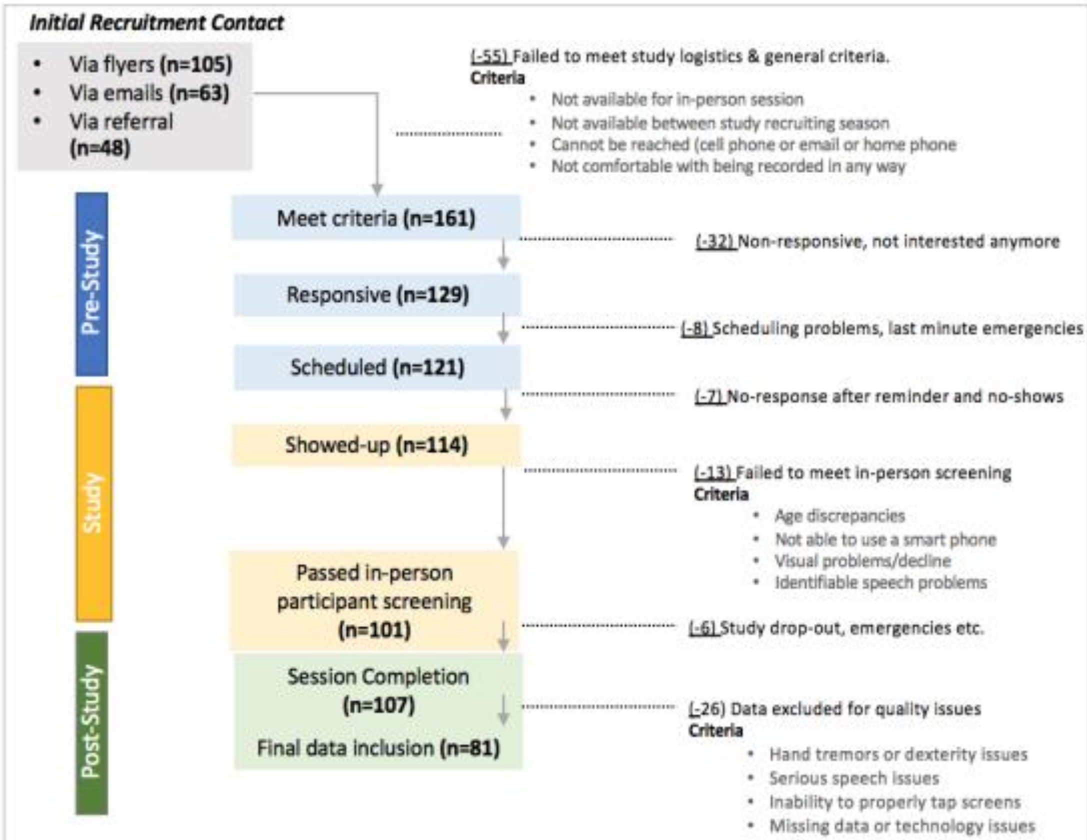


Figure 5: Participant recruitment: Phases of Inclusion/Exclusion criteria

From the figure above, it is shown that a total of 216 (100%) participants were original contacted via emails, flyers, and referrals. Out of that number, 55(~25%) did not meet general study feasibility criteria and hence were excluded from the study. These criteria included: whether the participant is available within the scheduling season, whether the participant is available for an in-person study, whether the participant is comfortable with being recorded, etc. Out of the remaining 161 participants, 47 (~29%) were excluded because they were non-responsive, had scheduling issues, or did not show up for their study session. On the day of the session, 13 participants out of 114 failed to meet the in-person testing criteria. The criteria involved participants verifying their age, being able to conduct simple touch screen manipulations (such as swipe, pinch, scroll, tap, flip etc.), being able to speak clearly and read from a screen provided. A few participants (6) also did not complete the study session and so their data was excluded as well. Finally, when all the data were collected, 26 out of 107 participants (~24%) were excluded because they were either incomplete or the field notes indicated that the data had lost its integrity. A total of 81 participant data was included in the final data analyses.

3.3.2 Study Protocol

- *Setting:* The setting for this study varied. Participants were given the option to choose the location and time for their session. For each session, the researcher arrives with all the study paperwork, protocols and equipment needed for the session.

- *Procedure:* Prior to each experiment, participants are provided with consent forms and demographic forms to complete and sign. On the day of the session, a moderator guide (See Appendix D for moderator guide) along with the following outline is used to ensure a properly facilitated session:

- Set up [~8 mins]: Audio/video, observer, note taker etc.
- Introduction [~8 mins]: Consents signed, Participants trained on game structure and platform [electronic or paper]
- Part A1 [~10 mins]: Participants go through the 4-set brain game on platform A.
- Part A2 [~8 mins]: Participants discuss their experience on platform A.
- Part B1 [10 mins]: Participants go through the 4-set brain game on platform B.
- Part B2 [8 mins]: Participants discuss their experience on platform B.

- Tear down [8 mins]: Answer questions from participants, pack and leave.

A session is considered successful when the participant shows up, signs consent forms, completes all game-sets, and answer follow-up questions. Each study typically followed an end-to-end flow shown in the figure below.

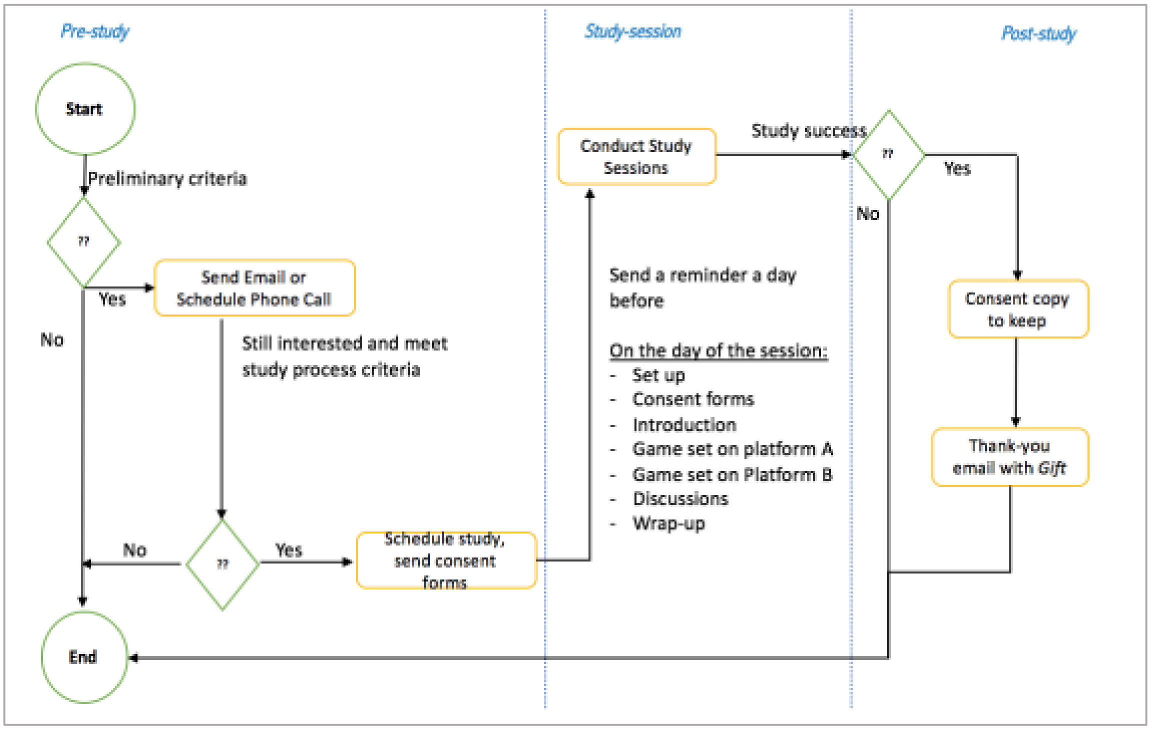


Figure 6: End-to-end flow diagram of a typical study session

3.3.3 Data Variables and Collection

During each session, data is collected in several formats: audio/video recordings, researcher notes, tally sheets. See appendix E for tally sheets and data dictionary. Data points collected prior to each session are demographics i.e. Age, Race, Gender, Technological Savviness, and Educational Background. Demographic data are confirmed by participants during the sessions. Data points recorded during the session included: Starting Platform Type, Time on Task (in seconds), Error Tally, Task Completion, and participants' comments about gaming experience. The table below summarizes the data variables collected for the study. Note that each variable may have several instances representing different games on different platforms.

ID#	*Variable Name*	*Description*	*Variable Type*
1	Platform (paper or electronic)	Platform type which players will be tested on.	Independent
2	Age	Participant's Age	Independent
3	Race	Participant's Race	Independent
4	Gender	Participant's Gender	Independent
5	Educational Background	Participant's level of education	Independent
6	Tech Savviness	Participant's computer competence.	Independent
7	Time on Task (in secs)	Time spent completing each game.	Dependent
8	Task Completion	If the participant could complete gaming session or not.	Dependent
11	Error Tally	Number of errors.	Dependent
13	Comments	User feedback after gaming experience.	Dependent

Table 2: Summary of Data Variables.

3.3.4 Data Preparation

As soon as a study session ends, the researcher checks for accuracy of data recorded. Checking for accuracy involves checking data to see if they are complete, have all related contextual information, and are legible/readable. Original data records are saved for possible future references. In this study, Microsoft Excel is used for logging and collating all the data points; storing them on the cloud. Excel is used because it provides the most flexibility and manipulation of data for this dissertation research study. A simple data dictionary which describes the data and indicates how it can be accessed, is generated for the data variables in this study. See Appendix E for reference. The data dictionary contains the following information for each variable collected: variable name, variable description, variable format, method of collection, date collected, and notes on variable. In case of missing values or corrupted values, specially designated values. are used to replace missing values.

3.3.5 Data Analysis

This section describes the quantitative and qualitative data analyses done to answer specific objectives outlined for this dissertation. Recalling from Chapter 1, the research questions are: *Research Question 1:* What are the perspectives and subjective experience of healthy older adults on cognitive decline, brain fitness games, and brain health? *Research Question 2:* Does select population demographics influence gaming outcomes healthy older adult players? *Research Question 3:* Does game platform influence game outcomes in healthy older adult players?

<u>Research Question 1- Qualitative Analysis</u>

For research question 1, qualitative data analyses are done on user comments collected during the session to deduce meaning from the data. Here a sample size of 18 (out of 81) participants is selected. Data gathered from this study that relates to RQ1 are in two forms; a) Transcripts from audio recording of interviews, and b) Researcher field notes from sessions. A verbatim transcription of participants' comments from the audio-recordings forms the basis from which themes, codes and categories related to the study are deduced. Transcripts are analyzed using a thematic content analysis (TCA) approach.

Although the TCA suggests a linear stepwise way to analyze data, the analysis itself is not a simplistic linear process. Rather an iterative process which involves constant reflection and internalization of what the information means. The literal and figurative meanings from the transcripts come to play.

Research Question 2 and Research Question 3- Quantitative Analysis

Descriptive statistics provide summaries about the sample and measures of the quantitative data collected. This process helps compare the variables by way of assessing similarities in the distribution of the various variables. In this descriptive analysis, variable characteristics that are examined include: distribution (frequency of individual ranges for a variable), central tendency (estimate of the 'center'-mean, median, mode- of the distribution values), and dispersion (the spread of the values around the central tendency). The descriptive statistics describes what the data collection shows. However, to reach conclusions that go beyond the immediate data, the following statistical analyses and tests are done. A univariate analysis in the form of ANOVA tests and data comparisons are used to examine each variable across select scenarios in this study. All demographic and platform data (independent variables) as well as outcome data (dependent variables) are each inspected with descriptive statistical analysis.

Subsequent repeated ANOVA tests are done for both research question two (2) and (3) to understand the relations and interactions which exist between variables. The following H_1s and H_0s form the basis of the tests.

	Objective	Hypotheses Statement	Null Hypothesis (H_0)	Alternative Hypothesis (H_1)
RQ2	To investigate if older adults' demographics influence brain fitness gaming outcomes.	If older adults have certain demographic factors then their brain fitness gaming outcomes will improve.	Gaming outcomes like time on task, errors, and task completion *are not influenced* by population demographics such as age, gender, race, computer experience, and educational background.	Gaming outcomes like time on task, errors, and task completion *are influenced* by population demographics such as age, gender, race, computer experience, and educational background.
RQ3	To investigate if game platform influence gaming outcomes in older adults.	If older adults play brain fitness games on certain platforms then their gaming outcomes will improve.	Game platform (paper versus mobile/tablet) *does not influence* gaming outcomes like time on task, errors, and task completion.	Game platform (paper versus mobile/tablet) *does influence* gaming outcomes like time on task, errors, and task completion.

Table 3: Main Hypotheses for Research Questions 2 and 3

3.3.6 Study Outcomes and Measures

The outcomes of the study are findings based on the objectives of the study. Discussions on findings also expound on the metrics, outcomes and measures used in this study. The validation of outcomes is done by subject matter experts in cognitive maintenance and enhancement, games user researchers and researchers whose primary research area is geriatric/gerontology.

3.4 Other Research Issues

3.4.1 Research Ethics/IRB Approval

This study is approved by the UMBC IRB and ethics committee as well as overseeing bodies in the main participant recruiting centers (i.e. The Arbutus and Catonsville Senior Centers).

3.4.2 Pilot Studies and Instrument Validation

Prior to study implementation, a pilot study was conducted with four (4) older adult participants. The researcher conducted the sessions just as would be done in the main study sessions. Once the pilot study was completed, the entire research process and data were reviewed and necessary additions, revisions, and changes made.

3.5 Chapter Summary

Chapter three gives a detailed description of the overarching study plan along with specific research methodologies selected for the research study. This chapter digs deeper into the processes and methods surrounding the initial selection of the brain fitness game used for this study, the study protocol, recruiting protocols, data collection, preparation, then analyses methods. The Table below summarizes the objectives, methodology and outcomes for this study.

Objectives	Participants selection	Data Collection	Analysis & outcomes
• To investigate perspectives and experiences of older adults on brain health, fitness and games. • To investigate older adult demographics and its effect on gaming outcomes. • To compare participant gaming outcomes on both paper and electronic platforms.	• Population: Baby boomers. • Sample(n): 81 • 18 for qualitative component.	• Paper platform • Electronic platform • Age • Race • Gender • Educational Background • Tech. Savviness • Time on Task • Task Completion • Error Tally • Participants' Comments	<u>Quantitative Analysis:</u> Descriptive statistics, Comparative Analyses, and ANOVA tests. <u>Qualitative Analysis:</u> Data coding, categorization into themes.

Table 4: Summary of Research Study Plan & Methodology

Chapter 4: Research Findings

This chapter presents the analysis of data and the findings from the results. The research questions that guides the study are as follows: 1: What perspectives and subjective experience do older adults have on cognitive decline, brain fitness games, and brain health? 2: Does population demographics such as gender, race, age, tech savviness and educational background influence gaming outcomes like speed, satisfaction, errors, and task completion? 3: Does game platform type (paper versus electronic) influence game outcomes (speed, errors, and task completion) in healthy older adult players?

4.1 Summary of Overall Findings

The research study conducted shows the following main findings.

From the pilot study, the original game set had to be reduced from 8-gameset to 4-game set. This is because while it was easier for the researcher to go through all 8-game set for both platforms (making 16 games) at a sitting, older adult participants found it draining to go through all 8 game sets in a sitting. Some games also did not translate well into a paper platform version thereby greatly influencing the potential participants' reaction and biasing the study. Finally, from the pilot study, the data variables were standardized and coded making it easier to record and prepare for analysis after the study.

From the main study, the main findings from the qualitative analysis are that: Older adults are indeed concerned with their brain health and fitness as they get older. Whereas most participants are not sure how different brain health, brain fitness, age-related cognitive-decline are related, they however do know that there must be some sort of way to exercise the brain especially as they get older. Most participants are starting to embrace electronic games but not solely for brain fitness exercises. Participants talked about playing board games (like Bingo, Sudoku, Chess, Checkers, Monopoly) occasionally as a way of getting "back in the game". Finally, most older adults will like to be informed of different ways to maintain and enhance their cognitive acuity.

The main findings from the quantitative analysis are that; older adult demographics such as gender, race, educational background, and technological savviness do affect gaming outcomes such as completion time, error rate and task completion. Game platform selection (paper or electronic) did not affect overall task completion and error rates but slightly affected time to completion of the game sets.

4.2 Findings from Pilot Study

Prior to the main study, a pilot study was conducted with 4 participants. The purpose of the pilot study in the context of this dissertation study were:

1. To determine the overall feasibility of the research proposed.
2. To time the entire study from start to finish.
3. To refine the process in recruiting and scheduling a study.
4. To have sample data available for pre-standardization and coding preparations.
5. To understand older adult constraints and hone in on participants' selection criteria.
6. To test the research instruments for collecting the study data.
7. To ensure all the proposed variables are right and enough to be used in reach and effect size (statistical variability) and hone in on an appropriate sample size.

Setting, and procedure of pilot studies: The pilot study procedure followed the same procedure originally proposed for the study. First participants were recruited using convenience sampling. The participants were all known by the researcher. Each participant was asked to select two days/times form a list of availabilities provided by the student researcher. Out of the two, one date was scheduled for the study session. About a day to the study, the study venue was agreed upon. A confirmation email which includes the study day, time, venue and reminder of the study objectives was sent to the participant. On the day of the study, the researcher met the participant at the agreed venue, set up study, made sure consent was read and completed, went through the session guide, and recorded all data. Notes were made as to what changes could and should be made on the study design.

Outcomes and takeaways from pilot studies: Outcomes from the pilot study were as follows:

1. The overall study takes than the 60 minutes allocated time. It took 40 minutes to complete the session. Although scheduling was done with a 60 minutes' time frame, the researcher now knew that some scheduling wiggle room was built into the study.
2. The originally planned questions designed to be asked after each play was changed to a discussion session where the researcher engaged in a discussion of the experience… seldom asking questions to drive the discussion.
3. The original game set was reduced from 8-gameset to 4-game set. This is because whiles it was easier for the researcher to go through all 8-game set for both platforms (making 16 games) at a sitting, this was especially difficult for older adults.
4. Some games did not translate well into a paper platform version thereby greatly influencing the potential participants' reaction and biasing the study.

5. A cut off point of level 20 was set for all game plays to standardize the recording of time data.
6. Obvious and subtle gamification techniques embedded in the electronic platform were identified.
7. Full video/audio recording of the sessions were replaced with hand-only recording with audio from the session.
8. Data variables were standardized and coded making it easier to record and prepare for analysis after the study.
9. A note was made to ask participants about what they understood the game to be before they played the game.
10. Finally, all participants were made to understand that the goal of each games study was not to measure skills, IQ, or competence but rather to understand user/participant experience and get insights from each play/experience.

4.3 Findings from quantitative analyses

4.3. 1 Demographics Data

A total of eighty-one (81) participants were part of the study sessions. i.e. **n=81**. The following table shows the breakdown of the five-demographic data collected from this research study.

Age	Gender	Race	Educational Background	Tech Savviness
(in years) 52-55 56-60 61-65 66-70	Male= 39 (~48%)	Black = 22 (~27%)	High School Level= 30 (~37%)	Beginner = 28 (~35%)
	Female= 42 (~52%)	Asian = 11 (~14%)	College Level= 28 (~35%)	Intermediate =26 (~32%)
		Mixed = 13 (~16%)	Graduate Level= 23 (~28%)	Advanced= 27 (~33%)
		Caucasian = 24 (~30%)		
		Hispanic = 11(~14%)		

Table 5: Summary of Participants' Demographics Data Collected.

Participants' Age Range

Per study recruiting criteria, all participants were baby boomers. This means that all the age data collected ranges from 52-70 years old (as of 2016). The age data are sub-grouped into ranges: 52-55yrs, 56-60years, 61– 65 years and 66-70 years. Below shows a frequency distribution of the age data collected.

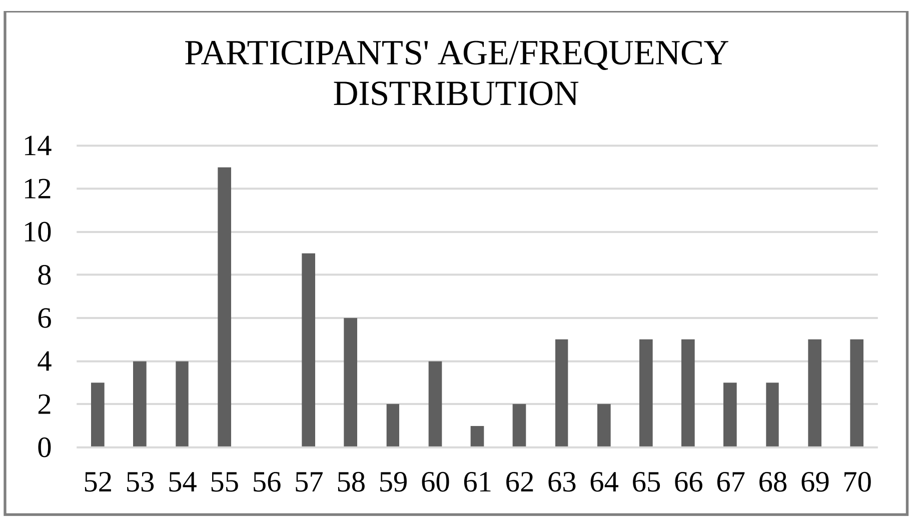


Figure 7: Participants' Age Distribution

Gender

The data on gender collected for this study resulted in 39 males and 42 females. Although provision was made for non-binary and gender-fluid participants, all participants identified as either male or female. The gender variable was coded as follows: Female (F)=1, Male (M)=2.

Age Group (52-55)	Male	Female
	54, 55, 54, 55, 54, 52, 55, 55, 55,55, 55, 55	53, 55, 54, 53, 55, 53, 55, 52, 53, 55, 55,52
Total	**12**	**12**

Age Group (56 - 60)	Male	Female
	59, 58, 57, 58, 58, 57, 60, 58, 58, 57, 60	60, 57, 57, 58, 57, 59, 57, 60, 57, 57
Total	**11**	**10**

Age Group (61 - 65)	Male	Female
	63, 64, 62, 65, 65	65, 62, 63, 65, 64, 65, 63, 63, 63, 61
Total	**5**	**10**

Age Group (66 - 70)	Male	Female
	69, 70, 69, 67, 68, 66, 66, 70, 66, 69, 70	70, 68, 67, 66, 69, 70, 66, 69, 67, 68,
Total	**11**	**10**

Figure 8: Age Group Distribution by Gender Type.

Race

The data on race collected for this study resulted in the following: Black (B) – 22, Asian (A) – 11, Mixed (M) – 13, Caucasian (C) – 24, and Hispanic(H) – 11. The race term Black was used to group any participant who identified as African American or Black. Asian was used to group any participant from Asian origins and particularly identified as Asian. Mixed was used to group any participant form 2 or more origins and/ or could not identify with any of the main race options provided. Caucasian was used to group any participant who identified as white and from the indigenous American or European descent. Hispanic was used to group any participant who identified as Latino or from a south American descent. The race variable was coded as follows: Black (B) – 1, Asian (A) – 2, Mixed (M) – 3, Caucasian (C) – 4, and Hispanic(H) – 5.

Educational Background

The data on educational background collected for this study resulted in the following: High School Level – 30, College Level – 28, Graduate Level – 23. High School Level refers to any participant who has completed up to high school or GED schooling. College Level refers to any participant who has completed up to college or associate degree schooling. Graduate Level refers to any participant who has completed post graduate level schooling. The educational background variable was coded as follows: High School Level – 1, College Level – 2, Graduate Level – 3.

Tech Savviness

The data on technology savviness collected for this study resulted in the following: Beginner – 28, Intermediate – 26, Advanced – 27. Beginner refers to any participant who has basic technology savviness. i.e. They know and can comfortably operate household electronics such as microwave, coffee brewer, TV, fridge etc. Intermediate refers to any participant whose savviness goes a little beyond beginners in that they have and can operate a mobile phone, use tablets and laptops for basic tasks. Advanced refers to any participant who can do more advanced tasked with technology such as download and play games on a mobile phone, send and received emails, facetimes and engages in social media. The tech savviness variable was coded as follows: Beginner – 1, Intermediate – 2, Advanced – 3.

Other variables (independent)

Other independent variables recorded are: Participant ID#, Session Date, and Platform Type Used. Participant ID numbers are generic alpha-numeric codes assigned to participants for easy referencing. These alphanumeric codes ranges from P1-P81. Thus, representing the 81 participants recruited for this research study. Session dates were recorded to show the date the study happened. The dates were recorded in a short-date format. Platform Type Used data was recorded to remember the platform (paper or electronic) on which a participant started the study. Since the starting platform was randomized in this study, it was important to note which participant started with what platform during analysis of the data. The starting platform data was recorded as P (to represent paper, and E to represent electronic… later coded as P – 2, and E – 1.

4.3. 2 Descriptive Statistics on Games Outcomes Data (Dependent)

Games outcomes data are all the data collected during the gaming experience in each session. The Senior Games App games selected for the study are Matching, Awareness, Calculus, and Speed. Note that these game-set were played on both paper platform as well as electronic platforms. The outcomes recorded for each game in each platform set (making 8 set of outcomes recorded per participant) are: Time (in Seconds), Completion, Error Tally, and Participant Comments. The following table shows the breakdown of the overall games outcomes data collected from this research study.

Paper Platform			
Time (Secs)	Task Completion	Error Tally	Participants' Comments
Electronic Platform			
Time (Secs)	Task Completion	Error Tally	Participants' Comments

Table 6: Overview of Outcomes Data Tally Sheet

Time (in Seconds)

Time represents the time spent in completing a single game. The time is measured in seconds. For each game, the participant is asked to play till level 20 and the time used is recorded. The data collected on time for this study resulted in the following:

A. Descriptive Statistics for Overall Time on Electronic Vs. Paper Platform

Descriptive Statistics on Time (All 4 games on Electronic platform)	
Mean	97.13580247
Standard Error	0.853460777
Median	95
Mode	92
Standard Deviation	15.36229398
Sample Variance	236.0000764
Kurtosis	0.595320176
Skewness	0.331354566
Range	104
Minimum	45
Maximum	149
Sum	31472
Count	324

Descriptive Statistics on Time (All 4 games on Paper Platform)	
Mean	102.7592593
Standard Error	0.888228718
Median	101
Mode	99
Standard Deviation	15.98811693
Sample Variance	255.619883
Kurtosis	0.646598712
Skewness	0.024696012
Range	85
Minimum	62
Maximum	147
Sum	33294
Count	324

Figure 9: Descriptive Statistics of Time on Task: Electronic vs. Paper Platform

Task Completion

Completion represents if a participant could play the game from start to finish without quitting or finding the experience extremely difficult to follow through. The completion data was coded: 1 for completion success and 0 for completion failure. The data collected on completion for this study resulted in the following:

Paper Platform	Matching Game	Awareness Game	Calculus Game	Speed Game	**Overall**
Completion Rate	90.1%	92.6%	91.4%	88.9%	90.8%
# of Successes	73	75	74	72	73.5
# of Failures	8	6	7	9	7.5

Table 7: Summary of data collected on task completion (Paper platform)

Electronic Platform	Matching Game	Awareness Game	Calculus Game	Speed Game	**Overall**
Completion Rate	92.6%	96.3%	88.9%	87.7%	91.4%
# of Successes	75	78	72	71	74
# of Failures	6	3	9	10	7

Table 8: Summary of data collected on task completion (Electronic platform)

Error Tally

Error Tally represents the number or mistakes a participant made in each game. The completion data was recorded as numeric integers and ranged from 0 to any number of errors made. The data collected on error tally for this study resulted in the following:

Paper Platform	Matching	Awareness	Calculus	Speed	**Overall**
Error Range	0 - 3	0 - 2	0 - 4	0 - 3	0-4
Avg. Error per participant)	0.36	0.32	0.67	0.53	0.47
Tally of Errors	29	26	54	43	38

Table 9: Summary of data collected on Error Tally (Paper platform)

Electronic Platform	Matching	Awareness	Calculus	Speed	**Overall**
Error Range	0 - 4	0 - 3	0 - 5	0 - 4	0-5
Avg. Error per participant)	0.57	0.42	0.59	0.57	0.54
Tally of Errors	46	34	48	46	43.5

Table 10: Summary of data collected on Error Tally (Electronic platform)

Participants' Comments

Qualitative data from the study sessions were recorded in the form participants' comments on games, researcher field notes and video/ audio recordings. The data on participants' comments collected for this study were filed and analyzed separately. Each comment however was referenced back into the main data tally sheet with the following nomenclature. Each participant played 4 games sets on both paper and electronic platforms making 8 games in all. So, for participant P1, comments were referenced as: 1A, 1B, 1C, and 1D for the games played on the electronic platform and 1E, 1F, 1G, and 1H for the games played on the paper platform. See appendix H for a full list of participants' comments. The ANOVA sections provide more findings on the variable time as it relates to the other independent variables.

4.3. 3 Analysis of Variance (ANOVA)

The following single factor or one-way ANOVA (analyses of variance) are performed on the data using Excel functionalities. From the Research Questions 2 and 3 for this dissertation, the following hypotheses and sub hypotheses are formed to help answer the questions.

A. Research Question 2: Do population demographics such as gender, race, tech savviness and educational background influence electronic gaming outcomes like speed, errors, and task completion?

The ANOVA below tests the null hypotheses to determine if they are true.

1. Age Group and Outcome Variables

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Age 52-55	96	9192	95.75	269.0315789
Age 56-60	84	8062	95.97619048	220.2644865
Age 61-65	60	5807	96.78333333	204.3759887
Age 66-70	84	8411	100.1309524	232.1874641

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1058.329453	3	352.7764844	1.501781731	0.214000555	2.632826
Within Groups	75169.69524	320	234.9052976			
Total	76228.02469	323				

Table 12: ANOVA Test for Time on Tasks for various Age Groups.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Age 52-55	96	89	0.927083333	0.068311404
Age 56-60	84	77	0.916666667	0.077309237
Age 61-65	60	48	0.8	0.162711864
Age 66-70	84	78	0.928571429	0.067125645

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.761827601	3	0.253942534	2.894171276	0.035426609	2.632826736

Within Groups	28.07767857	320	0.087742746
Total	28.83950617	323	

Table 13: ANOVA Test for Task Completion for various Age Groups.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Age 52-55	96	48	0.5	0.673684211
Age 56-60	84	44	0.523809524	1.047619048
Age 61-65	60	28	0.466666667	0.49039548
Age 66-70	84	54	0.642857143	0.858864028

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.384126984	3	0.461375661	0.587806553	0.623387745	2.632826736
Within Groups	251.1714286	320	0.784910714			
Total	252.5555556	323				

Table 14: ANOVA Test for Errors Made by various Age Groups.

2. Gender and Outcome Variables

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Females	168	16469	98.0297619	224.9392287
Males	136	13127	96.52205882	276.2365468

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	170.8465649	1	170.8465649	0.68925833	0.407072574	3.872434
Within Groups	74856.78501	302	247.8701491			
Total	75027.63158	303				

Table 15: ANOVA on Female vs. Male Time on Task

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Females	168	149	0.886904762	0.100905332
Males	156	143	0.916666667	0.07688172

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.07164903	1	0.07164903	0.801971017	0.371173672	3.870499803
Within Groups	28.76785714	322	0.089341171			
Total	28.83950617	323				

Table 16: ANOVA on Female vs. Male Task Completion

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Variance*
Females	168	91	0.87250499
Males	156	83	0.689288668

ANOVA

Source of Variation	*SS*	*df*	*F*	*P-value*	*F crit*
Between Groups	0.007478632	1	0.009535292	0.922271911	3.870499803
Within Groups	252.5480769	322			
Total	252.5555556	323			

Table 17: ANOVA on Female vs. Male Errors made

3. Race on Outcome Variables

ANOVA (single Factor) analyses on the game time comparing the race groups.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Blacks	88	8372	95.13636364	241.245559
Asians	44	4307	97.88636364	299.8705074
Mixed	52	5160	99.23076923	224.7300151
Caucasians	96	9232	96.16666667	189.9298246
Hispanics	44	4401	100.0227273	273.929704

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1061.687862	4	265.4219654	1.126429869	0.343950994	2.399952692
Within Groups	75166.33683	319	235.6311499			
Total	76228.02469	323				

Table 18: ANOVA on Time on Task for Race groups

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Blacks	88	80	0.909090909	0.083594566
Asians	44	40	0.909090909	0.084566596
Mixed	52	48	0.923076923	0.07239819
Caucasians	96	87	0.90625	0.085855263
Hispanics	44	37	0.840909091	0.136892178

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.195493935	4	0.048873484	0.544289717	0.703324636	2.39995269
Within Groups	28.64401224	319	0.089793142			
Total	28.83950617	323				

Table 19: ANOVA of task Completion for Race groups

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Blacks	88	44	0.5	0.689655172
Asians	44	24	0.545454545	0.858350951
Mixed	52	20	0.384615385	0.790346908
Caucasians	96	56	0.583333333	0.750877193
Hispanics	44	30	0.681818182	0.966173362

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.45998446	4	0.614996115	0.78443 5165	0.5359 55089	2.3999 52692
Within Groups	250.0955711	319	0.783998655			
Total	252.5555556	323				

Table 20: ANOVA of Errors made by Race groups

4. Tech Savviness on Outcome variables

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Advanced	108	10429	96.56481481	296.4350121
Intermediate	104	9924	95.42307692	177.6639283
Beginners	112	11119	99.27678571	228.436213

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	853.6741368	2	426.8370684	1.817789446	0.1640 51879	3.023864701
Within Groups	75374.35055	321	234.8110609			
Total	76228.02469	323				

Table 21: ANOVA on Time on Task by Tech Savviness groups

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Beginners	112	100	0.892857143	0.096525097
Intermediate	104	92	0.884615385	0.103061987
Advanced	108	100	0.925925926	0.069228107

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.102428436	2	0.051214218	0.572075007	0.564927491	3.023864701
Within Groups	28.73707774	321	0.089523607			
Total	28.83950617	323				

Table 22: ANOVA on Task Completion by Tech Savviness groups

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Beginners	112	63	0.5625	0.824887387
Intermediate	104	52	0.5	0.757281553
Advanced	108	59	0.546296296	0.773537556

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.224537037	2	0.112268519	0.142821103	0.866964199	3.023864701
Within Groups	252.3310185	321	0.786077939			
Total	252.5555556	323				

Table 23: ANOVA on Errors made by Tech Savviness groups

5. Educational Background on Outcome Variables

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Graduate	92	8889	96.61956522	290.1284042
College	112	10796	96.39285714	191.033462
High School	120	11787	98.225	238.5960084

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	228.700623	2	114.3503115	0.48298 3901	0.6173 87356	3.0238 64701
Within Groups	75999.32407	321	236.7580189			
Total	76228.02469	323				

Table 24: ANOVA test on time by Educational Background groups

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High School	120	106	0.883333333	0.103921569
College	112	101	0.901785714	0.089366152
Graduate	92	85	0.923913043	0.071070234

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.085805345	2	0.0429026 72	0.478956 01	0.61987 168	3.02386 4701
Within Groups	28.75370083	321	0.0895753 92			
Total	28.83950617	323				

Table 25: ANOVA of Task Completion by Educational Background Groups

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High School	120	69	0.575	0.767436975
College	112	57	0.508928571	0.792712355
Graduate	92	48	0.52173913	0.801720019

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.282962388	2	0.141481194	0.180025355	0.835333304	3.023864701
Within Groups	252.2725932	321	0.785895929			
Total	252.5555556	323				

Table 26: ANOVA of Error made by Educational Background Groups

B. <u>Research Question 3:</u> Does game platform type influence game outcomes in healthy older adult players?

1. ANOVA on Paper versus Electronic Platform on Outcome Variables

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Paper Platform	324	33294	102.7592593	255.6198 83
Electronic Platform	324	31472	97.13580247	236.0000 764

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5122.969136	1	5122.969136	20.84117 635	5.9749 1E-06	3.8558 93847
Within Groups	158793.2469	646	245.8099797			
Total	163916.216	647				

Table 27: ANOVA test on Time on Task: Electronic vs. Paper platform

2. Analyses of Error Tally on Electronic Platform versus Paper Platform

ELECTRONIC PLATFORM					
Game Platform (Electronic n=81)	Matching Game	Awareness Game	Calculus Game	Speed Game	Avg. All 4 Games
Error Range	0-4	0-3	0-5	0-4	0-5
Avg. Error per participant)	0.57	0.42	0.59	0.57	0.54
Tally of Errors	46	34	48	46	43.5
PAPER PLATFORM					
Game Platform (Paper n=81)	Matching Game	Awareness Game	Calculus Game	Speed Game	Avg. All 4 Games
Error Range	0-3	0-4	0-4	0-3	0-4
Avg. Error per participant)	0.36	0.32	0.67	0.53	0.47
Tally of Errors	29	26	54	43	38

Table 28: Analyses on Errors comparing Electronic vs. Paper platform

3. Analysis of Task Completion on Electronic Platform versus Paper Platform

ELECTRONIC PLATFORM					
Game Platform (Electronic. n=81)	Matching Game	Awareness Game	Calculus Game	Speed Game	Avg. All 4 Games
Completion Rate	88%	96%	89%	88%	90%
# of Successes	71	78	72	71	73
# of Failures	10	3	9	10	8
PAPER PLATFORM					
Game Platform (Paper. n=81)	Matching Game	Awareness Game	Calculus Game	Speed Game	Avg. All 4 Games
Completion Rate	90%	93%	86%	89%	90%
# of Successes	73	75	70	72	72.5
# of Failures	8	6	11	9	8.5

Table 29: Analyses on Task Completion comparing Electronic vs. Paper platform

4.3. 4 Power Table and Statistical Results

Sample Size	Minimum Difference (Effect)	Probability of Type I error (Alpha)	P- Value (Ideally)	Power
91	0.15	0.05	<or =0.05	0.80
81(Study n)	**“Study effect size”**	0.05	<or =0.05	0.80
70	0.2	0.05	<or =0.05	0.80

Table 30: Statistical Power Table

The table above describes the ideal statistical parameters to either accept or reject a null hypothesis. With a sample size of 81, the minimum difference between population for this study lies between 0.15 and 0.2. P-values less or equal to alpha are suggests that the data supports the null hypothesis.

4.3. 5 Re-visitation of Research Questions 2 & 3

Research questions two surrounds the relationship between the various demographic factors (variables) and the outcomes variables while research question three investigates the relationships between platform choice and the various outcomes variables. Using single-factor ANOVA tests, subsequent multiple-run ANOVA, and data analysis, conclusions are drawn on the null hypotheses formed at the beginning of the data analyses. In summary, the data analyses show that from the cohort of older adults (baby boomers) who participated in this research study, their demographic factors such as race, gender, educational background and tech. savviness influences their player outcomes such as time on completion, error tally, and task completion. Platform choice – electronic or paper- also influences player outcomes. In-depth discussions on findings and implications are presented in Chapter 5 of this thesis.

4.4 *Findings from Qualitative Analyses*

Out of the 81 participants recruited for this study, 18 participants' discussions were further analyzed for insights into research question 1.

#	Participants ID	Age	Gender	Race	Educational Background	Tech Savviness
1	P2	53	Female	Black	Graduate level	Advanced
2	P11	54	Male	Black	Graduate level	Advanced
3	P15	69	Male	Caucasian	Graduate level	Advanced
4	P17	55	Male	Asian	Graduate level	Advanced
5	P23	67	Male	Black	Graduate level	Advanced
6	P30	65	Female	Hispanic	High Sch. Level	Intermediate
7	P42	57	Female	Black	High Sch. Level	Intermediate
8	P48	59	Female	Black	High Sch. Level	Intermediate
9	P50	63	Female	Hispanic	College Level	Beginner
10	P52	57	Female	Black	College Level	Beginner
11	P54	60	Female	Mixed	College Level	Beginner
12	P56	65	Male	Black	High Sch. Level	Beginner
13	P58	55	Male	Mixed	High Sch. Level	Beginner
14	P64	57	Female	Asian	College Level	Intermediate
15	P69	57	Female	Mixed	High Sch. Level	Intermediate
16	P73	68	Female	Caucasian	College Level	Beginner
17	P80	61	Female	Caucasian	High Sch. Level	Beginner
18	P81	52	Female	Caucasian	College Level	Beginner

Table 31: Participants' Demographics for Qualitative Data Analyses

Recall that the research question 1 is *"What are the perspectives and subjective experience of healthy older adults with regards to cognitive decline, brain fitness games, and brain health?"* The themes that were highlighted in the data collected from the qualitative study include the following:

1. Older adults are concerned with their brain fitness as they get older.
2. Most participants are not sure how different brain health, brain fitness, age-related cognitive-decline are related. They however know that there must be some sort of way to exercise the brain especially as they get older.
3. Most participants are starting to embrace electronic games but not solely for brain fitness exercises.
4. A few of the participants talked about n playing board games (like Bingo, Sudoku, Chess, Checkers, Monopoly) occasionally as a way of getting "back in the game".
5. Finally, most older adults will like to be informed of different ways to maintain and enhance their cognitive acuity.

4.4. 1 Thematic outcomes from participants' discussions

- **Game Concept (all four types of games)**

Overall, participants liked the idea that this game was designed with older adults in mind. Most participants enjoyed the matching and awareness games better than the calculus and speed games. Comments like "*I see myself playing this game all the time because it engages me*" or "*I like to play this game… I don't know what comes next so I am excited taking that leap of faith*" came up whiles other expressed their thoughts on why they don't think they liked the games so well. From these user studies, it was found that the gaming experience was more challenging for females with nail extensions and left handed people. The former because the electronic screens would not respond to nail tip taps but with the palm of the fingers, and the latter because the game was designed for right handed players. Of all the 4 games, the awareness and speed games had titles and descriptions that were easily understood by the players. On the other hand, speed and calculus games descriptions were not self-explanatory ("*Titles do not capture what games means…*").

In terms of individual game experience, the calculus game gave the most concerns. Whiles most participants thought that naming the game calculus implied some sort of advanced math, ("*I think it means hard math*"; "*I don't think of adding as calculus…I was thinking of derivatives and integrals"; "Well, I didn't do good in calculus back in school so I am not sure if this game is for me*") others expressed concerns about how the game description did not do much justice in explaining what the player was to expect or do ("*What am I doing…. there are no directions*.").

The speed game was the most engaging of all the 4 games mostly because it was the only game that players could feel the pressure and need of a times. Partially because players had to actively count the squares…making then use all sorts of strategies to come up with the total number of squares.

In general, the awareness game was the most fun of all four. Participants especially enjoyed it because it was like other games where the player had to identify the intruder or the differences in 2 photos. Some participants however had concerns about being able to find the intruder as the levels progressed *("I think I am having anxiety attacks from this game… just kidding, but it gets harder as you go up the levels"*) ... making them less motivated to play for long periods of time.

The matching game was received with a lot of mixed feelings. Participants who loved the game talked about how it easier to find the matching pairs using one of the following strategies: top-down search, bottom-up search, color search, shape search. They also expressed how complicated the game could get if the matching pairs are more than one. *"I am confused! Are there be more than one set?"; "Hopefully there is not more than 2 that match"; "Am I looking for two pairs?"; "I have no idea what I am going to do."*

At the end of the gaming experience both on the paper and electronic platform, it was clear that whiles most players preferred the electronic platform because it was more fun to play, convenient for their schedules, had the timer, automatic scoring system, and gamification cues inbuilt into the platform. It was interesting to note that the concept of a paper platform was not entirely dismissed. Participants felt that a paper platform gave you time and space to enjoy the process of playing the game and getting to the desired computation or outcome. They hoped the paper platform would give them a bigger screen size and answers to the games at the back. Finally, the paper platform concept hit close to home for these older adult players… often starting a conversation on what games they played when they were children. At the end of the day, providing both computerized and non-computerized gaming options was a clear direction worth pursuing.

- **Player Strategies (Paper and Electronic)**

In looking at the strategies that players used to complete the tasks, 2 things were sure: Process versus End goal. While some participants were more interested in the process or gaming experience in general, others were more concerned with completing the tasks or winning the games. Thus, generating a “get through or survival” strategy versus a winning or competitive strategy. Here are details on the strategies employed for the various games.

The calculus game required players to tap on any numbers on the right that they thought adds up to the number provided on the left. If they are right, they advance to the next level. (See figures below)

Figure 10: Interface of Calculus Game on Electronic Platform

Strategies that were employed to successfully play this game were the following: *“I just selecting the biggest number and finding complementary numbers to add if need be.”; I look at the colors first to see if it gives a clue to number clusters that add up to the total”; I randomly tapped on numbers to see if I am right”; “…use multiples of 5 and 6 and supplement with other numbers”.*

The matching game required players to find matching pairs and tap on both to advance to the next level if they are right. (See figures below)

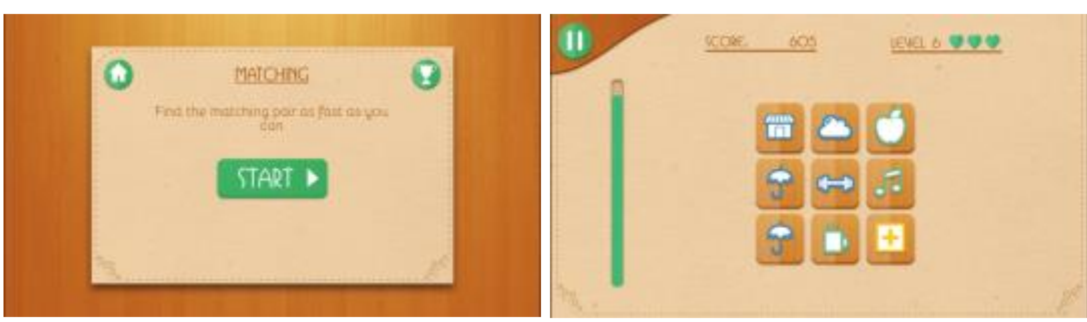


Figure 11: Interface of Matching Game on Electronic Platform

Strategies that were employed to successfully play this game were the following: *"I use the colors…I will look at all the yellows and then the blues and so on."; "I will sometimes scan through the entire grid to see if I can quickly find the pair."; "…shape before colors and then later resort to colors to find the matching pairs."; "The ones that are right next to each other are easy but I kinda look at them first and then I look at the colors first and then the shapes."; "Where it was quite obvious I looked at the shape but otherwise I looked at colors."*

The awareness game required players to look through a grid of almost identical shapes and tap on the one that is different from the rest. A right answer advances player to the next level. (See figures below)

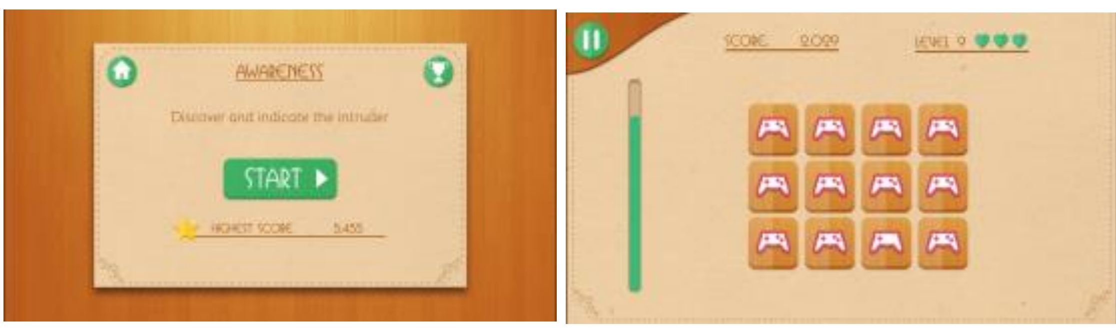


Figure 12: Interface of Awareness Game on Electronic Platform

Strategies that were employed to successfully play this game were the following: *"Top down approach but this strategy breaks down after higher levels."; "Look at patterns, some were easier than others."; "I play these games often so it is an okay game for me… I am used to finding differences in pictures."*

The speed game required players to (See figures below)

Figure 13: Interface of Speed Game on Electronic Platform

Strategies that were employed to successfully play this game were the following: *"I usually group the squares 2s and 4s"; "Best guess in what I do. Especially with the longer ones."; "…see number first and then use multiplication, counting in clusters."; "… aimed for what I want …no attention to time or colors or screen changes.", "I hate any games that has to do with counting…ever since I was little, I had to count with fingers and toes."*

- **User Interface(UI) Design and Gamification Features**

Players enjoyed the UI design of the games. The gamification features such as: timers, stars to show achievements in levels and scores, visual taping feedback (checks and crosses) all together made the game enjoyable for the players. More importantly, the gamification features made the electronic platform preferred to the paper platform. In terms of specific UI design features, some questions and concerns that came up were: "*How do I go back from if I make a mistake?",* "*How do I tell which ones I had selected?", "The colors are pale…maybe they should be brighter.", "The screen size is too small for my eyes… it's harder to see on the tablet and the words are small.", "When I have to do touching at my age, I feel my fingers may not touch the right button.", "When there is more on the platform, it was hard to point out what was on* *there.", " I wish the color change during selection was deeper because at some time, you lose track of what you selected.", "I have color blindness…. I think I am having trouble with red and greens. Can they change those?"*

Other gamification features like timers had conflicting comments. *"I did not even notice the timer was running.*" …compared to *"The timer feels more pressured and you feel you should hurry up when you play"*. Other comments were: *"I like that it has sounds and features that tell me what I did.", "I noticed the timer and I likes* the little *checkmarks on the game that tells me what I picked".*

- **Use Cases for the Games**

Use cases play an important role in understanding the scenarios or context in which a user may use a technology. In the study sessions, use cases were explored by asking the following question: do you see yourself playing this game? And in what ways or contexts? Common use cases and supporting comments were: *" I don't see myself playing it all the time or as much as I want to because I have big hands and fat fingers" , " I am a competitive player and this game does not include multiple players so I see myself getting bored.", "I usually get my manicure done and it is much harder to type let alone tap on the screens for this game so I don't know how far that will get me.", "I see myself whipping out this game when my kids are running around or whiles I am waiting around at the hospital." , " I like the idea of the paper platform… kinda like the crossword puzzle or Sudoku at the back of newspapers or magazines but with this game, I don't see how I would get the feedback for when I am wrong."*

- **Player Context & Background:**

For player context and background, the discussion probed into player background and environment that influenced play and outcomes. The following sub-themes emerged:

Player age-related co-morbidities: Players shared concerns on age related co-morbidities that may prevent them from playing and/or enjoying the game. For example, one participant mentioned that she had always been worried about having dementia or Alzheimer's and that made her train her brain any chance she got.

Player prior experience with other technology/games: Players who had some experience with brain games were more comfortable playing the games. They gave a better explanation for which games they played and why they liked and hated each platform. Other players had not prior experience with brain games be it board games, card games or computerized games. This made it very difficult for them to see themselves learning a new game. *"I don't like playing games.", "I don't use a phone let alone play games on them… and I am fine with my life.", "I play bingo with my friends so I am fine.", "I still work so my work is my brain fitness strategy…. Well until I retire.", "I don't enjoy talking on the telephone because the message does not come out clear.", "… I don't know anything about computers and so I don't know if I will be of any help.", "What am I supposed to do?" All I want to do is to be able to talk to my grandkids and family."*

Environment (stay at home, nursing home, senior centers, working older adults): With regards to environment, 4 main older adults living environments were identified within our participants. 1. Those who stayed at home all day and were cared for by family members or caregivers, 2. Those who lived in a nursing home or assisted living facility,

3. Those who stayed at home but frequently visited senior centers and participated in activities provided by the centers, and 4. Those who still worked and are yet to retire from work. All these 4 living environments influenced perceptions and experience with brain fitness and brain fitness activities. *"I simply do not have any time on my hands to play… I am practically swamped at work.", "I usually come here (senior center) to eat, exercise and do some painting or pottery…these activities keep me sane.", "I don't think about exercises for the brain. Once I can remember dates and where I placed my keys, I am good.", "We usually have game nights and activities with other people and that helps me remember stuff."*

<u>Other themes</u>: Player personality type, mood at the time of play, gender and gender stereotypes were reported to have influenced willingness to play, player experience played and potential gaming outcomes. Study related context also seem to affect player experience. "*Nervousness …I am always nervous when people watch me do something… it's just me. I can't help it."*

Gaming Platform Experience:

Participants' Overall Thoughts on Electronic Platform:

Older adult participants who enjoyed the experience of playing the games on the electronic platform better than that of the paper platform shared the following comments to support the pros of the electronic game platform: "*The game gives instant feedback on how I am doing and I like that.*", "*The paper one[platform] does not have a timer and I think that is what keeps the game challenging*.", *"… changes stuff and keeps it engaging*."

Alongside comments generally favoring the electronic platform over the paper platform, there were others that touched on the cons of the electronic platform: "*I can stay on the phone playing this for a long time…I just can't.*", *"The game is too fast and gives me mild panic attacks."*, "*…there is no reason looking at the timer. I don't care about the timer. All I want to do is have fun and this platform[electronic] just speeds things up."* To sum, the electronic platform's instant feedback, gamification features, timer, and convenience [having it on the phone] made the experience enjoyable for older adults.

Participants' Overall Thoughts on Paper Platforms:

Older adult participants who enjoyed the experience of playing the games on the paper platform better than that of the electronic platform also shared the following comments to support the pros of the paper game platform: *"When I was younger, I liked circling because we did not know better but that experience makes me love paper games where you can write and circle with a pen or pencil.", "I think it will be pretty good… My mom has no short-term memory, and I got a tablet which but if she got a booklet then she can work some games herself.", "…just be sure than you don't memorize all the games on the paper platform*".

Others who did not enjoy the game as much on the paper platform shared the following thoughts: *"No timer… hate it!", "It's not as fun as the electronic platform.", "Very cumbersome, I don't get any feedback from it.", "I would never use the paper platform", "I don't like this … no! I don't like this at all." , "This will be boring." , "This platform [Electronic] does the flipping for me… kind of flipping the book." , "Bigger takes a while to get from here to here." , "Paper takes up too much space.", "It* *feels like I am doing a whole lot of work on the paper platform than I did on the electronic platform.", "I did not hear the feedback and will have loved to hear it."*

Perspectives and Experience on Brain Health, Fitness and Games

During discussions on brain health, brain fitness and brain games, the following were true: 1. All the participants had heard about brain health, and knew what brain fitness is. 2. Most participants made conscious effort to maintain their brain fitness. "*Yes! I care about my brain fitness. Sometimes I read, play bingo sometimes, watch TV but not too much. ...Don't exercise much."* 3. Most participants did not know what they could do to enhance their brain fitness. Almost all participants had their understanding of brain fitness and/or goals they in place for "remembering" things. *"For brain fitness, I think if you can remember names, dates and what you are supposed to do every day quickly then your mind is pretty good at this day and age.", "I do TI CHI to keep me sharp and active."*

For the participants who had some experience with brain fitness games, the following games were referenced: Sudoku, Bingo, Crosswords, Candy Crush [and similar games], Luminosity Games, Chess, Checkers, Find the differences**,** TI CHI. When older adults play brain games, they hope to achieve one or more of the following benefits: be engaged, get social, keep up with motor functions, have fun. They keep playing these games because they have great user experiences with these games. "*These games made me think harder.", "I do it every day because I was worried of getting Dementia or Alzheimer's.", "My brain has changed and if I switched jobs or positions so I have to stay on top of things." ,* **"***Social media outlets and games like Candy Crush have made me want to keep up and stay on top of your brain fitness." , "...learning new* *technologies…" , "Thinking précising and expressing them." , "Youthful taking test and older adults not taking tests."*

4.4. 2 Re-visitation of Research Questions 1

Research question one (1) investigated perspectives and subjective experiences of older adults with regards to brain health, brain fitness and computerized brain games. An in-depth discussion sessions with study participants on the topic revealed more than just narratives of their subjective experiences, perspectives and their mental models surrounding brain health, brain fitness and using brain games as interventions to age-related cognitive decline. Older adults' subjective experiences, perspectives and mental model directly relates to insights on how to design games that cater to their very needs. More important is the fact that information gleaned from such discussion could potentially lead to fine-tuning approaches for wider adoption and implementation.

4.5 Chapter Conclusions

In this chapter, data collected from the study is analyzed for meaning. Findings or results are presented in 'buckets' under each research question. Research question one investigated what older adults' experience, perspectives and general understanding of brain fitness were. Qualitative data in the form of audio/video recordings, researcher field notes, and transcripts were analyzed with a thematic content approach. Older adults indeed have perspectives and experiences surrounding brain health, brain fitness and the use of brain fitness games to intervene age related cognitive decline. These perspectives and experiences range from more general ones to subjective ones. Findings were shared in the form of generated themes and sub-themes relevant to the study. Research questions two and three sought to investigate if older adult demographics influence game outcomes in brain fitness games and if platform type influences game outcomes respectively. Data were collected and analyzed with statistical tests. Findings showed that both user demographics and platform type influences player gaming outcomes measured. The next chapter discusses the findings in this chapter as well as delves into implications of research and research findings such as these.

Chapter 5: Discussions and Conclusions

This chapter discusses the key findings from chapter 4 and concludes the dissertation research study. To understand the use of brain fitness games by older adult populations, the dissertation research investigates computerized and non-computerized approaches to brain fitness games. The focus is placed on brain fitness games for maintaining and enhancing the mental acuity in older adults. The study plan mapped out a games user research where older adult participants experience player gaming sessions on a set of games specially designed for 'seniors'. In each user session, demographic factors such as: Age (Baby boomers), Gender (Male-Female), Race (Blacks, Asians, Mixed, Caucasian, Hispanics), Technological Savviness (Advanced, Intermediate, Beginners), and Educational Background (Graduate, College, High School) is collected. Outcomes data such as: Time on Task (seconds), Task Completion, and Error Tally are also collected. In accordance to the research questions and subsequent hypotheses formed, demographic factor data is tested against outcomes data of the electronic game platform. Data from both platform types is also tested against the outcomes data. Thus, looking at how the choice to play brain fitness games on electronic or paper platform makes a difference in the selected gaming outcomes measured.

Participants' comments (in the form of qualitative data) from a sub-set of 18 participants were also collected, transcribed, analyzed, grouped in themes. This was done to bring out insights that helps understand user/player satisfaction, platform preferences and subjective experiences (brain health and fitness). Results from these participants' game sessions provide comprehensive information on the overarching goal of better adoption and implementation strategies for older adults to use brain fitness games for enhancing and maintaining their mental acuity.

5.1 Discussions

The discussion sections below are grouped per the research questions they fall under. This means that findings for research question one are discussed first, followed by findings of research question two, then that of research question three. The section also discusses other findings that are particularly interesting or noteworthy but do not fall under any research question.

5.1.1 Discussion on Research Question 1 Findings

In research question 1 (RQ1), the study sessions investigated what healthy older adults' perspectives and subjective experiences are with regards to cognitive decline, brain fitness games, and brain health.

In terms of player context and background, the following four areas are reported by participants to influence general player gaming experience and outcomes:

1. Age-related co-morbidities,
2. Prior experience with other technology or games,
3. Player living environment (stay at home, nursing home, senior centers, working older adults), and
4. Player personality type, mood (at time of play), and gender stereotypes.

When this research was being planned, there was no doubt that other age-related conditions akin to cognitive decline would influence older adult use and experience of brain fitness games. Related research show that as people age, cognitive, dexterity, mobility and visual, auditory (+ many more) functionalities decline. What is not too clear in related research is how these decreased functionalities play a role in interventions. In this case, focus was placed on cognitive decline. Referring to the inclusion and exclusion factors in Figure 5 below, it is quite interesting that more than 30% (39 out of 129) of participants who were responsive and interested in the study were excluded because of other age related functional decline that made it difficult to assess their gaming outcomes used in the study.

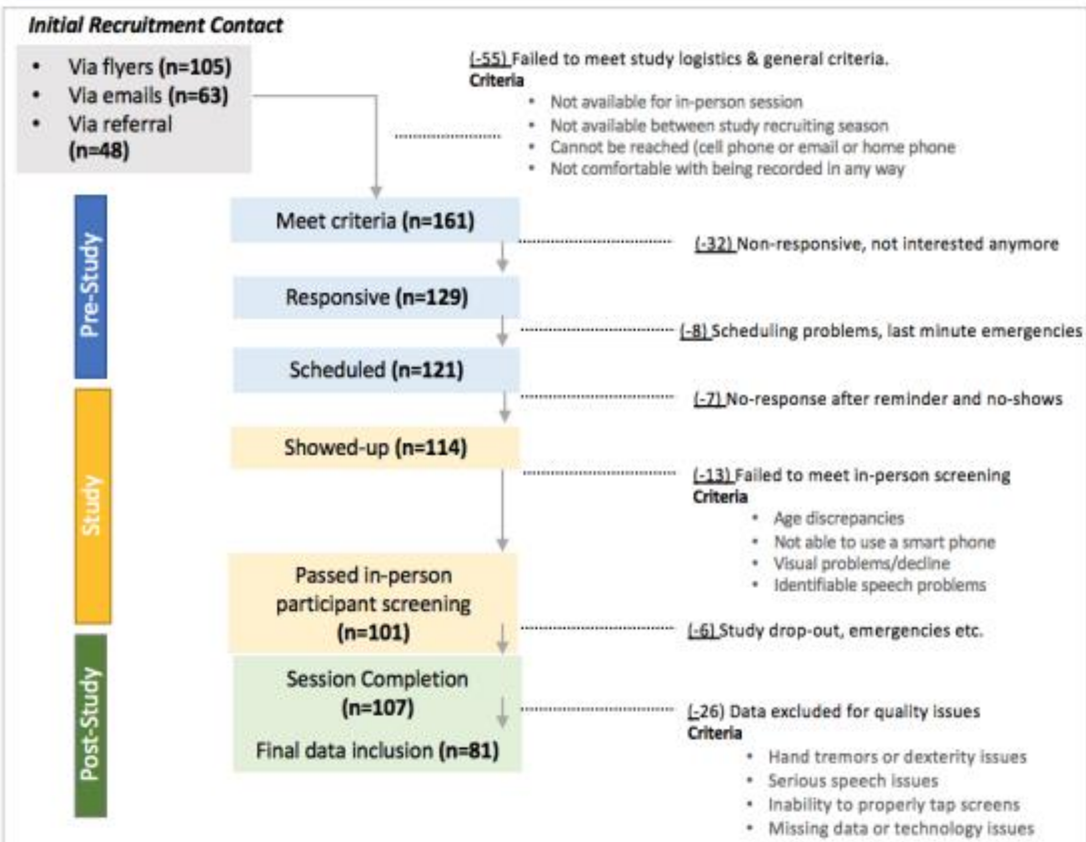


Figure 5: ***Participant recruitment: Phases of Inclusion/Exclusion criteria***

Findings from this research highlights the interrelation of the functionalities, and specific to this research, a significant source of bias to the study. It is evident that brain fitness games and games in general have not fully been designed to cater to older adult functionality decline in general and this finding leads to discussions on how games could be adapted in the future to be accessible to older adults. Although cognitive decline is the focus in this study, participants mentioned (rather frequently) how decline in other functionalities (such as mobility, visual, dexterity, auditory etc.) affected their experience and perspectives on brain fitness and brain activities. While this finding may sound obvious, the implication to designing and implementing brain fitness games for older adults is not. In fact, most games are categorized based on some form of functional or cognitive decline. The key insight from this finding is to slowly move away from isolated interventions (especially with brain games) to more comprehensive approaches. Slightly related to the issue of age-related co-morbidities is the perspectives older adults have on the role they play in seeking to maintain and enhance their mental acuity as they get older.

It is also surprising to hear the various perspectives of older adults and how their perspectives have been formed over time based on their experience, knowledge, education, and acceptance of their condition. The following questions surface:

1. How do you encourage someone who has come to understand that Alzheimer's is something that they are going to have and sees no reason to exercise their brain?

2. How do you empower people to understand that watching TV or listening to the radio actively engages the brain but not as much as social interactions or perhaps reading?

3. How do we encourage group brain fitness activities just like how group physical activities are encouraged?

4. How do we quantify the differences in both paper and electronic game platforms (if any) so older adults have variety with regards to brain games?

5. How do we encourage social interaction over individual activities?

As humans, our experiences form our framework and lens with which we view the world. That is no different with older adults. Participants from this research study shared their perspectives on brain health, fitness and games with a lot of citations on how other functionality decline interrelates with their cognitive decline.

Second, during our discussion on the perspectives and experience of older adults regarding brain health, fitness and games, we found out that past and current experience with technology influenced participants' perspectives. In that very quickly, a trend started to form. Older adults who 1. had earlier exposure to new technology, and/or 2. Stove to experience/learn new things and/or 3. Had advanced degrees were more likely to have a positive perspective on brain health, brain fitness and using games as interventions. On the contrary, participants who 1. Reveled in times where everything was 'simple', and/or 2. Use basic technology at home, and/or 3. Did not have advance degrees were more likely have a neutral or negative perspective on brain health, brain fitness and using games as interventions. With these two groups, we weren't looking for any write or wrong choice. The research did not gravitate on any perspective or approach (computerized or non-computerized) to using brain fitness games. The key take away is rather enlightening. In terms of designing and implementing interventions for brain fitness games for older adults, the user perspective or belief system, ideally should drive the design and implementation approach. In one case, there may need to be some education, or awareness creation or perhaps a plan to shift user ideologies and mental models. The biggest takeaway from participants' comments was the fact that older adults wanted options. They wanted to be able to pick and choose which approach they felt comfortable with. More tech savvy older adults wanted to be able to keep learning; to be able to find the games on their new smartphones that they just got for Christmas; to embrace the new world of technology. Others wanted to be able to find these games in designs that they could identify with; to not have to learn anything new to play a simple game, to have designs come down to their level of savviness.

Third, older adults living environment (stay at home, nursing home, senior centers, working older adults), played a huge role in influencing their perspectives on brain health, fitness and games. This is by far the most interesting finding that surfaced during the discussion sessions. From our participants' discussion sessions, the following four living environments were noticed to be typical for older adults:

1. Stay at home (These were older adults who still lives in their homes or with families in family homes). Typically, these older adults were independent and seldom required desiccated care. The few who required dedicated care had caretakers (family or otherwise) come to them with care.

2. Nursing homes (These were older adults who stayed in nursing home or senior assisted living communities). They had care provided to them in a community or living facility other than their homes.

3.Senior centers (These are older adults who live at home, but spend most of their time in senior centers or senior community centers). These community centers are often public community centers which are operated by the local government in various counties.

4. Working older adults (These are older adults who continue to work or keep themselves occupied with either a full-time job or part-time job).

Here note that a significant number of these older adults (in this case 52-70) with advanced degrees and had reached retirement age continued to work. Some who had retired from one job, picked up another less stressful and with shorter hours to somewhat keep up with the working life they previously had. The initial recruitment attempt for this study was with senior community centers. However, to get a mix of participants to represent all the demographics we were looking to analyze, recruitment efforts were extended to cover older adults who would typically not go to senior community centers. Little was it obvious back then that these four main living environments summarized the who (older adult) and where (environments) to find older adults. A trend that was noticed was the ethnic composition of older adults and their environments. In retrospect, it was not too surprising that nursing homes (depending on where you go) generally tend to have older adults from European or Caucasian descent. Stay at homes generally tend to have more ethnically diverse older adults. With regards to working older adults versus 'senior community center' older adult population, the trend was divided along the lines of educational background with more advanced degree holders working.

Fourth, older adult player personality type, mood (at time of play), gender stereotypes typically influenced their perspectives not only on brain games as an intervention for age-related cognitive decline but also on how they tend to perceive an ideal way to implement these games. When older adults talked about their experience with brain fitness, their individual personalities came through. While most generally had the propensity to maintain their mental acuity, men typically had more drive to stay mentally active. That gender divide usually stemmed from personality type splits generally along the lines of gender. Another influencing factor was gender stereotypes and ethnical stereotypes. The sessions involved couples who both participated separately in the study. When notes were compared between the husband and wife, it was noticed that husbands generally tend to be more interested in physical as well as cognitive exercises and activities. They were hence more likely to want to exercise their brains. Hence, the stereotype that they had to continue to take care of their wives and family even at the stage when they are experiencing age- related cognitive decline. Just like any game player population, older adult game players also had mood (either for the day or at the time of play) influence their playing experience or outcome of game. Player mood also influenced how accepting older adult players were of social interaction in such brain fitness games. In the literature review from chapter 2, it was found that research along the domain of kids versus older adult gaming experience. Older adults generally tend to enjoy games that supported cooperation that competition. The discussions with our participants gave a more personal insight which revealed that older adults tend to be in a better mood when playing games with others (especially grandkids) and hence enjoy the cooperation and social part of the game better than the competitive side. The point here is that in exploring the various approaches to using brain games for enhancing mental acuity, user factors which often cannot be explained, mapped out, or predicted may very well be the key to a successful implementation of such brain fitness interventions.

Fifth, while all participants have heard about brain fitness, most make conscious efforts to exercise their brain, a few other still did not know what to do to maintain and enhance their mental acuity. Almost all participants had their own understanding of brain fitness and/or goals they had in place for “remembering” things. For them, the concept of brain health and the activities to increase brain fitness is a matter of thriving not flourishing. Brain fitness awareness generally starts from brain health awareness. In all the senior community centers visited to recruit participants, there were ongoing brain fitness activities regularly scheduled for their older adults in the community. It was later revealed that 2016 was the year of brain health for all the senior community centers across country. To that end, senior center directors were encouraged and under obligation to create as much awareness, provide as much education, and provide as many activities as possible for older adults who visited the community centers.

Remember from the literature review in Chapter 2 that many initiatives for brain health as well as studies towards implementing brain health awareness campaigns had already started and are still ongoing as of 2017. It’s no secret that the issue of cognitive decline in older adults is a concern. It is quite refreshing to see all these interventions across awareness, education, training, activities, and support are being provided. The main issue of discussion surrounds the many more older adults who are not involved in these opportunities. As mentioned earlier, there are many more older adults who do not visit such community centers or continue to work in places that provide periodic emphasis on brain health. Here I am referring to stay at home older adults and perhaps nursing homes older adults. What is the right approach to get to these populations? How are they being educated and given the support that others have because of their regular visit to senior community centers or their work? How do they consciously work on their brain health and fitness with no system structure, intervention options and external motivation? Many more questions with multiple implications continue to be asked.

Finally, for the participants who had some experience with brain fitness games, the following games were referenced from their previous and current experience: Sudoku, Bingo, Crosswords, Candy Crush [and similar games], Luminosity Brain Games, Chess, Checkers, Find the differences, and Ti-Chi. Although none of these games were specifically designed for older adult populations, it was interesting to know that each game had a major good reason why older adults played (or continue to play) the game. Sudoku is challenging, fun, and mostly played in paper platform for its easy to recover from error reason. Bingo (the most popular game) is easy to learn, fun, strategic and social. Crosswords was single-player, easy to find (at the back of newspapers), and supported the recollection and remembering of information. Candy Crush is delightful, current, social and gamified. It also had the option to play with others or play yourself. Luminosity brain games is gamified, had structure to it, gives you continual progress and feedback and had a lot of variations to it. Chess and checkers are strategic, simple to play, social and has both board and electronic options. Find-the-differences game is simple to play, mentally stimulating, easy to find (at the back of newspapers) and single player. Finally, Ti-Chi is both physically and mentally stimulated, structured, had a coach, and involves other people. These games have varying approaches; different pros ad perhaps cons but one thing remains true in all of them. User continue to play them because of their current experience benefits they get from playing the games. Although questions did not probe into user first experience playing these games but whatever (good or bad) they were, these users moved past the learning curve and first time experience to a continual use.

When older adults play brain games, they hope to achieve one or more of the following benefits: be engaged, get social, keep up with motor functions, have fun. They keep playing these games because they have great user experiences with these games. Whereas the design of games for older adults matters, the real goal (of implementing brain fitness interventions especially in the form of games) here is to make more of these games used just as much as the ones listed here.

5.1.2 Discussion on Research Question 2 Findings

Research question two (RQ2) surrounds the relation between older adult population demographics (age, gender, race, technological savviness and educational background) and their electronic brain fitness gaming outcomes (time, errors, and task completion). It is important to note that since a cohort of older adults called baby boomers were studied, age represented the entire cohort. No categorizations were done on age as a variable. Any conclusions made with age as a variable refers to the entire baby boomers age-group. Since the original platform for the game selected for the research is electronic, all analyses for RQ2 was done with data from the electronic platform only. Key findings from the quantitative data analyses are stated and discussed below:

Gender (Male/Female) influences all three game outcomes- time, error rate and task completion. Older adult male players tend to do slightly better on the games in terms of the time it takes them to complete the game sets in this study. Older adult males however tend to make more mistakes in playing the game than older adult female players. With regards to task completion, females have a slightly better average task completion rate than males. This means that for older adult participants, being male or female could or may lead to predictions on time to complete game sets, error rates as well as task completion rates. Refer to tables 12, 15, 16, 17 and 18.

Race (Black/Asian/ Mixed/Caucasian/Hispanics) also influences all three game outcomes- time, error rate and task completion. With respect to completion time, black older adults tend to on average spend less time completing the game-sets. Followed by Caucasian older adults, Asian older adults, Mixed older adults and then Hispanic older adults. Here it is important to note that there were four fundamentally different games in the game set and while the general average time completions may show the trends above, individual games showed different trends across races. For error rates, Mixed older adults tend to on average make the least errors. Followed by Black older adults, Asian older adults, Caucasian older adults and then Hispanic older adults. In increasing magnitude of average errors made per participant during game play. With regards to task completion, Mixed older adults had the highest task completion rate followed by Asian older adults, then Black older adults, Caucasian older adults and then Hispanic older adults. This means that for older adult participants, racial background could or may lead to predictions on time to complete game sets, error rates as well as task completion rates. Refer to tables 19, 25, 26, 27, 28, 29, 30, 31, 32, 33, and 34.

Technological savviness (Advanced/Intermediate/Beginners) also influences all three game outcomes- time, error rate and task completion. With respect to completion time, ‘intermediate’ older adults tend to on average spend the least time completing the game-sets. Followed by ‘Advanced’ older adults, and then ‘Beginners’ older adults. Again, while the general average time completions may show the trends above, individual games showed different trends across level of technological savviness in older adults.

For error rates, ‘Intermediate’ older adults tend to on average make the least errors. Followed by ‘Advanced’ older adults, and then ‘Beginners’ older adults. With regards to task completion, ‘Advanced’ older adults, had the highest task completion rates. Followed by ‘Beginners’, and then ‘Intermediates’ older adults. Whereas there are no immediate or obvious reasons as to why and how exactly the level of tech savviness affected all three gaming outcomes measured for this study, finding may lead to an in-depth study with a more comprehensive data collection and analyses. Findings could or may lead to predictions on time to complete game sets, error rates as well as task completion rates. Refer to tables 35, 39, 40, 41, 42, 43, and 44.

Educational Background (Graduate level/College level/ High school level) influences all three game outcomes- time, error rate and task completion. With respect to completion time, College level older adults tend to on average spend the least time completing the game-sets. Followed by Graduate level older adults, and then High school level older adults. Again, while the general average time completions may show the trends above, individual games showed different trends across educational levels in older adults. For error rates, again College level older adults tend to on average make the least errors. Followed by Graduate level older adults, and then High School level older adults. With regards to task completion, Graduate level older adults had the highest task completion rates. Followed by College level older adults, and then High School level older adults. Refer to tables 45, 49, 50, 51, 52, 53, and 54.

5.1.3 Discussion on Research Question 3 Findings

In research question 3 (RQ3), the study investigated if for older adults, game platform type (paper or electronic) influence brain fitness game outcomes (time, errors, and task completion). Whereas the paper platform did not fully replicate the electronic game platform, the design was enough to note the differences in gaming experience and outcomes as described by older adult participants recruited for this study. Most of the subjective experience insights have already been shared and discussed in findings from research question one. This section however reports on and discusses finding from the quantitative analyses of data collected on both the paper and electronic platforms as analyzed against the three outcomes data measured. Key findings from the quantitative data analyses are stated and discussed in the sections below:

Both Electronic and Paper platform selection influences all three game outcomes- time, error rate and task completion- in various ways. With respect to completion time, older adult participants who played on the electronic game platform tend to on average spend slightly lesser time completing the game-sets that those who played on the paper platform. For error rates, both the paper and electronic platform had the same performance with a light edge for the paper platform. This means that while there was generally no difference in error rates between both platforms, in detail older adult participants performed slightly less errors on the paper platform compared to the electronic platform. With regards to task completion, again both the paper and electronic platform had the same performance with a light edge for the electronic platform. This means that while there was generally no difference in task completion between both platforms, in detail older adult participants were more likely to complete the game sets if they played on the electronic platform. Refer to tables 58, 59 and 60.

5.2 *Implications of Dissertation Research*

The implications section below shares the 'what then' question that usually arises from thesis research such as this. The dissertation thesis started with a research problem, research question and the proposal of a study plan that shows specific methodologies selected to investigate the research problem. Once all the user studies were done and all data collected, analyses of the data provided key findings which have been discussed above. Implications of the findings and discussions provide what all this means and possible key actionable insights to what must be done, what can be done, and what should be done as possible next steps to this research.

5.2.1 Research implications

Incorporating social and/or behavioral science research into clinical intervention research studies and making it influence directions, perspectives and goals of current as well as future interventions for older adults. Social science which is the science of society and groups helps understand population perspectives and mental models on anything. Behavioral science which is the science of how populations or users act and make decisions, teaches so many theories that give insights as to how people act. For example, within theories surrounding biases alone, behavioral sciences research covers a wide range of cognitive biases in humans. The following theories on biases become particularly noteworthy; the projection bias, the snake bite effect, the regency bias, the hindsight bias, the loss aversion bias, and the confirmation bias. Knowing more about these cognitive behavioral theories helps better understand the older adult population as well as how this knowledge shapes user studies and research.

Research on brain fitness games stem from broader research that supports frequent brain activities for challenging the brain. The implication of this research further supports other activities that goes together with brain fitness games. Older adults shared that other activities such as reading newspapers, talking on the phone, recalling where they placed items or dates sometimes helped them exercise their brains. This means that typical approaches to brain fitness games and activities should not be restricted to games or gamified technology only but extended beyond natural activities such as walking, watching television or reading a newspaper.

Another implication of the perspectives generated from this research is that children and/or grandchildren of older adults should be encouraged to take an active role in motivating and engaging older adults in brain fitness activities. Caregivers and family members should make it a point to remind them of the past events or keep prodding them with questions related to their childhood or early days, which can make a remarkable difference on the memory of the seniors.

Online or electronic brain games for older adults is not the best or only approach for older adults. There is a wide array of games to cater to different seniors with different interests and intellectual capacity. The goal to a better adoption is to use findings from this dissertation as a first step in determining unique user characteristics that influence game play. The better a game is tailored to its user, the higher the changes of repeat play, engagement and good outcomes. The question that begs to be answered remains how much is enough gaming experience to help maintain and enhance cognitive decline? While some research recommends a daily gaming experience, others recommend multiple gaming sessions per day.

5.2.2 Practical (Adoption & Implementation) implications

The current way of implementing games may suggest that online or electronic brain fitness games gives the most benefits. Contrary to this notion is what this research finds; that there are just about as many different types of games and brain exercises that are available and used by older adults. In selecting computerized or non-computerized approaches, the choice really depends on how the approach fits into an overall lifestyle that includes regular mental stimulation involving a variety of activities, including those that one may not be good at, to induce learning.

Expert recommendations and user subjective experiences both highlight the following brain fitness games and activities: playing board games such as Scrabble, Risk, Pictionary, or Monopoly with friends to combine mental stimulation with social interaction; doing Sudoku, crossword, or jigsaw puzzles; and, playing card games or chess. While ongoing research investigates, which games enhance which brain functionalities, games like *Senior games* gives a preview to tailoring games specifically for brain functionalities that needs to be improved.

If current computerized and non-computerized brain fitness games are to provide options for healthy older adults to self-maintain and enhance their mental acuity, then it will be ideal to approach user performance enhancement of such games in several dimensions. Currently, many of these games are being evaluated for clinical outcomes. Clinical outcomes tests if an intervention works by making users better. However, performance enhancement in terms of gaming experience may answer questions relating to the usefulness and usability of the serious game intervention.

Another implication of a study like this relates to adoption of serious games interventions. It is not surprising that findings from this dissertation align with findings from related brain fitness for older adult studies. Older adults understand the need for brain fitness to keep them sharp. They want technology designed for them to cater to their needs. In the face of uncertain effectiveness, the brain fitness market continues to expand. Implications of such shared findings start to push boundaries of implementation. Whiles most of these brain fitness games and technology are specifically designed for assisted living and senior centers, how can they be expanded to home use where motivation to use such interventions are mainly intrinsic?

5.2.3 Policy implications

Evidence-based policy on older adults suggests that using behavioral science insights, research findings from other fields can be used to design policies that better serve users. Whereas 2016 was the year dedicated to brain health in most senior centers, much attention and resources was dedicated to awareness creation and education on brain fitness activities. A necessary continuation from awareness creation is to start thinking about what types of cognitive training programs are needed now for older adults and how interventions can target more older adults. Finding where the greatest payoff lies among the range of intervention strategies is now a high research priority; so is pinpointing the optimal times and ways to introduce interventions for maximal benefits in older adult populations.

Public policy aimed at improving cognitive health should follow a health prevention model, focusing on training programs' sustainability and long-term health benefits. How do we motivate older adults to keep using these training programs when the novelty wears off or when progress seems slow? How do we make the programs meaningful and integrate them with older adults' daily life activities? What is the best way to make such programs accessible and affordable for all who may benefit? Should older adults receive health insurance benefits for undertaking cognitive training, and should Medicare pay for such training? Given older adults' strong desire to remain independent and the high costs of institutionalized care, raising public awareness of cognitive training's potential for maintaining an active, healthy lifestyle may be key to improving the overall health of an aging population.

With baby boomers slowly defining what present day older adult population or generation looks like, an implication of dissertation findings is to target baby boomers to reach older adult communities. These efforts, in combination with finding more effective ways to translate findings from small research studies in highly controlled settings to populations in real-world settings, will govern the nation's health as the aging population grows.

5.3 Research Contributions

The dissertation research study makes the following contributions to the body of research surrounding older adult study, games user study and health information technology. First, the study gives a clearer and more comprehensive understanding of older adult user demographics and how it influences the overall brain fitness gaming experience during play. Second, this study gives a better understanding of current gaming platforms for brain fitness and how platform preference influence game experience and outcomes in health older adults. Third, the study exemplifies using baby-boomers as a case study of healthy older adults in their natural settings. Fourth, this study builds a working theory on better strategies for effective adoption, implementation and use of brain fitness games as interventions for age-related cognitive decline based on user narratives and sampled data analyses. Fifth, the study merges the burgeoning research domain called user research (widely adopted in entertainment, technology and gaming industries) with healthcare technology intervention research. Sixth, the study serves as a feasibility study of a fully blown user research into an ever-increasing population group that can be empowered to maintain age-related cognitive decline as well as other age-related conditions with gamified technological interventions. Seventh, the study proposes a future direction of research in which technology to be designed for specific user populations such older adults use guided user research to ensure acceptance, engagement and adoption.

5.4 Research Limitations

As with any research study, this study has some limitations. First, the study uses mixed-methods (both qualitative and quantitative). While mixed- methods study gives a better understanding of a problem, it restricts how deep a student researcher can get into data collection and analyses. The way forward with this limitation is either to plan a one-method study or to conduct each study methodology in succession; hence findings from the preceding methodology feeds into the subsequent.

Another limitation is that all the participants were recruited from the state of Maryland. Out of the over 200 participants who were recruited for the study, only 81 met the study and participant inclusion criteria. To have a better representation of older adults, recruitment had to be wider than just the Maryland area. Although qualitative user studies are usually generalized to be representative of other geographic locations, this is because themes start forming after about 10 user sessions. The case is not so for quantitative studies. As previously mentioned, older adults can be found in various living environments and these environments and geography affects their perspectives and gaming experience. It would have been good to get a fair representation. The way forward with this limitation ties back to the solution for the previous limitation; separating research methods. Another solution is to have more time allocated for recruiting so efforts can be made to reach out to a wider geographic location. Study and participant criteria can be well reviewed to include a wide range of older adults while maintaining the integrity of the study

The study also does not conclude with a standardized user satisfaction survey. Generally, after a user testing or study like this, users are giving either an immediate satisfaction survey on study or a follow-up feedback survey in the form of overall satisfaction. This study did not have a standardized survey and that may be a limitation to the feedback collected on platform satisfaction.

Finally, a limitation of this study is that in-person user studies resulted in higher completion rates. For older adult studies such as this, one main goal is to identify motivation factors for using brain fitness games in the first place. For a truly unbiased study, it would have been better to conduct a study with minimal structure and researcher supervision (such as a diary study) to assess older adult use and completion rates in the absence of structure and researcher supervision., external influences will be better to consider.

5.5 Future Work

Any research leaves room for future work and this dissertation research has a few suggestions for opportunities for potential future work. This dissertation study is an initial exploration into a larger research area of user research for better design and implementation of age- related cognitive decline interventions for older adults.

The first opportunity for future work is to also investigate current design and development team perspectives, standards and guidelines in designing brain games for older adults. Possibly comparing and contrasting user design and feature needs/wants to current designs and available gaming technology. As well as exploring associated challenges with designing brain games with older adults.

The second opportunity is to examine how to apply the findings from this work directly into brain fitness games designs. User research and games research have a lot of user testing standards that fits and feeds into design and development cycles. However, the older adult population have not been fully explored; in terms of how to get them involved in the design and development process due to specific limited capabilities and functionalities.

The third opportunity has also been previously mentioned in the limitation section. It will be great to expand the study objectives and research questions to investigate external or environmental factors that contribute to older adults use of brain fitness games. Questions may include: what social or family ties motivate and/or engage older adults in maintaining brain fitness? What context surrounds the use of brain fitness in older adults? How does group play affect engagement, completion rates and overall tendency to play brain fitness games? Etc.

The fourth opportunity is to extend investigation to cardboard games that come in both electronic and paper platforms and are already widely accepted. Examples may include: Chess, Checkers, Sudoku, Bingo. Although there may not be a lot of older adults who already play these games, the focus could be on group player sessions in senior centers.

The fifth opportunity is to investigate gaming performance enhancement by testing users for learnability. Here the goal will be to know how much the older adult user learns from playing such brain fitness games. Perhaps expand to other technology designed of older adults. Related to this opportunity is to direct research studies to other age-related functional decline such as physical, motor, and visual functions.

Finally, an opportunity here may using eye trackers to understand how older adults differ in exploring interfaces of gaming interventions such as brain fitness games.

5.6 Chapter Summary

In chapter 1, a problem is described. Older adults with no cognitive or physical comorbidities are also experiencing risks of memory loss that simply comes with aging. Whereas approaches to maintain and enhancing mental acuity in older adults have been explored, specific approaches with serious games that combine the motivation and fun in gaming with a specific health benefit have been barely investigated and designed for study aging older adults. Hence the study proposes to consider player and platform factors and their relation to gaming outcomes for older adults. Chapter 2 presents current related work around the domain of this dissertation research. Chapter 3 describes a detail methodology for carrying out this dissertation. In Chapter 4, a user study with older adults is conducted to collect data for this dissertation research. Since both qualitative and quantitative data is collected, both statistical analysis and qualitative analysis is used to derive meaning from the data. Chapter 5 discusses and concludes a dissertation study which significantly furthers the study of older adult brain fitness games and how important user/game factors are in attaining the desired cognitive health performance enhancement through computerized and non-computerized platforms.

5.7 Dissertation Research Conclusions

In this dissertation research study, the goal was to investigate older adult user and platform performance enhancement in both computerized and non-computerized approaches to brain fitness games for mental acuity. The research premise is that whiles age-related cognitive decline increases, approaches to self-empowered interventions show great potential in maintaining and enhancing brain fitness in older adults. The problem however was not to research into whether brain fitness games help with cognitive decline but to consider ways in which current approaches to brain fitness can be better designed and implemented for the older adult population. The research problem was later honed down to three research questions; what are the perspectives and subjective experiences of older adults in relation to brain health, brain fitness and brain fitness games? Do demographic factors influence gaming outcomes in older adults who play brain fitness games? Do game platform type influence gaming outcomes in older adults who play brain fitness games?

A mixed-method study plan was designed to investigate the problem and hopefully get some answers to the research questions. 81 older adult participants were recruited to play a set of brain fitness games on both electronic and paper platforms. Quantitative data in the form of participant demographics, outcomes data and game platform type were collected and analyzed with ANOVA tests. A sub-set of 18 participants' responses were qualitatively analyzed to generate insights in answering research question one. Findings from the study showed that older adults' subjective experiences, perspectives and mental model directly relates to insights on how to design games that cater to their very needs. More important is the fact that information gleaned from such discussion could potentially lead to fine-tuning approaches for wider adoption and implementation. Although player demographics influenced gaming outcomes, unique user personality type, mood, culture and pre-conceived notions seem to also affect first time experiences with these games. Player gaming outcomes were generally even across platforms. The electronic platform however had a slight advantage on preference especially since gamification played a huge role in the engagement of players on the electronic platform.

Some major implications of the findings from this research study include: A re-visitation of social and behavioral science research in evaluating clinical intervention outcomes, understanding the baby boomer generation as they start to define the typical older adult population everywhere; a future investigation into how user differences in demographics can be incorporated into design; a push to generate the awareness of brain fitness games as a substitute to social interactions and physical fitness instead of a total replacement.

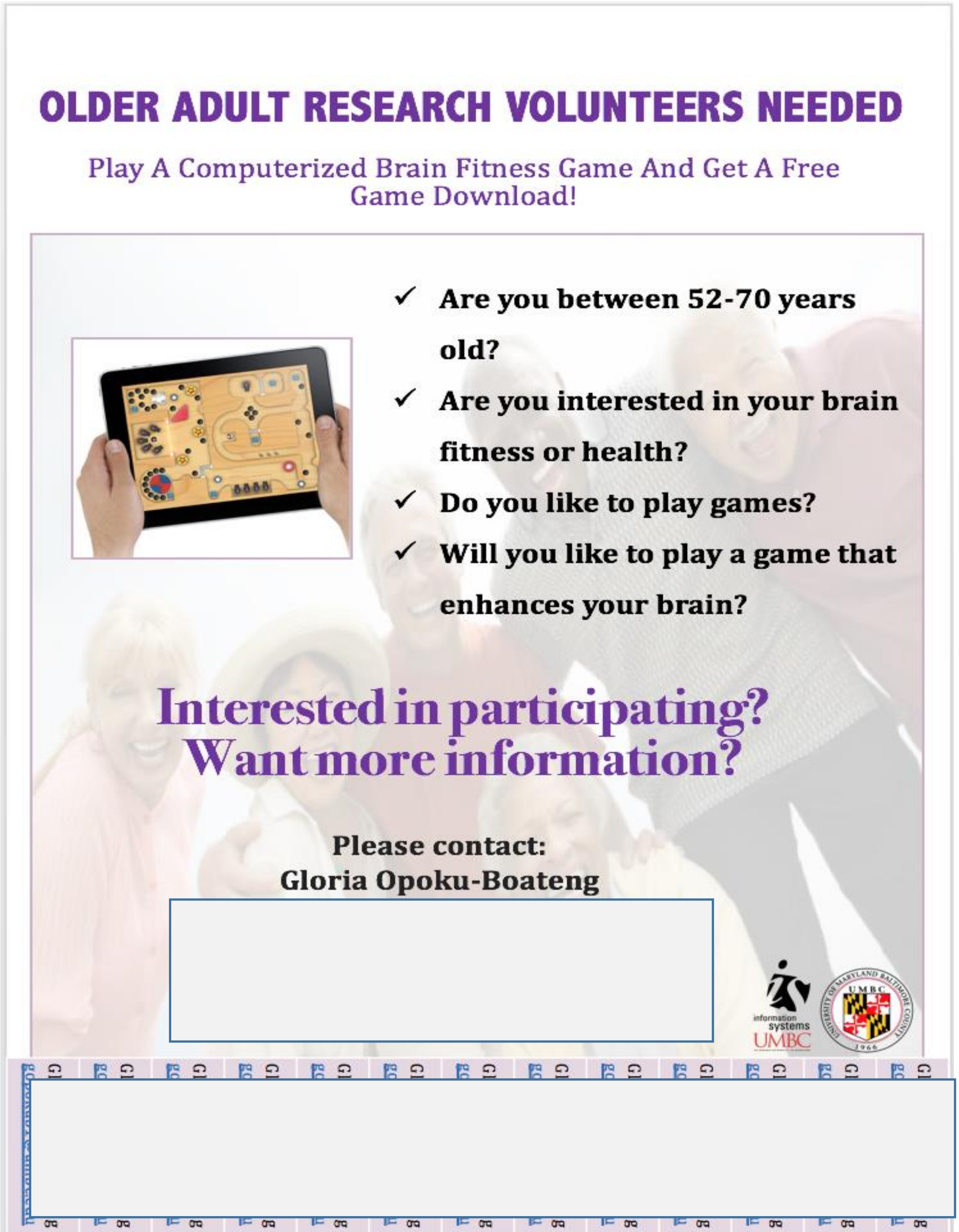
Often increase in cognition in populations tend to become the sole standard against which brain fitness gaming outcomes are measured. This study uncovers user experience and adoption as alternate standards against which gaming outcomes in such games can alternatively be measured. This does not mean that increase in cognitive performance should be substituted with alternate standards. The baby boomer generation define the present day older adult population. As a formidable population group with a huge spending power and outspending trends on technology, the need for new medical technologies resources currently used to empower them may continue to grow. Baby

Boomers have paved the way for later generations with respect to many aspects of our social lives, and they will pave the way now to show the rest of us how to maximize our senior years using the technological interventions. The older user population (50 and above) will only continue to grow and become more influential in our design considerations.

In conclusion while most older adults will continue to view and accept brain fitness they way they choose, it is important to continue to provide cognitive interventions in various approaches and platforms as possible. This variety gives them options and caters to a broader population that just for e.g. older adults at home or in senior centers or in assisted living homes. The goal of brain fitness games for older adults should include making them a habitual experience to keep the brain sharp and smart for a longer time. This will eventually make the older adult population confident, self-reliant and empowered. Thus, designing technology to meet them where they are, continues to be a major request for the older adults in this study. Studies like this dissertation work start to push into domains that combine user research with innovation.

Appendices

<u>Appendix A: Recruitment Flier</u>



Appendix B: Recruitment Emails

Hi [Participant Name]!

Thank you for reaching out to me. This email is to tell you more about the dissertation research study I am conducting. This study is about brain fitness games that enhance or maintain the mental acuity of older adults like yourself. After a successful completion of this study, I can provide you a free download of an online electronic brain game for older adults like you.

For my research, I'm interested in exploring approaches to brain fitness enhancement and maintenance in older adults and what approaches enhance performance. Besides being a healthy older adult, what makes for an ideal participant is willing to play a brain game and answer a few questions about your experience. The study will be ~60 minutes of your time. During this time, you will answer some questions about your subjective views and experience with age-related cognitive decline, brain games, and technology. You will also get the chance to play a selected game during which you will be observed. Data will be collected as you play the game. Finally, you will provide us with feedback on your experience. If this still sounds of interesting to you, please email or call me to let me know and we can move on from here.

[Follow-up email[11]]

Hello again, [Name]!

Thanks so much for offering to help. I've attached the consent form[12] for this study; you can just reply via email with your completed and signed consent. Below I'll explain more about the study. *[Go through study plan and moderator guide with participant]* If you have any questions about the study, please feel free to call me at [researcher phone number]. Otherwise, please reply with your consent forms.

Thank you in advance for taking time to complete the forms.

PS: [Attach consent forms]

Sincerely, Gloria Opoku-Boateng

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[11] Initial email and follow-up email may be sent out closely together depending on interest of participant.

[12] Consent form can and may be completed in person.

[Scheduling email]

Hello, [Name]!

Thanks so much for your interest in my study. This email is to tell you more about the study and share some availability so you can pick a time that works best for you.

This study is about brain fitness games that are designed to enhance or maintain the mental acuity of older adults like yourself. For my research, I'm interested in exploring what approaches enhance performance. Besides being a healthy older adult, what makes for an ideal participant is the willingness to play a brain game and answer a few questions about the experience.

The study will be ~60 minutes of your time. This includes my setup and tear down of study equipment. During this time, you will answer some questions about your subjective views and experience with age-related cognitive decline, brain games, and technology. After a successful completion of this study, I can provide you a free download of an online electronic brain fitness game.

I have attached the consent form for you to review. Also, I have availability slots from now to next week Tuesday. Please reply this email with two options below.

[Sample dates and timeslots]

Thank you in advance for taking time to schedule your session. I look forward to hearing back from you soon.

Thanks,
Gloria

[Thank you email]

Hello [Participant Name],

Thank you so much for participating in my study. As promised, your free download has been sent to your email address. You should have received it from an apple iTunes email address.

I have a copy of your consent for you to keep. See attachments below. Please feel free to contact me with questions, suggestions of simply to recommend others who may be good candidates for this study. Once again, thank you!

Sincerely,

Gloria

Appendix C: Adult Participant Consent Form

Whom to Contact about this study:
Principal Investigator: *Gloria Opoku-Boateng, Anthony Norcio*
Department: *Information Systems*
Phone number: [redacted]

Preamble: This consent forms is an agreement between the student researcher of this dissertation study and the participant of this study. *"Computerized and Non-Computerized Approaches to Brain Fitness Games for Maintaining and Enhancing Mental Acuity in Older Adults*."

I. INTRODUCTION/PURPOSE:

I am being asked to participate in a research study. The purpose of this study is to investigate the experience of healthy older adults with brain fitness games designed to maintain and enhance cognitive acuity. I am being asked to volunteer because I meet the participant recruitment criteria for participation in this study.

I hereby authorize Gloria Opoku-Boateng, Doctoral Candidate to include me and all my data hereafter collected in the following dissertation research study: *"Approaches to Brain Fitness Games for Maintaining and Enhancing Mental Acuity in Older Adults*."

II. PROCEDURES:

The student researcher [Gloria] has explained the procedures to me. As a participant in this study, I will be asked to play a game on both paper and electronic platforms for a few minutes and answer questions regarding my experience. About 100 persons will be invited to participate in this study and my participation will last ~60 minutes (1 hr).

III. RISKS AND BENEFITS:

My participation in this study does not involve any significant risks and I have been informed that my participation in this research will not benefit me personally, but will provide insights on how technology can help increase mental acuity in older adults.

IV. CONFIDENTIALITY:

I understand that my session and responses will be video/audio-taped in the process of these research procedures. It has been explained to me that these tapes will be used for research purposes only and that my identity will not be disclosed.

I have been assured that the tapes will be destroyed after their use in this research project is completed. I understand that I have the right to review tapes made as part of the study to determine whether they should be edited or erased in whole or in part and I agree that the tapes can be retained for research purposes.

V. COMPENSATION/COSTS:

My participation in this study will involve no cost to me. I will be compensated with a free subscription to the brain fitness game used for this study.

***VI.* CONTACTS AND QUESTIONS:**

The principal investigator, Gloria Opoku-Boateng and Anthony Norcio has offered to and has answered all questions regarding my participation in this research study. If I have any further questions, I can contact Gloria Opoku-Boateng at [redacted] or [email] or Anthony Norcio, [email].

If I have any questions about my rights as a participant in this research study, I can contact the Office of Research Protections and Compliance at (410) 455-2737 or compliance@umbc.edu.

VII. VOLUNTARY PARTICIPATION

I have been informed that my participation in this research study is voluntary and that I am free to withdraw or discontinue participation at any time. I have been informed that data collected for this study will be retained by the investigator and analyzed even if I choose to withdraw from the research. If I do choose to withdraw, the investigator and I have discussed my withdrawal and the investigator may use my information up to the time I decide to withdraw.

I will be given a copy of this consent form to keep.

VIII. SIGNATURE FOR CONSENT

The above-named investigator has answered my questions and I agree to be a research participant in this study.

Participant's Name: ________________________________ Date: ______________________

Participant's Signature: ____________________________Date: ______________________

Investigator's Signature: ________________________ Date: ___________________________

Approved by the
UMBC Institutional Review Board
IRB Protocol Y17AN12050

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From 10/07/2016
To 10/06/2017
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Brain Game User Study Plan and Moderator Guide

Researchers: Gloria Opoku-Boateng

Research Study: **"***Approaches to Brain Fitness Games for Maintaining and Enhancing Mental Acuity in Older Adults"*

Goal: To gather player insights and experience with brain fitness games by conducting a games user study with older adults.

Participants: Older adults in independent assisted living.

Sample size: 81 participants

Session time: ~ 60 minutes.

Location: Senior centers, UMBC labs, Community centers.

Dates: Late October to Late December 2016

Props/Artefacts:

- Interview guide
- Tablet with game
- Paper platform for game
- Audio/video recording set
- Pen/pencil
- Notepad
- Stopwatch/timer
- Tally Sheets

Interviewer Guide:

→Set-up [8 mins] *Audio/video, observer, note taker etc.*

- Get writing aids ready to take notes
- Get consent forms ready for all participants to sign
- Set up video/audio recording
- Set up game ahead of time
- Check battery power on phone and recording devices
- Have water readily available; just in case user is thirsty
- Summarize consent form and have them sign before session

→Introduction [8 mins] *Consents signed, Participants trained on game structure and platform [electronic or paper]*

- Introduce yourself (and another researcher with you)
- Remind participant of study goals, duration of session
- Thank them for participating
- Let them know that they can take a break any time.
- Collect/confirm data on demographics.
- Ask questions on thoughts and experience with brain fitness games.
- Check which platform participant starts with.

→Part A1[10 mins] *Participants go through all 8 parts of brain game on platform A.*

- Record scores, completion rates, completion time.
- Observe user player non-verbal communication.

→Part A2: Player subjective experience [8 mins] *Participants answer short questions on their experience, satisfaction, and game functionality on platform A.*

- Ask questions on likes, dislikes, experience, frustrations, big ideas, features.
- Have a discussion on all that the user said and did.
- Speak less, listen more!
- Ask for clarification from your notes.
- Make sure you have all the information needed. Especially for user likes, dislikes, future features, big ideas, frustrations.
- [Summarize all that you have heard] Is there anything you left out that you would like to add?

[Switch to another game platform]

→Part B1[10 mins] *Participants go through all 8 parts of brain game on platform B.*

- Record scores, completion rates, completion time.
- Observe user player non-verbal communication.

→Part B2: Player subjective experience [8 mins] *Participants answer short questions on their experience, satisfaction, and game functionality on platform B.*

- Ask questions on likes, dislikes, experience, frustrations, big ideas, features.
- Have a discussion on all that the user said and did.
- Speak less, listen more!
- Ask for clarification from your notes.
- Make sure you have all the information needed. Especially for user likes, dislikes, future features, big ideas, frustrations.
- [Summarize all that you have heard] Is there anything you left out that you would like to add?

→Wrap-up [8 mins] *Take questions from participants, pack and leave.*

- Summarize key points
- Thank participant for coming
- Stop recording
- Offer incentives and collate session notes

Appendix E: Field Data Tally Sheets

The tally sheets are in the form of a Microsoft Excel spread sheet. Participants' demographic data were collected via Google forms, while participants' session data were manually entered onto spreadsheet]

- Screenshot of portion of Data Tally Sheet

Participant ID	Session Data	Age	Gender	Gender coding	Race	Race coding	Tech Saviness	TS Coding	Edu. Background	EB Coding	Pltfm	
									101			
P0	10/17/16	27	F	1	B	1	Advanced	3	Graduate level	3	E	1
P1	10/25/16	69	M	2	C	4	Advanced	3	Graduate level	3	E	1
P2	10/25/16	53	F	1	B	1	Advanced	3	College level	2	P	2
P3	10/25/16	54	M	2	A	2	Intermediate	2	High school level	1	E	1
P4	10/25/16	59	M	2	M	3	Beginner	1	High school level	1	P	2
P5	11/06/16	55	F	1	A	2	Advanced	3	College level	2	E	1
P6	10/26/16	60	F	1	C	4	Advanced	3	Graduate level	3	P	2
P7	10/26/16	55	M	2	B	1	Advanced	3	Graduate level	3	E	1
P8	10/31/16	65	F	1	H	5	Intermediate	2	College level	2	P	2
P9	11/1/16	70	F	1	H	5	Advanced	3	Graduate level	3	E	1
P10	11/1/16	63	M	2	C	4	Advanced	3	Graduate level	3	P	2
P11	11/11/16	54	M	2	B	1	Advanced	3	Graduate level	3	E	1
P12	10/31/16	54	F	1	B	1	Advanced	3	Graduate level	3	P	2
P13	11/1/16	62	F	1	H	5	Advanced	3	Graduate level	3	E	1
P14	11/11/16	70	M	2	C	4	Advanced	3	Graduate level	3	P	2
P15	11/11/16	69	M	2	C	4	Advanced	3	Graduate level	3	E	1
P16	11/15/16	63	F	1	H	5	Advanced	3	Graduate level	3	P	2
P17	11/15/16	55	M	2	A	2	Advanced	3	Graduate level	3	E	1
P18	11/16/16	57	F	1	M	3	Advanced	3	Graduate level	3	P	2
P19	11/16/16	53	F	1	H	5	Advanced	3	Graduate level	3	E	1
P20	11/16/16	58	M	2	H	5	Advanced	3	Graduate level	3	P	2
P21	11/16/16	57	M	2	M	3	Advanced	3	Graduate level	3	E	1
P22	11/17/16	58	M	2	B	1	Advanced	3	Graduate level	3	P	2
P23	11/18/16	67	M	2	B	1	Advanced	3	Graduate level	3	E	1
P24	11/18/16	55	F	1	A	2	Advanced	3	Graduate level	3	P	2
P25	11/18/16	68	M	2	A	2	Advanced	3	Graduate level	3	E	1
P26	11/21/16	65	F	1	H	5	Intermediate	2	High school level	1	P	2
P27	11/21/16	64	F	1	H	5	Intermediate	2	College level	2	E	1
P28	11/21/16	68	F	1	H	5	Beginner	1	High school level	1	P	2
P29	11/22/16	66	M	2	C	4	Intermediate	2	College level	2	E	1
P30	11/22/16	57	F	1	C	4	Intermediate	2	College level	2	P	2
P31	11/22/16	54	M	2	M	3	Intermediate	2	College level	2	E	1

	ELECTRONIC TABLET PLATFORM																
	MATCHING GAME				AWARENESS GAME				CALCULUS GAME				SPEED GAME				
Participant ID	Time(secs)	Task Completion	Error Tally	Participant Comments	Time(secs)	Task Completion	Error Tally	Participant Comments	Time(secs)	Task Completion	Error Tally	Participant Comments	Time(secs)	Task Completion	Error Tally	Participant Comments	Time(secs)
P0	83	1	1	0A	58	1	0	0B	102	1	0	0C	95	1	3	0D	75
P1	86	1	1	1A	65	1	0	1B	133	1	0	1C	101	1	3	1D	82
P2	100	1	0	2A	64	1	0	2B	131	1	2	2C	89	1	1	2D	79
P3	98	1	0	3A	65	1	1	3B	140	1	1	3C	111	1	0	3D	82
P4	101	1	2	4A	73	1	0	4B	149	0	3	4C	121	1	4	4D	85
P5	62	1	0	5A	108	1	1	5B	101	1	0	5C	100	1	0	5D	84
P6	45	0	1	6A	96	1	0	6B	109	1	0	6C	113	1	0	6D	105
P7	56	1	0	7A	88	1	0	7B	87	1	1	7C	92	1	0	7D	118
P8	92	1	0	8A	98	1	0	8B	98	1	1	8C	84	1	0	8D	100
P9	113	1	2	9A	76	1	0	9B	119	1	4	9C	129	1	1	9D	81
P10	88	1	1	10A	93	1	1	10B	129	1	0	10C	108	1	1	10D	85
P11	102	1	0	11A	97	1	0	11B	122	1	0	11C	128	1	0	11D	99
P12	97	1	0	12A	81	1	0	12B	101	1	1	12C	87	1	0	12D	89
P13	77	1	1	13A	82	1	0	13B	126	0	0	13C	90	1	0	13D	75
P14	116	1	0	14A	116	1	0	14B	88	1	3	14C	86	1	0	14D	128
P15	121	1	0	15A	97	1	0	15B	125	1	1	15C	87	1	1	15D	100
P16	81	1	0	16A	110	1	2	16B	80	1	1	16C	98	0	2	16D	98
P17	80	1	0	17A	82	1	0	17B	97	1	0	17C	85	1	0	17D	96
P18	80	1	0	18A	116	1	0	18B	100	1	0	18C	98	1	0	18D	86
P19	113	1	0	19A	75	1	0	19B	114	1	1	19C	99	1	0	19D	92
P20	91	1	0	20A	89	1	0	20B	120	1	1	20C	76	1	2	20D	77
P21	84	1	1	21A	88	1	0	21B	90	1	0	21C	127	1	0	21D	80
P22	99	1	0	22A	87	1	0	22B	87	1	0	22C	108	1	0	22D	92
P23	91	1	0	23A	81	1	0	23B	124	1	0	23C	113	1	0	23D	65
P24	62	0	2	24A	95	1	1	24B	98	0	2	24C	115	0	4	24D	65
P25	122	1	0	25A	92	1	1	25B	79	1	1	25C	111	1	1	25D	63
P26	94	0	2	26A	93	1	0	26B	93	1	0	26C	90	0	0	26D	121
P27	121	1	0	27A	87	1	1	27B	113	1	2	27C	108	1	0	27D	97
P28	130	1	0	28A	130	1	1	28B	137	0	2	28C	126	1	1	28D	81
P29	109	1	0	29A	106	1	1	29B	94	1	0	29C	82	1	1	29D	98
P30	85	0	4	30A	86	1	0	30B	93	0	0	30C	92	0	0	30D	105
P31	135	1	1	31A	77	0	0	31B	104	1	1	31C	94	1	1	31D	75

- Screenshot of data dictionary

Opoku-Boateng, Gloria Dissertation Data Dictionary
Built on 11/1/16 0:00

	Column ID	Column Name	Data Description	Data Type	Data Range/Categories	Defult Value	Mandatory?	Unique?
1	A	Participant ID	Unique Identification Numbers assigned to Participants of this study.	Alpha numeric	All IDs start with P and is followed by a numeric integer. Range of Integer 1-81	#	Yes	Yes
2	B	Session Date	The date (MM/DD/YY) the session was completed/recorded.	Numeric Date (Short)	Range of dates	00/00/00	No	No
3	D	Age	Participant age as of 2016	Integer	52-70	##	Yes	No
4	E	Gender	Participant Gender	Character	M, F	#	Yes	No
5	F	Gender Coding	Participant Gender Coding	Integer	1,2	#	Yes	No
6	G	Race	Participant Race (BAMCH)	Character	B: Black, A: Asian, M: Mixed, C: Caucasian, H: Hispanic	#	Yes	No
7	H	Race Coding	Participant Race Coding	Integer	Range: 1 to 5 where B=1, A=2, M=3, C=4, H=5	0	Yes	No
8	I	Tech Saviness	Level of comfortability of Participant's technology use	String	Advanced, Intemediate, Beginner	0	Yes	No
9	J	Tech Saviness Coding	Coding of level of comfortability of Participant's technology use	Integer	Range: 1 to 3 where Advanced =3, Intermediate =2, and Beginner =1	#	Yes	No
10	K	Educational Background	Educational Background of participant	String	Graduate level, College level, High school level		Yes	No
11	L	Educational Background Coding	Educational Background of participant coding	Integer	Range: 1 to 3 where Graduate =3, College =2, and High School =1	#	Yes	No
12	N	Starting Platform	The platform which participant started with	Character	Electronic paltform and Paper platform	E,P	Yes	No
13	O	Starting Platform Coding	Coding for platform started with	Integer	Range: 1 to 2 where Electronic =1, and Paper =2	#	Yes	No
14	P	Time on task (secs)	Time taken to complete the matching game of paper platform	Integer	Time in seconds	###	Yes	No
15	Q	Task Completeion	whther or not the participant finished playing the matching game on the paper platform	Bit	0,1	#	Yes	No
16	R	Error Tally	Number of mistakes made during the game	Integer	0-5	#	Yes	No
17	S	Participants Comments	Participants comments after playing the matching game on the paper platform.	Long String	Transcribed comments		No	Yes

Appendix F: IRB Approval Documents

- *UMBC IRB Approval Certificate:*

UMBC

AN HONORS UNIVERSITY IN MARYLAND

Office of Research Protections and Compliance
University of Maryland, Baltimore County
1000 Hilltop Circle
Baltimore, MD 21250

PHONE: 410-455-2737
EMAIL: compliance@umbc.edu
WEB: research.umbc.edu

Date: 10/10/2016
To: Gloria Opoku-Boateng, Anthony Norcio
Re: Expedited Review Approval
Protocol #: Y17AN12050

Your protocol entitled **Computerized and Non-computerized Approaches to Brain Fitness Games** has been **approved by expedited review** by the Institutional Review Board. This study fulfills the criteria for expedited review under 45 CFR 46.110, category # 6&7 as ☐ *less than minimal risk* or ☒ *minimal risk.*

Approval of this protocol will terminate on the below end date unless an Annual Continuation Report is submitted, in writing, ***no later than the due date*** highlighted below. As a courtesy, the Office of Research Protections and Compliance will send you an email reminder prior to the end of the protocol; it is your responsibility, however, to assure that project activities are not conducted past the expiration date.

Reporting Calendar

Original approval date	Current end date	The next Annual Continuation Report is due by	Expect a reminder to renew by
10/7/2016	10/6/2017	**9/8/2017**	**9/22/2017**

Investigators are responsible for reporting ***in writing*** to the IRB any changes to the human subject research protocol, measures or in the informed consent documents. This includes changes to the research design or procedures that could introduce new or increased risks to human subjects and thereby change the nature of the research. In addition, you must report any adverse events or unanticipated problems to the IRB for review and approval. All correspondence and materials used in this protocol must reference the above IRB number.

Investigators are also reminded that all UMBC IRB approved consent forms will display an expiration date at the bottom of each page. Please check this date carefully each time an approved consent form is used, as using an expired form to consent participants is considered a substantial deviation from the Federal regulations governing research involving human subjects.

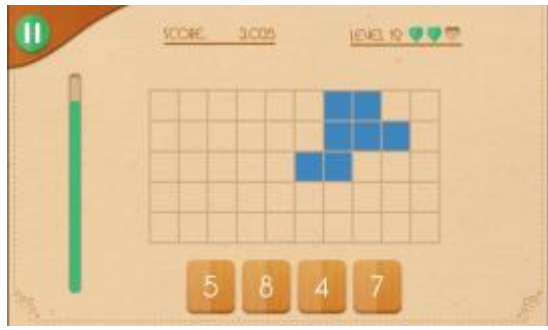
The investigator(s) identified above are required to retain an IRB protocol file, including a record of IRB-related activity, data summaries and consent forms. This file is to be made available for review for internal procedural (audit) monitoring.

Expedited review approved by:

Susan Sonnenschein, Ph.D.
IRB Chair

Appendix G: Artifacts for both paper and electronic platforms.

- ***Electronic Platform:***



These artifacts are screenshots of the games as captures on an iPhone 6s. In reading order: Photo1: Home screen with description of the matching game. Photo 2: A sample level 7 screen of the matching game. Photo 3: Home screen with description of the speed game. Photo 4: A sample level 12 screen of the speed game. Photo 5: Home screen with description of the calculus game. Photo 6: A sample level 13 screen of the calculus game. Photo 7: Home screen with description of the awareness game. Photo 8: A sample level 6 screen of the awareness game.

- ***<u>Paper Platform:</u>***

The paper platform artefacts are printed, laminated and filed copies of the electronic games. Note that the paper version does not have a timer or automatic scoring system.

Appendix H: Supplementary Analyses Tables from Chapter 4

MALES

ANOVA: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Matching Time	39	3635	93.20512821	182.9568151
Awareness Time	39	3629	93.05128205	300.9446694
Calculus Time	39	3930	100.7692308	312.0769231
Speed Time	39	3809	97.66666667	171.122807

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1634.480769	3	544.8269231	2.253443238	0.084453283	2.664106703
Within Groups	36749.84615	152	241.7753036			
Total	38384.32692	155				

Table A: ANOVA on male time (all 4 games) on electronic platform

Conclusion: Since F < F crit, the null hypothesis(H_0) is accepted. This means within all four (4) games on the electronic platform, gender (male) affects the player time outcome.

FEMALES

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Matching Time	42	3978	94.71428571	258.0139373
Awareness Time	42	4237	100.8809524	239.5708479
Calculus Time	42	4191	99.78571429	209.5383275
Speed Time	42	4063	96.73809524	184.6370499

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1002.684524	3	334.2281746	1.4991 84147	0.2167 52917	2.6597 20184
Within Groups	36562.16667	164	222.9400407			
Total	37564.85119	167				

Table B: ANOVA on female time (all 4 games) on electronic platform

Conclusion: Since F < F crit, the null hypothesis(H_0) is accepted. This means within all four (4) games on the electronic platform, gender (female) affects the player time outcome.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	22	2049	93.13636364	183.0757576
Column 2	22	1994	90.63636364	342.6233766
Column 3	22	2209	100.4090909	282.0627706
Column 4	22	2120	96.36363636	135.5757576

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1178.272 727	3	392.7575758	1.665395506	0.18065 5827	2.7132 27129
Within Groups	19810.09 091	84	235.8344156			
Total	20988.36 364	87				

Table C: ANOVA test on time by Blacks between games

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	11	981	89.18181818	339.5636364
Column 2	11	1127	102.4545455	383.4727273
Column 3	11	1087	98.81818182	297.7636364
Column 4	11	1112	101.0909091	150.0909091

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1185.522727	3	395.1742424	1.349995083	0.271888721	2.838745398
Within Groups	11708.90909	40	292.7227273			
Total	12894.43182	43				

Table D: ANOVA test on time by Asians between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	13	1252	96.30769231	125.7307692
Column 2	13	1306	100.4615385	286.2692308
Column 3	13	1301	100.0769231	275.9102564
Column 4	13	1301	100.0769231	254.7435897

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	149.3846154	3	49.79487179	0.211296531	0.888088958	2.798060635
Within Groups	11311.84615	48	235.6634615			
Total	11461.23077	51				

Table E: ANOVA test on time by Mixed between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	24	2228	92.83333333	226.4057971
Column 2	24	2394	99.75	170.0217391
Column 3	24	2339	97.45833333	221.1286232
Column 4	24	2271	94.625	137.7228261

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	671.9166667	3	223.9722222	1.18616949	0.31943617	2.703594041
Within Groups	17371.41667	92	188.8197464			
Total	18043.33333	95				

Table F: ANOVA test on time by Caucasians between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Matching	11	1103	100.2727273	281.4181818
Awareness	11	1045	95	252.4
Calculus	11	1185	107.7272727	234.6181818
Speed	11	1068	97.09090909	306.8909091

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1025.704545	3	341.9015152	1.271804496	0.297065531	2.838745398
Within Groups	10753.27273	40	268.8318182			
Total	11778.97727	43				

Table G: ANOVA test on time by Hispanics between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	27	2413	89.37037037	374.8575499
Column 2	27	2467	91.37037037	189.011396
Column 3	27	2804	103.8518519	283.3618234
Column 4	27	2745	101.6666667	208.7692308

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4262.546296	3	1420.848765	5.382002899	0.001749581	2.691978638

Within Groups	27456	104	264			
Total	31718.5463	107				

Table H: ANOVA test on time by Advanced between games

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	26	2482	95.46153846	129.6984615
Column 2	26	2490	95.76923077	297.7846154
Column 3	26	2557	98.34615385	211.2753846
Column 4	26	2395	92.11538462	72.82615385

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	509.7692308	3	169.9230769	0.955181286	0.417072946	2.695534255
Within Groups	17789.61538	100	177.8961538			
Total	18299.38462	103				

Table I: ANOVA test on time by Intermediate between games

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	28	2718	97.07142857	136.6613757
Column 2	28	2909	103.8928571	293.1362434
Column 3	28	2760	98.57142857	270.2539683
Column 4	28	2732	97.57142857	208.4021164

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	828.16 96429	3	276.0565476	1.215500786	0.307673599	2.688691468
Within Groups	24528. 25	108	227.1134259			

Total	25356.41964	111

Table J: ANOVA test on time by Beginners between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	23	2070	90	390.3636364
Column 2	23	2071	90.04347826	151.0434783
Column 3	23	2405	104.5652174	261.7114625
Column 4	23	2343	101.8695652	211.1185771

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4088.467391	3	1362.822464	5.374768448	0.001914521	2.708186474
Within Groups	22313.21739	88	253.5592885			
Total	26401.68478	91				

Table K: ANOVA test on time by Graduate between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	28	2663	95.10714286	161.3584656
Column 2	28	2777	99.17857143	320.6706349
Column 3	28	2691	96.10714286	136.9880952
Column 4	28	2665	95.17857143	154.9669312

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	307.1428571	3	102.3809524	0.52911138	0.663241325	2.688691468
Within Groups	20897.57143	108	193.4960317			
Total	21204.71429	111				

Table L: ANOVA test on time by College between games

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	30	2880	96	141.7241379
Column 2	30	3018	100.6	306.3172414
Column 3	30	3025	100.8333333	348.0747126
Column 4	30	2864	95.46666667	157.0850575

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	750.0916667	3	250.0305556	1.049224734	0.373634081	2.682809407
Within Groups	27642.83333	116	238.3002874			
Total	28392.925	119				

Table M: ANOVA test on time by High School between games

1. ANOVA of Time (secs) on Electronic Platform

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Matching Game	81	7613	93.98765432	219.7123457
Awareness Game	81	7866	97.11111111	281.225
Calculus Game	81	8121	100.2592593	255.8694444
Speed Game	81	7872	97.18518519	176.1277778

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1593.259259	3	531.0864198	2.277057526	0.079608125	2.632826736
Within Groups	74634.76543	320	233.233642			
Total	76228.02469	323				

Table N: ANOVA test on time by Electronic Platform games

2. ANOVA of Time (secs) on Paper Platform

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	81	7734	95.48148148	253.0027778
Column 2	81	8340	102.962963	277.8861111
Column 3	81	8753	108.0617284	184.058642
Column 4	81	8467	104.5308642	231.8021605

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6825.246914	3	2275.082305	9.612180813	4.2947 2E-06	2.6328 26736
Within Groups	75739.97531	320	236.6874228			
Total	82565.22222	323				

Table O: ANOVA test on time by Paper Platform game

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