Summer 2019

Mathematical Literacy and Video Games

Craig Carrigee
University of Southern Mississippi

MATHEMATICAL LITERACY AND VIDEO GAMES

by

Craig Steven Carrigee

A Dissertation
Submitted to the Graduate School,
the College of Education and Human Sciences
and the School of Education
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

Approved by:

Dr. Richard Mohn, Committee Chair
Dr. Kyna Shelley
Dr. Lilian Hill
Dr. Jon Beedle

Dr. Richard Mohn Committee Chair	Dr. Sandra Nichols Director of School	Dr. Karen S. Coats Dean of the Graduate School

August 2019

Published by the Graduate School

ABSTRACT

Mathematical literacy refers to the ability of a person to be able to comprehend and conceptualize real-world data and mathematical situations to make informed decisions. Minimal research exists compared to the explosion of video games available to the public over the past two decades. This study investigates the relationships between playing video games and the ability of a person to answer real-world questions about mathematics as well as the person's attitude toward mathematics, including their self-confidence, perceived value, enjoyment, and motivation. Previous studies have shown mixed results related to the influence of playing video games on cognitive math ability, but research has shown some positive effects related to the influence of playing video games on attitudes toward mathematics.

A sample of adult participants (*N* = 255) were included in this study. Independent variables included video gameplay, measured in hours per week, as well as demographic characteristics. Cognitive math ability was measured using a 17-item multiple-choice exam while attitude components were measured using the *Attitudes Toward Mathematics Inventory* (Tapia, 1996). A confirmatory factor analysis assessed the four-factor model fit of the items of the Attitudes survey and then two structural models determined the relationships between the measured variables. Demographic characteristics were included as components of the second structural model.

Results indicate that playing video games has no statistically significant direct effect on cognitive math ability. Latent variables measured by the Attitudes survey showed positive effects on math ability related to self-confidence and perceived value, but negative effects related to motivation. Effects of demographic characteristics including age, gender, and academic major were also analyzed. Significant indirect path effects were found, but these effects were minimal. Limitations of the study are discussed as well as implications for future research.

ACKNOWLEDGMENTS

First, I would like to express the utmost appreciation to Dr. Richard Mohn, committee chair of this dissertation. The guidance and assistance provided by Dr. Mohn was instrumental not only with the completion of my research but also as a trusted confidant. Without Dr. Mohn's direction, I would not be here today.

I would also like to extend my gratitude to the remaining members of my committee, including Dr. Kyna Shelley, Dr. Lilian Hill, and Dr. Jon Beedle for their continued support throughout the process of completing this research. Without the superior supervision and direction of this committee, it would have been impossible to complete this dissertation.

I would also like to thank my colleagues; Mr. Raymunda Barnes, for giving me the time and support I needed to complete this dissertation, Dr. Jennifer Seal, for always asking about my progress and pushing me to finish, and Dr. James Hudson, for words of encouragement that helped push me to continue working on this project until it was completed.

DEDICATION

This work is dedicated to my amazingly supportive family, including my wife, Lyndsay Ann Carrigee, my two children, Valor Eason Carrigee and Lillian Garnet Carrigee, and my parents Steven and Donna Carrigee.

TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGMENTS iv

DEDICATION v

LIST OF TABLES ix

LIST OF ILLUSTRATIONS x

LIST OF ABBREVIATIONS xi

CHAPTER I - INTRODUCTION 1

Background 1

Theoretical Framework 7

Purpose 7

Definition of Terms 8

Delimitations 9

Assumptions 10

Justification 10

CHAPTER II – LITERATURE REVIEW 12

Theoretical Framework 12

Experiential Learning Theory 12

Literature Review 14

Quantitative Literacy 14

Mathematics and Video Games 19

Video Games and Motivation 21

Demographic Considerations 24

Summary 24

CHAPTER III - METHOD 26

Participants 26

Variables 28

Instrument 29

Design 34

Procedure 36

Pilot Test 36

Data Collection 37

Analytic Approach 37

Confirmatory Factor Analysis and Path Analysis 37

Demographic Considerations 38

Operationalized Variables 40

Scholarly Significance 43

CHAPTER IV – RESULTS 45

Sample Collection and Descriptive Statistics 45

Confirmatory Factor Analysis 46

Path Analysis 51

Structural Model One... 51

Structural Model Two 54

CHAPTER V – DISCUSSION... 62

Discussion of the Results 62

Effects of Video Gameplay on Cognitive Math Ability 62

Effects of Video Gameplay on Attitudes Toward Mathematics 64

Effects of Attitudes Toward Mathematics on Math Ability 66

Effects of Demographics on Math Ability and Attitudes Toward Mathematics 67

Indirect Effects of Video Gameplay on Math Ability 70

Limitations of Results 72

Limitations of Sample... 72

Limitations of Analysis 73

Implications for Further Research 74

Summary of Research 75

APPENDIX A – Cognitive Math Exam 76

APPENDIX B USM IRB Approval Letter 83

APPENDIX C PRCC IRB Approval Letter.. 84

REFERENCES 85

LIST OF TABLES

Table 1 Standardized Loadings for CFA Model (Self-confidence) 49

Table 2 Standardized Loadings for CFA Model (Value) 50

Table 3 Standardized Loadings for CFA Model (Enjoyment) 50

Table 4 Standardized Loadings for CFA Model (Motivation) 51

Table 5 Scale Reliabilities for CFA Model 51

Table 6 Direct Effects (Model 1) 53

Table 7 Indirect Effects of Gameplay on Math Ability (Model 1) 54

Table 8 Direct Effects (Model 2) 56

Table 9 Direct Effects of Academic Major (Model 2) 58

Table 10 Direct Effects of ATMI Variables on Math Ability (Model 2) 59

Table 11 Indirect Effects of Age on Math Ability (Model 2) 60

Table 12 Indirect Effects of Video Gameplay on Math Ability (Model 2) 60

Table 13 Indirect Effects of Gender on Math Ability (Model 2) 60

Table 14 Indirect Effects of Academic Major on Math Ability (Model 2) 61

LIST OF ILLUSTRATIONS

Figure 1. Path Analysis Diagram (Model 1) 39

Figure 2. Path Analysis Diagram (Model 2 – Demographic Characteristics) 41

Figure 3. Confirmatory Factor Analysis Final Model 48

Figure 4. Structural Model 1 52

Figure 5. Structural Model 2 55

LIST OF ABBREVIATIONS

ATMI	Attitude Towards Mathematics Inventory
AVG	Action Video Game
CFA	Confirmatory Factor Analysis
FPS	First Person Shooter
RPG	Role-Playing Game
SEM	Structural Equation Model
TPS	Third Person Shooter

CHAPTER I - INTRODUCTION

Background

Literacy in mathematics refers to a specific skill set in which a person can comprehend and conceptualize real-world data and then utilize this understanding to benefit the community at large (Burdette & McLoughlin, 2010; Frith, Jaftha, & Prince, 2004; Gal, 2002; Linder, 2012; Matteson, 2006; Ozgen, 2013; Scherger, 2013; Wade & Goodfellow, 2009; Wilkins, 2010). Though many terms have been used to describe this concept and its components, including quantitative literacy (Burdette & McLoughlin, 2010; Scherger, 2013; Wilkins, 2010), mathematical literacy (Frith et al., 2004; Kaiser & Willander, 2005; Matteson, 2006; Ozgen, 2013; Stacey, 2012), or statistical literacy (Gal, 2002; Wade & Goodfellow, 2009), the general outcome of a more mathematically prepared person is shared by all definitions. Interest in this concept has arisen in light of changing standards in mathematics curricula across the country (Matteson, 2006; Stacey, 2012) and the continued poor performance of the United States in national numeracy studies (Goodman, Finnegan, Mohadjer, Krenzke, & Hogan, 2013). Research has investigated the theoretical constituents of this complex construct (Gal, 2002; Wilkins, 2010), the appropriate ways to measure and assess the construct as a whole (DeFreitas & Oliver, 2006; Dumford & Rocconi, 2015; Matteson, 2006), as well as the ways by which these components may be improved (Burdette & McLoughlin, 2010; Ozgen, 2013; Scherger, 2013; Wade & Goodfellow, 2009). Methods include experience with commercial and educational video games in and out of the classroom (Abrams, 2009; Beserra, Nussbaum, Zeni, Rodriguez, & Wurman, 2014; Carr, 2012; Drummond & Sauer, 2014; Ferguson, Garza, Jerabeck, Ramos, & Galindo, 2013; Gerber, Abrams, Onwuegbuzie, & Benge, 2014; Hoffman & Nadelson, 2010; Kim & Chang, 2010; Kühn, Gleich, Lorenz, Lindenberger, & Gallinat, 2014; Plass, O'Keefe, Homer, Case, Hayward, Stein, & Perlin, 2013; Ranalli & Ritzko, 2013; Unsworth, Redick, McMillan, Hambrick, Kane, & Engle, 2015), but because of the increasing production and popularity of commercial video games, there is a great deal of research yet to be completed.

Quantitative literacy is a structured concept that comes about to explain how people can understand and process numerical information to critically solve problems or to make beneficial decisions (Wilkins, 2000; Wilkins, 2004; Wilkins, 2010). Research into the components of quantitative literacy show that the construct is made up of multiple components (Gal, 2002; Wilkins, 2010). Though there is not one singular definition of quantitative literacy, nearly all models in the literature include aspects related to both the individual's cognitive capabilities (Scherger, 2013; Wilkins, 2010) as well as the person's beliefs and dispositions toward mathematical situations (Ozgen, 2013; Wilkins, 2004; Wilkins, 2010; Wilkins & Ma, 2003). Researchers have tested this construct as a whole by means of large-data statistical analysis (Wilkins, 2010) while others have explored treatments or interventions that focus on one particular component, primarily cognition (Linder, 2012; Wade & Goodfellow, 2009), in an effort to find ways to increase the quantitative understanding of the general public.

Accepting the term *quantitative literacy* as an overarching idea allows for further deconstruction to smaller, less generalized concepts. For example, researchers have used the terms *mathematical literacy* or *statistical literacy* nearly interchangeably with quantitative literacy, but often refer to lesser cognitive abstractions, such as quantitative reasoning (Dumford & Rocconi, 2015) or math achievement (Beserra et al., 2014; Carr, 2012; Drummond & Sauer, 2014; Kim & Chang, 2010; Plass et al., 2013); abstractions that could essentially be viewed as parts of a holistic concept. It is reasonable however to consider components of quantitative literacy separate from one-another because proposed models have shown that improvement in one aspect would imply improvement to the overall construct (Gal, 2002; Wilkins, 2009). In education, research using different strategies has shown both positive and negative results related to the components of quantitative literacy (Abrams, 2009; Beserra et al., 2014; Bowers and Breland, 2013; Carr, 2012; Ferguson et al., 2013; Gerber et al., 2014; Kim & Chang, 2010; Linder, 2012; Ranalli & Ritzko, 2013). Multiple studies have shown that experience with real-world data that is relevant to the learner can improve both achievement outcomes and motivation among participants (Burdette & Mcloughlin, 2010; Linder, 2012; Wade & Goodfellow, 2009). Clearly, motivation and relevance are significant factors to consider when attempting to understand how to improve a person's quantitative skills; therefore, investigating educational methods that may positively influence these variables could provide valuable pedagogical insights.

It is likely that a person will be more motivated to solve a mathematical problem if the problem is directly related to a personal experience rather than a proposed problem with no tangible outcomes or consequences. The intrinsic motivation established in this situation can be rooted in Kolb's experiential learning theory. According to Kolb (1984), learners grow through experience, particularly when they are made to resolve conflicts or adapt their knowledge to given situations. Kolb's and similar theories have been linked to studies of mathematical literacy (Abrams, 2009; Ackland, 2014; Carr, 2012; De Freitas &

Oliver, 2006; Frith et al., 2004; Gerber et al., 2014) and provide a necessary framework to investigate learning in a multitude of situations.

Kolb's experiential learning theory allows for a deeper understanding of the way that individual experiences can shape learning. In this respect, some researchers have chosen to investigate experiences that may have an impact on the quantitative abilities of a person (Abrams, 2009; Beserra et al., 2014; Bowers & Berland, 2013; Burdette & Mcloughlin, 2010; Carr, 2012; Drigas & Pappas, 2015; Drummond & Sauer, 2014; Ferguson et al., 2013; Gerber et al., 2014; Kim & Chang, 2010; Plass et al., 2013; Ranalli & Ritzko, 2013). These experiences can range from the analysis of real-world data in the classroom (Burdette & Mcloughlin, 2010; Linder, 2012; Wade & Goodfellow, 2009) to the use of educational and commercial video games as learning tools (Abrams, 2009; Beserra et al., 2014; Bowers & Berland, 2013; Carr, 2012; Drigas and Pappas, 2015; Drummond & Sauer, 2014; Ferguson et al., 2013; Gerber et al., 2014; Kim & Chang, 2010; Plass et al., 2013; Ranalli & Ritzko, 2013). In some cases these experiences have been shown to be beneficial to those involved (Abrams, 2009; Bowers and Breland, 2013; Kim & Chang, 2010; Gerber et al., 2014; Linder, 2012) and in some there were no measurable benefits (Beserra et al., 2014; Carr, 2012; Ferguson et al., 2013; Ranalli & Ritzko, 2013). Furthermore, the amount of research into improving mathematical abilities through tools like video games is minimal compared to the explosion of video games available to the public in the past fifteen years.

Video games were introduced to the public decades ago, but only in recent years have advances in technology led to a great proliferation of video games into society. High-definition televisions, wireless and streaming internet, smartphones, and software production have led to more games being available to more people at fractions of the cost to the user. In the early 1980s, video games were available in public arcades and on basic home consoles like the Atari and Nintendo systems but the games were primitive by today's standards and limited in quantity and scope by their simplistic technology, not to mention the respective cost. In stark contrast, today there is a nearly endless supply of games available to players on their personal devices with most free of charge.

There has been some research into the impacts of video gameplay on a variety of topics. Research has looked into the biological effects of video gameplay on brain matter (Kühn et al., 2012) as well as the violence prevalent in some video games and its effects on the behavior of adolescents and adults (Ferguson et al., 2013). Additional studies look at the impacts of educational games on mathematical literacy and achievement (Beserra et al., 2014; Carr, 2012; Drummond & Sauer, 2014; Kim & Chang, 2010; Plass et al., 2013) and still others look at similar effects with respect to commercial games that are played by large audiences (Abrams, 2009; Gerber et al., 2014; Ranalli & Ritzko, 2013; Unsworth et al., 2015). Many of these studies return mixed results with respect to the educational capabilities of commercial video games and the benefits afforded to players, but there is a general consensus that video games increase motivation among participants regardless of any direct cognitive improvement (Abrams, 2009; Beserra et al., 2014; Hoffman & Nadelson, 2010; Plass et al., 2013). As mentioned before, motivation is a factor that influences quantitative literacy, so clearly there may be a positive connection between the motivating effects of video game play and the components of quantitative literacy.

Motivation does not need be the only factor of quantitative literacy affected by video game play, however mixed results have been found when investigating cognitive improvements related to video games. Some research has shown that there is no measurable improvement (Collins & Freeman, 2014; Unsworth et al., 2015) while others have shown that video games can lead to cognitive improvements (Buelow, Okdie, & Cooper, 2015) including so-called *action video games*, such as first-person shooters. Due to the introduction of advanced computing capabilities in recent years, newer action video games are generally equipped with advanced mathematical gameplay systems based on probabilities or statistical concepts. For example, a game released in 2008, *Fallout 3*, is primarily a first-person shooter, but also contains a probabilistic attack system based on individual gameplay situations.

Action video games like *Fallout 3* expose players to multiple types of mathematical situations during gameplay. These scenarios extend from the choices made when improving a character's statistics to items available for purchase based on acquired resources to the actual interactions within the computerized gameplay. Players can experience these circumstances numerous times within the same game in a single session. Based on Kolb's theory of experiential learning, it is possible that the experiences players gain by resolving conflicts and adapting knowledge within the video game setting will allow the player to extrapolate that knowledge to situations outside of the context of the video game. Specifically, it is possible that there is some link between playing action video games and the cognitive abilities of a person to make reasoned decisions involving percentages and other mathematical abstractions; thus, another method available for the improvement of quantitative literacy.

Theoretical Framework

This study is framed in Kolb's experiential learning theory. Kolb's theory explains that knowledge can be created through the experiences of the learner, particularly when the learner must revise already acquired knowledge to make it applicable to a new situation (Kolb, 1984). In terms of this study, the experience of participants is related to their gameplay within the context of the video game. It is hypothesized that after the video game experience participants will be able to adapt the knowledge acquired and use it in real-life situations. It is in this way that learning mathematics can be understood as a component of an experience related to playing video games.

Purpose

The purpose of this study was to investigate the impacts of video game play on a person's ability to answer particular mathematical questions. Mathematical abstractions were based on those present during gameplay and include concepts involving percentages, ratios, rates, real number addition, and reading charts and graphs. Additionally, the study investigated the motivations of students with respect to their underlying quantitative literacy. Specifically, this study addressed the following research questions:

R1. What correlational relationships exist between playing an action video game, such as *Fallout 3,* and a person's ability to answer real-life questions about mathematics, including percentages, ratios, rates, real number addition, and reading charts and graphs?

R2. What correlational relationships exist between playing an action video game and a person's value and enjoyment of mathematics as well as their self-confidence and motivations toward mathematical situations?

Definition of Terms

When discussing video games, it is important to first understand the meaning of particular terms as they relate to video games and video gameplay. These terms and their associated abbreviations will be used throughout the discussions within this paper.

First, *action video games* (AVGs) refer to a particular genre of video games in which the player has control over a character and navigates challenges in the game as that character. The "actions" that the player must take varies from game to game. This particular genre would include different subgenres, such as fighting games, where players battle one another in a series of direct conflicts (i.e, *Mortal Kombat*); platform games, where players maneuver obstacles and collect items (i.e., *Super Mario Bros.)*; and shooter games, where players navigate a character through a particular storyline or sequential level challenges (i.e., *Fallout 3*). Each of these types of games have their own particular challenges, however shooter games are often more intricate and sometimes offer the player more control over their character and his/her attributes within the game.

Two particular types of shooter games are the *first-person shooter* (FPS) and *third-person shooter* (TPS) game. These games are similar in their gameplay, but differ in the way that the player visually interacts with the game based on the player's point of view. These games often allow the player to control numerous components of their character, giving the player the ability to change the character to match their own particular tastes. In addition to being able to directly influence character attributes, such as attack strength or accuracy, the player can also in some cases influence the look of their character or even the clothes that the character wears. Often the goal of a shooter game (first- or third- person) is to complete some type of level or overall challenge, but some shooter games are more of an open world, similar to those of role-playing games.

A *role-playing game* (RPG) is an action video game in which the player takes control of a character and progresses through a complex storyline while having a direct influence on the particular actions or statements made by their character in the game. RPGs differ from the average FPS or TPS because they immerse the player into the storyline of the characters, giving them much more control over the way the story plays out within the game. RPGs come in many forms, but in the context of this paper, RPGs will refer only to video games that meet these particular characteristics.

Delimitations

This research investigated the relationship between playing action video games and a person's quantitative literacy. Participants of interest to this study were adults of a college-going age, as this is one of the most common demographics that play video games. Additionally, the past mathematical education and performance of a participant was extremely important to this study. Those who have completed advanced mathematics courses, such as statistics or calculus, were excluded from the study, as they are likely to overperform on the quantitative literacy instrument and skew results. Similarly, younger adults were excluded from the study as they are often enrolled in mathematics courses in their high school years. Primarily, this study investigated those participants who completed the entirety of their mathematics education, whether it be in high school or college, in an attempt to remove possible confounding information.

Likewise, this study was limited in the scope of measuring video gameplay. There are thousands of games that any person could play and thus there is no way to directly ask participants about every single possible game. Instead, because this study focused primarily on younger college-age students, the scope of video game-play measurements was restricted to only the most popular games released in the past few years.

Assumptions

This research was based on the assumption that learning mathematics occurs while playing video games. Though the sample of the study was restricted to particular participants (college students), this research also based on the assumption that these students will have completed mathematics instruction within their academic career so that results will not be confounded by increased mathematical ability due to classroom instruction. Measures taken to mitigate this and other validity concerns are discussed further in the methodology chapter.

Justification

Significant benefits of this study can be seen across a multitude of contexts. Individually, the participants involved in the study may have experienced some benefit, such as an increase in their ability to solve mathematical problems. They may also have found an increase in motivation toward mathematical situations, particularly if they are able to associate those situations to the ones experienced in the video game. In the best possible case, participants may have found a combination of these two benefits and move toward a more functional understanding of the quantitative nature of the world.

Additionally, colleges and universities may benefit, as new ways of improving learning in mathematics may be understood. If students are learning from video games, a pastime that many college students are familiar with, then perhaps colleges could work to include components of video games in their classroom or even design their own games related to their particular course content. The more that colleges and universities are able to understand effective methods of teaching and learning, the better off students will be. This is particularly true if the method used (video games) is something that already proliferates the collegiate society.

Overall, the results of this study could be used to discover new methods of mathematics education, particularly for adults. Adults in the United States consistently score below many other countries in national numeracy studies, showing that American adults have some of the lowest numeracy scores of first-world nations (Goodman et al., 2013). Because video games are played by such a large number of people, it is possible that this could be an avenue to improve these national scores assuming there are positive results from this study. For example, adults who do not have time to attend college courses may find that video games are an entertaining alternative and may still learn similar skills that could be found in a classroom. Likewise, those who do not play video games may discover that playing could help them improve their mathematics abilities as well as their confidence in mathematical situations.

CHAPTER II – LITERATURE REVIEW

Theoretical Framework

Experiential Learning Theory

The theoretical framework of this study was grounded in concepts of experiential learning. Based on Kolb's experiential theory, learning is supported when the learners are met with conflict and are required to make particular decisions (Kolb, 1984). Essentially, participants learn by experiencing the event or situation in its own context. It is in this way that Kolb's theory can be applied to the overarching understanding of how learning can occur in a video game context. For example, prospective pilots who are first learning how to fly spend numerous hours in simulators which are in essence large video game systems devoted to the teaching the player how to fly. By practicing using a computerized plane, the learner is able to experience different situations that could arise while piloting and is able to generate the skills needed to adapt even before they ever set foot into a real plane. In this way, the experience of the simulator protects against harm to people and property and in some ways is vital to learning how to appropriately fly a plane.

Taking a step back, a flight simulator can be viewed as an intricate, large scale educational video game. If pilots can learn from simulators, then it should be easy to see how other video games could teach those players different skills. Even though the learning is often hidden behind entertainment in the realm of commercial video games, there is still something to be said about what a player could learn from the experience of the game. Action video games, like those previously discussed, provide numerous opportunities for conflict and in most cases allow the player to choose or influence the outcome of particular situations. For example, in the game *Fallout 3*, one of the first missions is to defuse a nuclear bomb left behind in a town after a nuclear-winter type event. The player must make multiple decisions with regard to this mission, including whether they even want to defuse the bomb at all, and these decisions influence the rest of the gameplay. Thus, the player becomes a learner in that they are made to actively plan multiple steps ahead for multiple possible outcomes.

Strategic planning is not the only benefit however. Throughout games like *Fallout* and *Grand Theft Auto* in-game monies are used to purchase items. These items can be used to revive characters or improve abilities but each item does have its own associated cost. The player must determine what items to purchase and where to purchase the items as some shops may have discounts or may sell specialty items. In this case, the player must consider how the money is spent and where it is possible to get more if needed. Likewise, discounted shops may be based on percentages, such that a player may earn a 10% discount at shops of a particular type. This gives the player experience with percentages and decision-making skills based on budgeting, both skills that would be beneficial outside the video game.

Thus, Kolb's theory can be applied to the current study. As players are faced with the conflicts within the game, decisions are made. These decisions can influence the outcome of the game both positively and negatively and as players learn these outcomes they can make more informed decisions in the future. If these decisions are related in some way to mathematical concepts, such as ratios and percentages, then by proxy the player is learning these skills as well. For example, before the player can make a decision about a 10% or 15% discount, he must first know how this discount would influence the overall price. This is not to say that everyone who plays the game will obtain these skills, but those who play frequently and complete large portions of the game likely consider these skills necessary to being successful within the game.

Literature Review

Understanding how quantitative literacy and its components can be related video gameplay requires a review of past research relevant to these topics. To establish these connections, first the foundation will be set by explaining quantitative literacy as a construct and its relationship to other types of mathematical literacy, including statistical literacy. Once the connection between quantitative literacy and statistical literacy has been established, this review will look to connect mathematical concepts related to statistical literacy to the mathematical systems prevalent in today's commercial video games. This discussion will continue with an explanation of recent research into the effects of commercial and educational video gameplay on quantitative literacy and other similar mathematical constructs. Additionally, this review will investigate the motivation component of quantitative literacy and its relationship to other intrinsic characteristics. Finally, demographic factors related to quantitative literacy will be discussed.

Quantitative Literacy

Quantitative literacy is a multi-dimensional construct that has been investigated numerous times (Gal, 2002; Kaiser & Willander, 2005; Matteson, 2006; Ozgen, 2013; Stacey, 2012; Wilkins, 2000; Wilkins, 2004; Wilkins, 2010; Wilkins & Ma, 2003). Some studies have worked to identify the components of this construct and in general there is an agreement on at least three major components of quantitative literacy: cognition, which is related to a person's inherent mathematical capabilities; beliefs, or a person's understanding of how mathematics can be used beneficially in society; and disposition, or how readily a person is prepared to use mathematics in their day-to-day life (Wilkins, 2010). This is not to say that all studies are in exact alignment, but in general refer to the same structure of the construct. For instance, Gal (2002) describes components of statistical literacy that can be easily equated to those that Wilkins (2010) proposed; however, Gal (2002) looks at this construct as having two components (cognition and disposition) with the beliefs component being included within the disposition component. Although these two models are fundamentally different, the essence of what each model is trying to capture remains congruent: quantitative literacy is constructed from a person's mathematical knowledge and their attitude about and towards mathematics.

The research mentioned above shows a clear link between different types of mathematical literacy and their components. Gal (2002) established a model of statistical literacy and Wilkins (2010) built upon this concept to further understand the factors that play a role in a person's quantitative literacy. As can be seen, literacy in mathematics is fundamentally linked to the cognitive capabilities of a person as well as their attitudes toward the particular subject and its perceived uses. Thus, if there is a way to influence all or part of these factors, perhaps a person's quantitative literacy can be influenced as well.

Recently, some research has delved even further into these particular components. For example, according to model proposed by Wilkins (2010), each of the three components that make up quantitative literacy are themselves larger constructs of multiple factors. Using multiple large samples ($N > 1000$) and factor analysis procedures, Wilkins (2010) was first able to establish a model for quantitative literacy and then to confirm such a model with a different sample by comparing his three-level model to similar models consisting of just one or two levels. In order to examine this model, participants were given a mathematical assessment that covered numerous concepts as well as different levels of higher order thinking. Wilkins' (2010) research allows for both an understanding of the construct of quantitative literacy but it also provides at least one way in which the construct itself can be measured; particularly, using mathematical assessments to measure cognitive capabilities and survey assessments to measure the other components.

Methods such as these have been used in previous studies where quantitative literacy has been of particular interest. Kaiser and Willander (2005) use mathematical assessments to establish a conceptual framework related to the development of quantitative literacy over time. Performed on a sample from a German school system, the authors describe the process to becoming quantitatively literate by first beginning at an illiteracy stage and moving up multiple levels to reach a multidimensional literacy, one in which the person has a complete understanding of mathematics and its usefulness in everyday contexts (Kaiser & Willander, 2005). This multidimensional understanding of mathematics is directly related to the construct of quantitative literacy and could generally be considered one in the same.

Likewise, others have used survey designs and other similar methods to investigate the beliefs and disposition factors of quantitative literacy. Matthews, Hodgson, and Varsavsky (2013) used a self-report analysis to investigate the participant's views toward their own mathematical capabilities. The purpose of their study was to determine factors that may influence a high school senior's perceptions of their own abilities. The results showed that those who were exposed to quantitative tasks throughout their curriculum were more likely to report higher levels of confidence in their abilities when compared to those who did not have such experience (Matthews et. al, 2013). This research exemplifies the notion that exposure to mathematics over time can lead to a greater self-confidence in a person's abilities although some research show discrepancies between this connection. In a study by Ozgen (2013), a small sample of students from Turkey were asked about their level of self-efficacy as it relates to the understanding and using mathematics in daily situations. Though this study was limited by a small sample size (N = 40), the results showed that some students reported having issues with linking concepts from the math classroom to their utility in the real world (Ozgen, 2013).

Linking the real world to a mathematics classroom can provide a particularly interesting challenge, one which has been probed numerous times by researchers. Scherger (2013), Linder (2012), and Burdette and McLoughlin (2010) all used real-world data within the classroom to attempt to bolster quantitative literacy, both by improving cognitive outcomes as well as inherent motivation of students. Scherger (2013) provided paired classroom curricula with lab-based data analysis to allow students to experience mathematics and its relationship to the real world. Although the participants in this study did not necessarily show a stark improvement in their cognitive abilities, there was evidence to show that this type of course was beneficial in improving participant's attitudes toward mathematics and their understanding of the utility of the particular concepts. Similarly, Linder (2012) used data collected from exams as a way to make real-world data directly applicable to the participants. A regression analysis was performed on quiz scores in order to predict a test score and then participants were asked to consider why they performed above or below their predicted score (Linder, 2012). This allowed the participants to reflect on their scores, determine what they could have done differently, and establish a direct link between their quiz scores and their test score. Finally, Burdette and McLoughlin (2010) used an assignment related to census data as a treatment condition for a particular course. Those who took the experimental component of the course, which included the census assignment, were shown to improve their quantitative skills, especially as it relates to data interpretation. These studies show that when students are engaged with real world data that relevant connections can be made from the data to its context outside the classroom, allowing students to be able to revisit this understanding when similar situations are experienced in the future. This inference helps to display the link between Kolb's experiential learning theory and studies of this nature.

Other research has shown links between technology and mathematics performance. Frith et al. (2004) used a Microsoft Excel worksheet to help instruct students on basic statistical concepts and then tested the students later to determine how much information was retained. Results of the study showed those who participated in the computer exercise were able to answer questions more focused on literacy than mathematics (Frith et al., 2004). In general, those who took the tutorial were able to retain information longer, which was attributed by the authors to the possibility that the students were able to use an example of real data for practice as opposed to working math problems with no context (Frith et al., 2004). Likewise, Schreyer-Bennethum and Albright (2011) looked at the inclusion of technology-based projects in a mathematics classroom, hoping to determine if these types of projects would have a positive influence on the outcomes of students. Using a mixed-method design, which included quantitative assessments and student interviews, this study showed those who participated in the technology-based projects reported a higher understanding of the topics at hand and performed at a higher level than those who did not.

Mathematics and Video Games

The studies described above exemplify the positive influence of making mathematical and quantitative skills relevant to the participant, a trait that can be linked to the disposition component of quantitative literacy. Using real-world data links concepts that are taught in class to a means of actually utilizing those concepts on an everyday basis. By making the information more relevant to those involved, motivation and self-reflection are improved, thereby improving the non-cognitive components of quantitative literacy. Participants' dispositions seem to improve as they are more engaged with the mathematical task at hand. Thus, if there is a way to show that different methods can be used to make mathematics relevant to the learner, such as playing video games, then perhaps these too can enhance quantitative literacy.

Previous research has investigated the link between playing video games and other cognitive abilities. Collins and Freeman (2014) studied participants who were video game players, either occasional or habitual, versus non-video game players by testing their performance on a multitude of tasks. Participants were asked to complete tasks measuring enumeration, mental rotation, task switching and visual short-term memory and then completed a survey that focused on their video game play. Results showed little difference in terms of outcomes between those who played video games and those who did not, including those who played video games very often (Collins & Freeman, 2014). This lack of significant results may have been a product of the methodological design itself. For example, the sample size was minimal ($N = 66$) and split across three groups, allowing for only large effects to be detected. This would imply that if there were a direct effect on cognitive tasks due to playing video games then this effect may be relatively small and may require a larger sample size to detect. Similarly, Unsworth et al. (2015) used a two-experiment study to investigate the cognitive impacts of playing video games. Based on their results, it was shown that video game players did outperform their non-playing counterparts when some data were left out of the analysis, but these significant effects were minimized when all the data were included (Unsworth et al., 2015). The second component of this study looked to replicate the first; however, even with more accurate measurement methods, the results still showed little difference between those who play video games and those who do not. From these results it is possible to conclude that video games may not be extremely useful in improving direct cognitive capabilities; however, because the performance of video game players and non-game players were similar, this provides evidence that video games are also not detrimental overall.

In society, commercial video games sometimes receive a negative stigma related to their usefulness as a learning tool; however, research has shown that negative effects related to video game play are somewhat nonexistent. Drummond and Sauer (2014) used a large-scale data set to compare the academic performance of students based on self-reported frequency of gameplay. Using an ordinal scale to measure gameplay from never to almost every day, the data show that those who reported frequent video game playing did not have negative impacts related to academic performance (Drummond & Sauer, 2014). This research contradicts the poor representation of video games as learning tools, but it also shows that those who play video games do not overperform compared to those who do not play regularly.

Video Games and Motivation

Additionally, some studies have shown video games to have positive impacts on the player, even if the impacts are not highly tangible. For example, Kuhn et al. (2014) conducted an experiment where participants were to play a *Super Mario* game for at least 30 minutes a day for two months and found that the gameplay led to an increase in the gray matter in the brain. The presence of this material in the brain is commonly associated with abilities like spatial navigation, planning, working memory, and motor performance. Thus, playing video games has a direct physiological impact on the player, one that may lead to improved abilities. Moreover, Ranalli and Ritzko (2013) used a popular game that allows the player to create and test fictional space vehicles to investigate the impact of playing the game on students in a first-year engineering course. Results of Ranalli and Ritzko's (2013) study do not show that those who played the game outperformed their counterparts but it does show that these students were more engaged with assignments, thus influencing the non-cognitive components of quantitative literacy. Beserra et al. (2014) also showed that there was little difference between those who played educational games as part of a classroom assignment and those who did not, but the difference existed again in terms of the motivation and engagement of the student. Finally, Hoffman and Nadelson (2010) investigated those motivational factors associated with video games to attempt to determine the reasons behind the increase in motivation. Hoffman and Nadelson found that most who played video games did so as a way of releasing stress, but also as a way to socialize with their peers. This information, if visualized through a classroom context, could at least partially explain why video games tend to positively influence the motivation of those who play.

If video games are sufficiently fun and entertaining then perhaps a motivated player may learn more than what they expect or realize at the time of the game. Abrams (2009) was able to exemplify this by interviewing young men who played games based on World War II, such as *Medal of Honor* and *Battlefield:1942.* The young men in Abrams (2009) study reported a dislike for schoolwork but were able to provide information about World War II from their gameplay, as well as an improvement in their vocabulary. In some cases, the gains occurred without their knowledge and were a result of the situations they were exposed to in the video game. Likewise, in a similar study, Gerber et al. (2014) found that students were able to understand English concepts, like plot and conflict, by being asked to design a video game. In addition to the positive aspects of video game play, this shows that video games can directly influence particular abstractions of a certain subject even though these subjects may or may not be related to the video game itself.

In general, most research into video games and its influences on the player is relatively new and its findings may be seen as constantly changing as new gaming systems and games are introduced. In 2015 alone, hundreds of new video games were released for use on personal computers, gaming consoles (Microsoft Xbox One, Playstation PS4, Nintendo WiiU), and portable devices, such as tablets and cell phones. In addition, the top ten best-selling games in the United States for 2015 include multiple action video games, displaying the immense popularity of these types of games (Grubb, 2016). On that list are games like *Call of Duty: Black Ops III,* a military-based first-person shooter; *Fallout 4,* another FPS combined with a trek through a post-apocalyptic U. S. East coast; and *Grand Theft Auto V,* a third-person shooter known for its disturbing plot lines, including the main character's involvement in organized crime. Though these games are all starkly different in the manner of gameplay, character development, and plot lines, a similarity does exist when the mathematical systems present in these games are considered. For example, in a game like *Fallout 4,* players receive "perks" based on completion of particular challenges or missions. These perks provide bonuses to the player, most often displayed in some form of percentage increase or decrease to a characters attributes. Likewise, these games also include buying and selling systems that allow the player to choose how to spend money earned within the game. It is these types of mathematical systems that are of interest to this study as they expose the player to experience with percentages, ratios, and making monetary decisions, which may have a positive effect on the player beyond the game setting.

Research into quantitative literacy has been shown to be constructed of multiple components, including not only the actual cognitive knowledge of the person but also that person's beliefs and dispositions toward mathematics (Wilkins, 2010; Gal, 2002). Because beliefs and dispositions outline a person's attitude toward mathematics, it can be seen as inherently related to a person's motivations. Those who believe that mathematics is useful and are self-confident in their abilities will likely be more motivated to solving a problem as opposed to those who are less confident or those who believe that mathematics is not a useful skill. Research has been done to determine appropriate measures of these constructs. Tapia (1996) developed an instrument to measure the attitudes of participants with regards to mathematics. In this study, Tapia (1996) completed a factor analysis, determining that attitudes toward mathematics could be explained as a four-part construct including self-confidence, value, enjoyment, and motivation. Known as the *Attitudes Toward Mathematics Inventory* (ATMI), the survey designed by Tapia (1996) shows a reliability of $\alpha = 0.9667$ and construct validity as determined by experienced mathematics teachers and the factor analysis results. Thus, this study shows that it is possible to measure the non-cognitive aspects of quantitative literacy as a separate construct.

Demographic Considerations

Demographic factors must also be considered when discussing quantitative literacy. Research has shown a difference in the cognitive mathematical performance of males and females on some assessment measures, with males generally outperforming females in most countries (Guiso, Monte, Sapienza, & Zingales, 2008). However, based on a grade-level analysis of state-certified mathematics exams, some research shows that there is little difference between the performance of males and females (Hyde, Lindberg, Linn, Ellis & Williams, 2008; Catsambis, 1994). Because of mixed results such as these, it is important that gender at least be considered when investigating mathematics ability.

Summary

Mathematical assessments have been used to test different components of quantitative literacy as well as to determine how some methods, such as the use of real-world data in the classroom, can influence particular components of quantitative literacy (Kaiser & Willander, 2005; Matthews et al., 2013; Ozgen, 2013; Scherger, 2013; Linder, 2012; Burdette & McLoughlin, 2010). Still other research has shown the influences of video games, including their direct influence on the brain (Kuhn et al., 2014), their influence on learning and motivation (Ranalli & Ritzko, 2013; Beserra et al, 2014), and their influence on cognitive abilities (Collins & Freeman, 2014; Unsworth et al., 2015). The research discussed here exemplifies a link between video games and learning but there are gaps still present in the research.

Though there has been research into the improvement of quantitative literacy, there are very few studies, if any, that investigate a link between quantitative literacy and video gameplay. In particular, no study has attempted to measure the influence of video gameplay on particular mathematical concepts and abstractions present in the video games, such as percentages or ratios. Similarly, the few studies that have investigated the link between cognitive abilities and video games have used very basic measures of game-play (Collins & Freeman, 2014; Drummond & Sauer, 2014; Gerber et al., 2014) or have used a particular game as a part of the investigation (Beserra et al., 2014; Carr, 2012; Frith et al., 2004). Likewise, few studies have looked at the relationship between video game play and attitudes toward mathematics. Thus, there is a need for research into how mathematical capabilities can be influenced by gameplay and whether different types of games have a different influence, or lack thereof, on the player. Particularly, this research aims to investigate the relationship between playing action video games and a person's ability to answer questions about percentages, ratios, rates, real number addition, reading charts and graphs, and a person's motivations toward mathematical situations.

CHAPTER III - METHOD

Participants

The participants for this study were selected from college-attending adults in the United States. The sample was chosen based on convenience and proximity to the researcher. Participants were recruited from both university and community college students with a focus on those from public institutions with higher enrollment. Additional participants were recruited through an online service, Amazon Mechanical Turk, which provides access to adults around the country. Public institutions were included in the research because of the ease of access to the researcher and although private institutions have shown slightly higher graduation rates (Scott, Bailey, & Kienzl, 2006) there is little evidence to support there is any effect on employability (Pascarella & Terenzini, 2005) and thus there should be little difference due to the type of institution. Likewise, larger institutions and online services were used in order to be able to target more potential participants by approaching fewer institutions.

After receiving the necessary permissions, students were contacted via email or other online sources such as learning management systems (Canvas, Blackboard, etc.), college message boards, and the Amazon system. Potential participants were provided with a brief description of the research as well as a link to the online questionnaire. With this information, those contacted were able to determine if they wished to participate in the research.

Undergraduate students, particularly first and second year students, were targeted for the research, but any college-age adults were ultimately contained in the sample. Having only attended college for a brief time, undergraduate students likely have not completed their mathematics requirements and/or have not taken any advanced mathematics courses. The research did not exclude participants who have been attending college for more than two years or had finished college, so long as they met all the participation criteria, but they were not heavily targeted by the researcher. With this in mind, the researcher contacted those who teach primarily undergraduate courses, such as English composition or history, to assist in distributing the questionnaire to a greater number of students.

Participants self-selected into the study; however, exclusion criteria were considered during the sampling process. First, participants who have completed upper-level math courses such as calculus or statistics were excluded from the study. This criterion attempted to "level the playing field" so that recent or advanced instruction did not directly influence the participants' capabilities. Second, participants who majored in natural sciences, which tend to have intensive mathematical curricula, were excluded from the study. Here the intent was to protect against selection bias and to avoid those who naturally scored higher on a mathematics exam. Overall, the intent was to collect a sample that consisted of participants with similar mathematics backgrounds while differing on levels of video gameplay.

One primary reason college students were recruited for the study is because they are of the appropriate age to have a larger proportion of video game players compared to other demographic groups. According to the Entertainment Software Association (ESA) (2015), 56% of video game players are under the age of 35, with the greatest number falling between the ages of 18 and 35 (30%). Because college students were included in the sample, alternative explanations related to the differences in college-educated participants versus high school-educated participants were minimized.

Variables

According to Wilkins (2010) and Gal (2002), mathematical literacy consists of multiple components including cognition, disposition, and beliefs. These dependent variables were measured as two components in this study. First, the cognitive component of mathematical literacy was measured by means of a 17-item multiple-choice mathematics exam. These items were chosen from a 25-item test based on the results of a pilot test. Particular details about this exam are provided in the next section. Second, the motivation component, consisting of the disposition and belief constructs associated with quantitative literacy, was measured using the *Attitudes Toward Mathematics Inventory* (ATMI) survey mentioned above (Tapia, 1996). The survey consists of 40 Likert-scale questions that were combined to generate a scaled score related to positive or negative dispositions and feelings toward mathematics, primarily the participant’s self-confidence related to mathematics, the perceived value of mathematics, the participant’s enjoyment of mathematics, and the motivation of the participant to experience mathematical situations. This survey is discussed further in the next section.

Independent variables in the study included a measure of video gameplay as well as demographic information. Previous studies have measured video gameplay (Collins & Freeman, 2014; Drummond & Sauer, 2014; Gerber et al., 2014) but generally focus on whether the participant played video games or how much time was spent playing one particular game. Previous research has not investigated further into the type of video games played by the participants. This study built upon previous studies by providing the participant with the opportunity to supply information about video games played as well as the types and frequencies of games played. This allowed for a greater understanding of which games may influence mathematical literacy and whether frequency of video game play has a role in mathematical literacy.

Instrument

As the goal of this study was to investigate mathematical literacy with respect to video games through survey research, the primary instrument used for this study included multiple components. First, the instrument contains 17 multiple-choice mathematics questions related to the most common mathematical abstractions present in video games. These abstractions included percentages, ratios, rates, real number addition, and reading charts and graphs. In order to measure these abstractions, questions were directed toward the everyday uses of mathematics. Examples included "Sales of frozen pizza for a club fundraiser increased from 500 one year to 695 the next year. What was the percent of increase?" which measured an understanding of percentages and “A cookie recipe calls for 1/3 of a cup of sugar and makes 1 dozen cookies. How many dozen cookies can you make if you have 7 cups of sugar and want to use it all?” which measured an understanding of ratios. Questions on the instrument increased in difficulty and were divided into sections based on the abstraction that is being measured. The items were not evenly separated between each of the five abstractions, but instead varied between three and four items for each. The mathematics portion of the questionnaire is provided in Appendix A.

Mathematical items were selected from a test bank for a current math literacy textbook, *Math Lit: A Pathway to College Mathematics* (Almy & Foes, 2017).

Participants were given four answer choices for each of the items. In order to protect against threats to validity that might have occurred by participants guessing, the mathematics portion of the survey was timed. Time spent on the questionnaire was assessed as a way to weed out invalid responses, as questionnaires completed too quickly would likely imply the participant did not properly respond to the survey. It was expected that each question take at least 30 seconds to read and respond, thus any response times that fell below this threshold were eliminated from the analysis.

Additionally, in order to maintain that participants properly completed the questionnaire, a series of attention filters were included within the mathematics portion of the questionnaire to make sure that participants did not "click-through" the survey too quickly. These items directed the participant to choose a particular response. If these responses were not chosen throughout the survey then the participant's data was removed from the analysis. An example of this type of item included "Please select the response 'Goodbye'" with four options provided to the participants. Only participants who correctly respond to all attention filters were considered valid.

In order to measure the dispositions, beliefs, and motivations components of mathematical literacy the participants were given the *ATMI* survey (Tapia, 1996). This questionnaire included 40 five-point Likert-scale questions and measured a range of factors related to mathematical literacy, including self-confidence, value, motivation, and enjoyment. This instrument was chosen because it has been shown to be effective in previous research (Tapia & Marsh, 2004; Primi, Busdraghi, Tomasetto, Morsanyi & Chiesi, 2014) and it covered information relevant to the understanding of a person's beliefs or dispositions toward mathematics. For example, items such as "Mathematics is a very worthwhile and necessary subject" show a person's beliefs about the subject while items such as "I learn mathematics easily" exemplifies a person's disposition toward their mathematical abilities.

The *ATMI* portion of the instrument was divided into four categories based on the original research done by Tapia (1996). The 40 items are not divided evenly among the subcategories: self-confidence (15 items), value (10 items), enjoyment (10 items), and motivation (5 items). The online questionnaire was sorted into four blocks, one for each of the subcategories. Each of the subcategories contains at least one reverse item, which can help to serve as attention filters for these particular items.

Finally, information about the video games played by the participants was investigated. Previous research has measured video gameplay in terms of the type of game or the amount of time spent playing video games, but often there is not enough information gleaned about the particular games that the participants played (Beserra et al., 2014; Carr, 2012; Frith et al., 2004). To counteract this effectively, participants in this study reported which games were played, how often, and for how long. The goal of this portion of the instrument was to determine if particular games or particular styles of games provided more support to mathematical literacy than others.

Within the instrument, the participant was asked about the type of video game systems owned (*Xbox, Playstation, Nintendo*) as well as the types of games that the participant usually played (*puzzle games, role-playing games, first- or third- person shooters, racing games, fighting games, or none*). In addition, the participant was provided with a list of popular and/or common video games from recent years (2015 – 2016). The list of video games was compiled from multiple web articles about popular video games of the time (Martin, 2016; Verge Staff, 2015) and were edited based on a pilot test. Participants selected which games they played and were also given the option to choose that they did not play video games or that the games they played were not listed. By allowing the last two options, those who did not play video games were known and if the game was not listed then there was an "other" option in case the participant had never played the games mentioned but still played video games.

For each of the games that the participants chose from the list, they were provided a separate set of questions pertaining specifically to that game. First, participants were asked if they own that particular game (yes/no). Second, they were asked to report how many days per week they play the game with options ranging from 0 to 7. Finally, they were asked to report how many hours per day they play that particular game. The available responses for this final item are broken down into three-hour blocks (Less than 3 hours, More than 3 hours but less than 6 hours, More than 6 hours but less than 9 hours, and More than 9 hours). The reason for this decision was two-fold. First, if the participant were asked to provide an exact value related to the hours played per week there would likely be miscalculations or blank responses. Second, this type of ordinal measure was scaled with questions of a similar type and provided a measurement of the amount of hours played per day or week. A discussion of this measurement is provided in a later section.

By providing the additional option "The video games I play are not listed," those who do not play games on the list were afforded the opportunity to answer questions about the frequency of gameplay, including the number of days per week and the number of hours per day. Those participants were given the option to generate a list of video games that they did play. Based on the list provided by the participant, it was still be possible to determine the measures needed for analysis.

The final component of the instrument contained demographic and background information about the participants. This information included common demographics (gender and age) but also inquired about the mathematical history of the participants. Age was included as a demographic factor for use in data analysis to compare younger and older video game players. In terms of gender, research into math achievement has shown mixed results. Guiso et al. (2008) has shown males generally outperforming females, Hyde et al. (2008) and Catsambis (1994) have shown little difference between males and females, and a metanalysis of achievement by Voyer and Voyer (2008) has shown conflicting results across numerous studies. While considering that the ESA (2015) reports that 44% of video game players are female, it was important to include this measure for data analysis purposes.

As well as age and gender, participants were asked about their recent mathematical background, particularly whether they have taken courses related to calculus, linear algebra, differential equations, or statistics. These choices were intentional, as those who have taken these courses were likely advanced in their mathematical ability and thus were excluded from the study. Participants were also asked to provide their current academic major (Liberal Arts, Business, Education and Psychology, Health and Nursing, and Natural Sciences). Those who selected Natural Sciences were excluded due to those participants likely having an intense mathematical background.

Specifically, the goal of the demographic portion was to group participants based on experience and knowledge level. For example, it would not have made sense to compare the mathematical abilities of someone who had taken calculus courses to those who had taken only algebra courses, regardless of whether either was an avid video game player. Thus, this portion of the instrument was used to mitigate threats to validity related to the history of the participant and provided information required for exclusion criteria. The demographic portion of the questionnaire appeared first in the web-based survey, saving those who were excluded from having to respond to the entire survey.

Design

This study employed a nonexperimental one-group posttest-only design in order to investigate a correlational relationship between mathematical literacy and playing video games (Shadish, Cook, and Campbell, 2002). This design included a treatment condition and then a posttest of the participants. In the case of this study, the treatment condition was operationalized as the act of the participant playing video games. The participants reported their level of treatment within the questionnaire and that was taken into consideration when the data from the posttest is analyzed. Similarly, the questionnaire represented two simultaneous posttests, one testing mathematical abilities and the other beliefs, dispositions, and motivations. Though Shadish, Cook, and Campbell (2002) report that this type of design is not generally effective at drawing inferences without a pretest and thus may introduce history threats to validity, other designs were rejected for the reasons listed below. Instead, efforts were made to account for the history of the participants before they are subjected to the posttest.

Other experimental and quasi-experimental designs were rejected for this study due to possible threats to validity. In an experimental design, participants would be exposed to a treatment, such as playing a particular video game for a given amount of time each week. Tests could be given at multiple time points within this study in order to determine the effect of playing the game on the person's mathematical abilities; however, by using this design or others that contain similar treatment conditions, there are direct implications to the goals of the study. First, choosing a game that participants will play would introduce an added level of control, one that would account for the possibility that some participants would be familiar with the game and some would not. Mathematical gains could be hidden if the participant is spending a portion of time actually familiarizing themselves with the game. Similarly, an experimental design would severely impair the available sample size, perhaps masking a small correlational effect. By using a posttest-only design, information was collected from all participants independent of the type of game played.

Another reason for using a posttest-only design is that during an experiment participants may have changes in exclusion factors, such as being required to take a mathematics course at some point within the study, or they could have other issues arise that could lead to attrition from the study, thus biasing the results. By collecting information at a single point in time these problems were minimized, allowing for a greater investigation into the correlational nature of video game play and mathematical literacy.

Furthermore, due to the posttest-only design, this research is unlikely to produce any truly generalizable results. The research study will inform future studies so that research could be more directed toward a particular type of game or a particular amount of gameplay time each week. For example, if it were found that those participants who enjoyed role-playing games also reported a higher level of self-confidence in mathematics then perhaps future research could focus on these two particular aspects. Thus, this study will provide foundations for future research.

Procedure

Pilot Test

Before the research began, a pilot test was performed using a sample of 28 participants who were not included in the final sample. This was to determine if there were any underlying issues with the questionnaire and to determine if the questionnaire served as an accurate measurement of the variables mentioned above. It was possible that issues could arise with those measurements, such as games included in the questionnaire that were not well known or underplayed, the means of measuring the time of gameplay were not accurate enough to determine enough variation, or the mathematics questions were too easy or too hard for participants to solve. Thus, a pilot test provided information on whether the questionnaire was effective in measuring the variables of interest. The pilot test also provided the researcher access to a small amount of data to complete an initial analysis to determine if there are any variables missing or confounding in the research.

Changes were made to the overall survey based on the results of the pilot test. First, it was determined that the initial number of 25 items on the cognitive portion of the questionnaire took too long to complete and some were much more difficult than others. Thus, the number of items was reduced to 17 and some of the more difficult items were removed. Likewise, the list of video games initially provided did not include some popular games that were reported as “other” on many of the pilot test responses and included some games that were not chosen by any of those in the pilot test. Thus, the list of video games was edited to adjust for these changes.

Data Collection

After the pilot test was successfully completed and the Institutional Review Boards at all of the participating institutions were successfully petitioned, a link to the questionnaire was distributed to the institutions and passed along to students. Each questionnaire began with an informed consent declaration that outlined not only the purpose of the study but the exclusion criteria that were imposed so that participants who did not meet the criteria did not attempt to take part in the study. Questionnaires were generated and distributed using the online survey software Qualtrics. This program allowed for combining the multiple styles of the questionnaire (numerical answers, Likert-scale questions, attention filters, etc.) into a single survey accessible through a link that was emailed. Data collection continued for five months through collegiate institutions. Because there was only a small sample that was collected at that point, the survey was distributed to the Amazon Mechanical Turk and a much larger sample was collected. This sample was reduced based on the exclusion criteria. At that point, the survey link was closed and data analysis began.

Analytic Approach

Confirmatory Factor Analysis and Path Analysis

A confirmatory factor analysis (CFA) was used on the subscales of the *ATMI* to determine if these constructs were accurately represented by the items provided in the questionnaire. The initial model for the CFA was based on the four constructs modeled by Tapia (1996). The factor loadings for each of the items were determined and the model was checked for goodness of fit. Other models including differing numbers of constructs were tested to establish that the four-construct model was appropriate.

After the CFA, a path analysis was used to investigate the relationships between video gameplay and the five dependent variables, including the cognitive abilities measured by the mathematics items and the latent variables of self-confidence, enjoyment, value and motivation measured by the *ATMI.* To investigate the question of whether a person's level of video gameplay had an influence on the cognitive or motivational aspects of quantitative literacy, individual paths between those components were analyzed. Additionally, because of previous research that had shown a connection between the motivational aspects measured in the *ATMI* and quantitative literacy (Wilkins, 2010), paths were included between the *ATMI* latent variables and the cognitive abilities measured. The fit characteristics of the structural model were determined to look for any significant paths or correlations within the model. A diagram of the initial path analysis is provided in Figure 1.

Demographic Considerations

A second model was analyzed which included demographic characteristics such as age, gender, and college major to determine if there were any statistically significant predictors of either cognitive ability or the characteristics measured in the *ATMI*. As shown in research by the Entertainment Software Association (2015), not all persons of every age play video games equally. Likewise, Abrams (2009) and Ranalli and Ritzko (2013) showed that age may play a factor in motivation. Additionally, age may also influence the level of a person's mathematical understanding based on their past experiences. Thus, paths for this model were included from the demographic factor of age to the other three factors measured in the study.

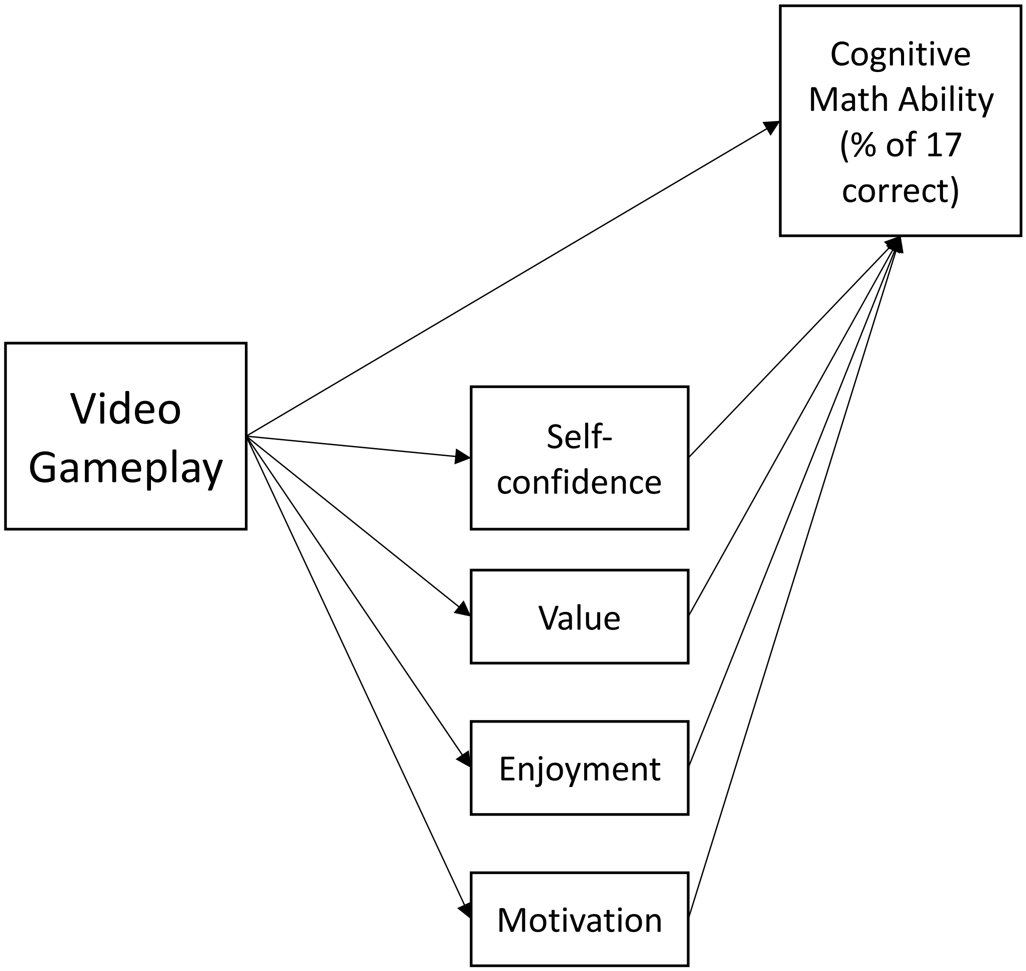


Figure 1. Path Analysis Diagram (Model 1)

Gender was also included in this model, introducing additional paths in the analysis. Research has shown mixed results in mathematical ability based on this variable (Catsambis, 1994; Guiso et al., 2008; Hyde et al., 2008); however, there is little difference between males and females in terms of playing video games (ESA, 2015). This introduced paths from gender to each of the dependent variables of cognition and *ATMI* characteristics measured in the research.

Finally, college major was included as a predictor of both *ATMI* characteristics and cognition as well. This is because students of different majors will experience different uses for mathematics and will have different experiences with mathematics, possibly influencing both of these measured characteristics. This type of detailed analysis provided additional insight into the nature of learning mathematics from playing video games. The second path analysis structure including these demographics is provided in Figure 2.

Operationalized Variables

Cognition was operationalized as the percentage of correct answers (out of 17) on the mathematics exam component of the instrument. Motivation and the other components were operationalized as the scale scores of the different components of the *ATMI* assessment. Video game play and other independent variables such as gender were included in the path analysis as predictor variables.

In order to account for video game play as an independent variable, a score was assigned to each participant based on the number of games played and the reported time of play each week. For each game selected, the number of days per week was multiplied by the number of hours per day. The sum of these values then represented the number of hours a participant played video games per week.

For example, assume that a participant chose three games from the list. The participant reported playing the first game one day per week for less than three hours, the second game three days per week for between three hours and six hours, and the third

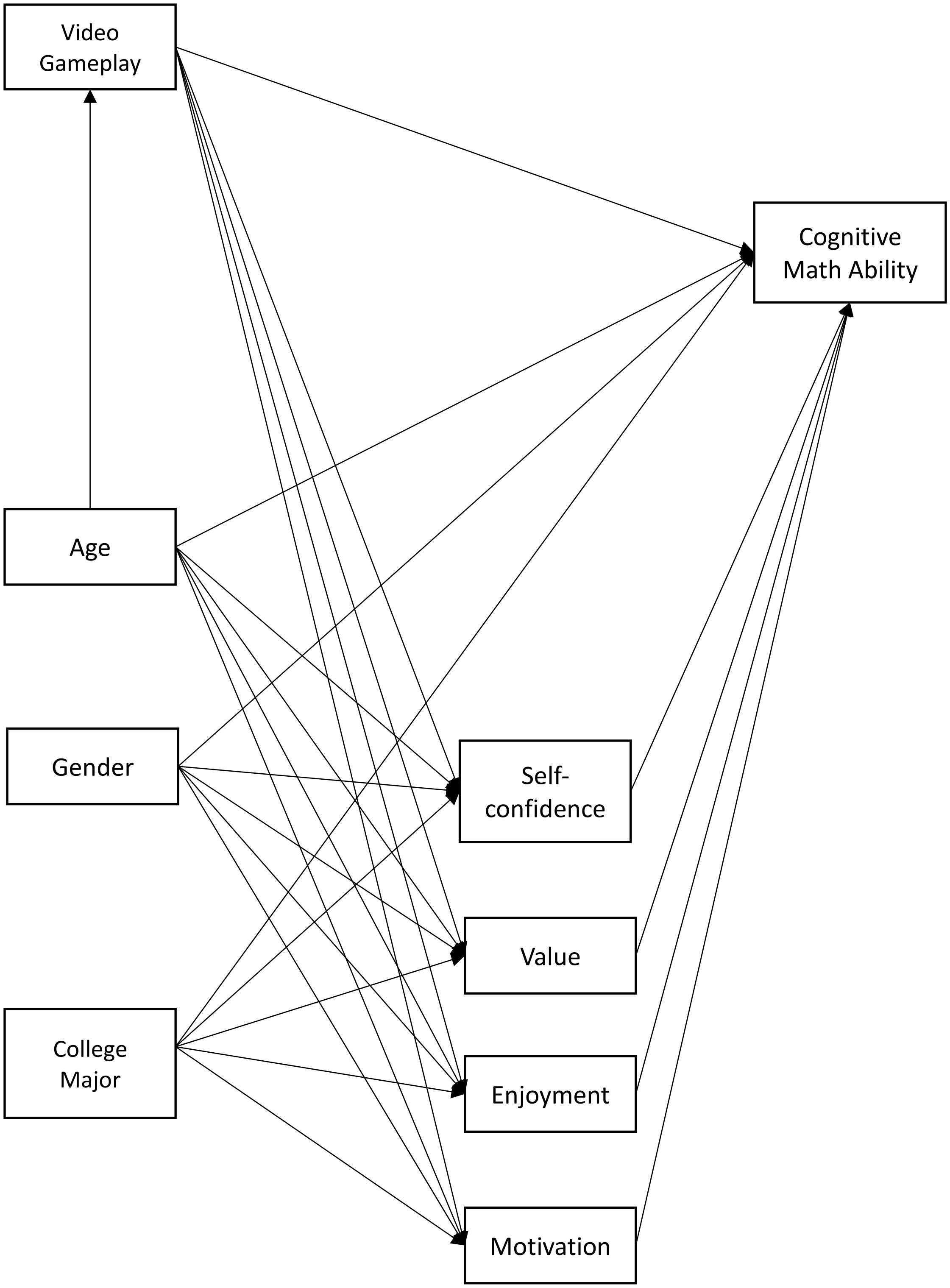


Figure 2. Path Analysis Diagram (Model 2 – Demographic Characteristics)

game two days per week for more than nine hours. Assuming that the actual number of hours played each day can be expressed as the median of the level reported (less than three hours ≈ 1.5 hours; between three and six hours ≈ 4.5 hours; between six and nine hours ≈ 7.5 hours; more than 9 hours ≈ 10.5 hours) then the number of hours of video game play per week for this hypothetical participant was calculated as the sum of the reported values for all three games.

$$1(1.5) + 3(4.5) + 2(10.5) = 36 \text{ hours per week}$$

Thus, the hypothetical student had a video gameplay value of 36 hours per week, or approximately 5.14 hours every day. This example can be taken further if the type of video game is considered, (role-playing, first- or third- person shooter, etc.), by breaking down the same calculation into different subcategories.

For those who chose that the games played were not listed, a slight variation was performed. When asked what games they did play, participants generated a list. The number of games in the list were counted (up to 5) and then this value was considered with the number of days per week and the number of hours per day that were reported. In this way, the same video gameplay value can be determined through direct multiplication. Assume that a participant listed four games not on the initial list, and reported that those games are played two days per week for between three and six hours. This hypothetical participant would have had a video gameplay value of 4(2)(4.5) = 36 hours per week. Likewise, this method was combined with those from the list if the participant reported both. If instead the participant provided that he did not play video games, then the value was set to zero. This method of calculation based on the responses provided a more in-depth measurement of video gameplay than any previous studies by generating a nearly continuous variable that was included as a predictive factor.

Scholarly Significance

Research into video games has shown that playing video games can have differential impacts on participants. The goal of this study was to further investigate these relationships to determine if the type of game or the level of gameplay played a significant role in the mathematical abilities of the player. Increasing the knowledge base in this regard could have impacts on college students, educators, commercial video game developers, and society at large.

Students could likely see immediate benefit from the results of this study. If it were found that certain types of games or time playing video games was beneficial to mathematical literacy, even if only the motivation factor, then this information could be used to consider what types of games that students chose to play and perhaps may they may choose games that will directly impact their mathematical understanding in the future.

Likewise, educators of students of all ages may find that video games are a useful tool both in and out of the classroom. If the results of this study were to show a benefit to a particular style of game or certain amount of gameplay then educators could likely use this information as a way to plan future lessons. By allowing students to play video games as a part of a curriculum, students will likely be more engaged and motivated and in turn may show better academic progress.

For video game developers the outcomes could have a very different impact. If the results show that video games do assist with mathematical literacy, then developers of games could use this information as they develop new games, perhaps building upon current games to make them more effective in this purpose. Video game developers could also use the information in terms of marketing, having research to show the positive effects of playing their game.

Finally, society could benefit by learning more about how video games influence the lives of those who play them. Often a negative stigma surrounds video game players (Ferguson et al., 2013), however showing that these games have positive influences on the players would work to combat this idea. Thus, it can be understood that investigating video games with respect to mathematical literacy could likely have a positive influence overall.

CHAPTER IV – RESULTS

The following chapter discusses the collection of data and the analyses completed with respect to the planned analysis discussed above. First, a brief section describes how the sample was collected as well as the descriptive statistics related to the collected data. This is followed by the confirmatory factor analysis used to model the latent variables in the *ATMI*. Finally, the path analysis results for each potential model are reported.

Sample Collection and Descriptive Statistics

Using the procedure described above, over a thousand questionnaires were collected from potential participants (N = 1102). Multiple screening measures were used to reduce the data. First, questionnaires that were not completed were removed, followed by questionnaires from participants who had taken advanced mathematics courses or majored in natural science subjects in college. Next, the screening questions within the survey were used to remove data for those who were not properly completing the questionnaire. After all of these participants who did not pass the screening criteria had been removed, the number of remaining cases was much less (N = 255).

The sample collected was nearly split equally between genders with slightly more males (50.6%) completing the survey compared to females (49.4%). The primary age range were participants between the ages of 25 to 31 (32.2%), followed by those aged 18 to 24 (21.6%) and those aged 32 to 38 (20.8%). Participants older than 46 (16.1%) and those aged 39 to 45 (9.4%) were the least represented groups. Participants who reported an academic major as "Other" (37.6%) were by far the largest group represented, followed by business (22.0%), liberal arts (21.6%), education and psychology (10.2%), and health and nursing (8.6%).

The data were used to calculate the necessary variables: a cognitive mathematics score was determined based on the percentage of items correct out of the total 17 items and a gameplay score was generated based on the number of games played and the amount of time played each week. In terms of the variables calculated from the data, the cognitive math scores ranged from 6% to 100% (M = 60.92%, SD = 24.08%). The gameplay scores were determined based on the number of hours of gameplay each week (M = 33.95, SD = 59.44). A Pearson correlation test between these two values showed a statistically significant weak correlation between these two variables (r = -0.157, $p <$ 0.05). In addition to the latent variables determined by the *ATMI* survey, these variables were used as major components of the path analysis.

Confirmatory Factor Analysis

Before a path analysis was completed, a confirmatory factor analysis was performed on the items from the *ATMI*. Multiple items from the survey were reverse coded so that a higher value related to a higher level of self-confidence, value, enjoyment, or motivation. These items were then analyzed based on an assumed four-factor model: self-confidence (15 items), value (10 items), enjoyment (10 items), and motivation (5 items). The initial model fit was poor ($\chi^2(734, N = 255)$ = 3007.03, $p <$ 0.01, CFI = 0.766, $RMSEA$ = 0.110 [90% CI = 0.106, 0.115]).

In order to improve the fit, the modification indices were used to first determine if there were any error terms that could be correlated between item indicators of each of the latent variables. Based on the modification indices, many of the items associated with self-confidence seemed to have error terms that could warrant being correlated. These items included statements such as “I have a lot of self-confidence when it comes to mathematics,” “Mathematics does not scare me at all,” “I am able to solve mathematics problems without too much difficulty,” “I expect to do fairly well in any math class I take,” “I learn mathematics easily,” and “I believe I am good at solving math problems.” Likewise, two of the items representing enjoyment also seemed to be correlated with each other, including statements such as “I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math” and “I am comfortable answering questions in math class.” When this adjustment to the model was tested, the fit improved but was still not adequate (($\chi^2(721)$ = 2296.24, p < 0.01, *CFI* = 0.838, *RMSEA* = 0.093 [90% CI = 0.088, 0.097]). However, a chi-square difference test showed that the model that included the correlations between error terms was a better fit to the data than the model without those correlations ($\Delta\chi^2_{diff}(13)$ = 710.79, p < 0.001).

Correlations between some items generally implies that the items are measuring the same construct so those indicators with correlating error terms were reduced down to a single item. Only the item that stated “I have a lot of self-confidence when it comes to mathematics” was retained along with the other nine indicators for self-confidence that did not have correlating error terms. This indicator was used because of its direct relationship to the latent variable of interest. For the enjoyment variable, the “I am comfortable answering questions in math class” was retained with the other eight indicators of enjoyment because it was a less complex indicator. These adjustments also improved the fit of the model but was still not adequate ($\chi^2(521)$ = 1621.21, p < 0.01, *CFI* = 0.859, *RMSEA* = 0.091 [90% CI = 0.086, 0.096]). Finally, based on the standardized estimates, the indicators with loadings less than or equal to 0.50 on each of the latent variables were removed. This led to the removal of one indicator on the motivation variable, “I would like to avoid using mathematics in college” and an additional indicator on the enjoyment variable “Mathematics is dull and boring.” The final model included ten indicators for self-confidence, ten indicators for value, eight indicators for enjoyment, and four indicators for motivation. The final revised model had acceptable fit ($\chi^2(458) = 1224.49$, $p < 0.01$, *CFI* = 0.895, *RMSEA* = 0.081 [90% CI = 0.076, 0.087]) (Schreiber, Nora, Stage, Barlow, & King, 2006). The items and their respective factor loadings onto each of the latent variables are given in Table 1 through Table 4. Additionally, the reliabilities of each scale are given in Table 5 and the confirmatory factor analysis diagram is given in Figure 3.

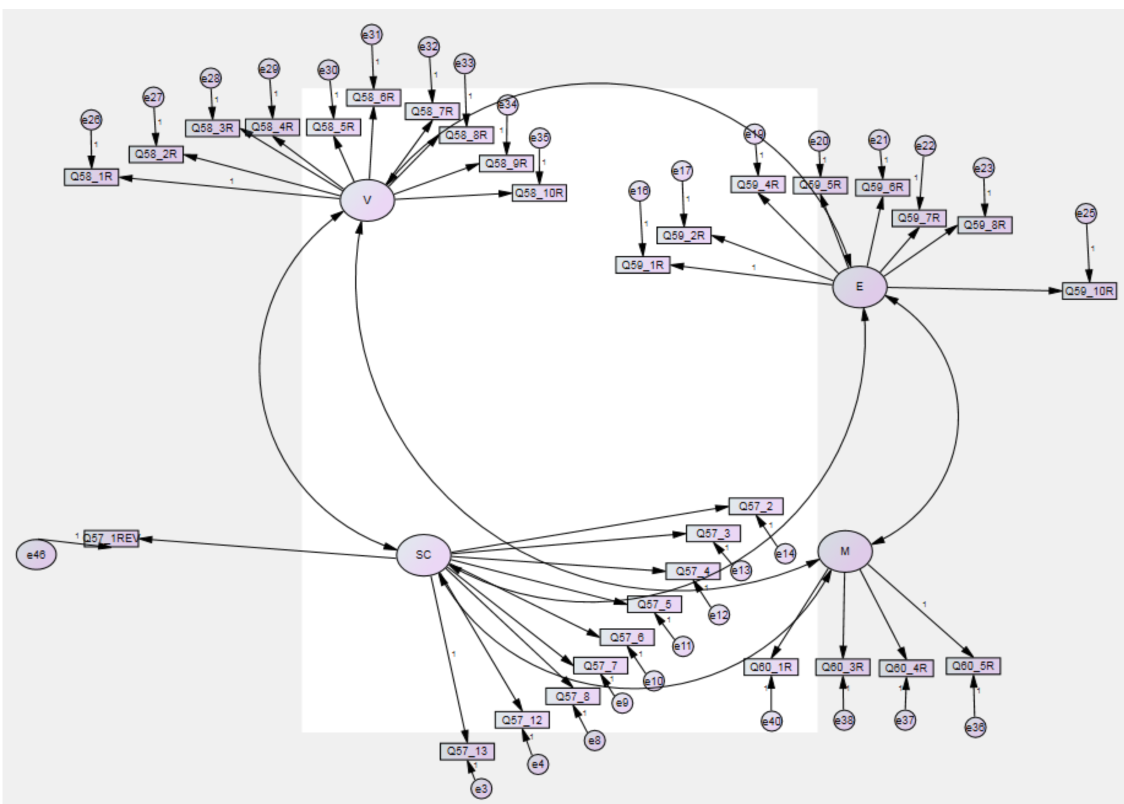


Figure 3. Confirmatory Factor Analysis Final Model

Tables 1 through 4 present the factor loadings of the indicator items onto the latent variable factors. As can be seen from the tables, all of the indictors used for each of the latent variables (self-confidence – 10 items, value – 10 items, enjoyment – 8 items, motivation – 4 items) have factors loadings greater than 0.5 and all are statistically significant ($p < 0.001$).

Table 1

Standardized Loadings for CFA Model (Self-confidence)

Item	Loading
I have a lot of self-confidence when it comes to mathematics.	0.555***
Mathematics is one of my most dreaded subjects.	0.816***
My mind goes blank and I am unable to think clearly when working with mathematics.	0.847***
Studying mathematics makes me feel nervous.	0.872***
Mathematics makes me feel uncomfortable.	0.903***
I am always under a terrible strain in math class.	0.904***
When I hear the word mathematics, I have a feeling of dislike.	0.866***
It makes me nervous to even think about having to a do a mathematics problem.	0.878***
I am always confused in my mathematics class.	0.824***
I feel a sense of insecurity when attempting mathematics.	0.846***
Mathematics does not scare me at all	Removed
I am able to solve mathematics problems without too much difficulty.	Removed
I expect to do fairly well in any math class I take	Removed
I learn mathematics easily	Removed
I believe I am good at solving math problems	Removed

Notes: *** $p < 0.001$

Table 5 shows the reliability of the scales used for each of the latent variables based on a calculation of Cronbach's alpha. All four of the latent variables had a reliability greater than 0.9 with the reliability of the self-confidence variable being the greatest ($\alpha = 0.957$) and motivation the least ($\alpha = 0.909$).

Table 2

Standardized Loadings for CFA Model (Value)

Item	Loading
Mathematics is a very worthwhile and necessary subject.	0.738***
I want to develop my mathematics skills.	0.654***
Mathematics helps develop the mind and teaches a person to think.	0.715***
Mathematics is important in everyday life.	0.760***
Mathematics is one of the most important subjects for people to study.	0.756***
High school math courses would be very helpful no matter what I decide to study.	0.703***
I can think of many ways that I use math outside of school.	0.751***
I think studying advanced mathematics is useful.	0.765***
I believe studying math helps me with problem solving in other areas.	0.829***
A strong math background could help me in my professional life.	0.815***

Notes: *** $p < 0.001$

Table 3

Standardized Loadings for CFA Model (Enjoyment)

Item	Loading
I get a great deal of satisfaction out of solving a mathematics problem.	0.705***
I have usually enjoyed studying mathematics in school.	0.882***
I like to solve new problems in mathematics.	0.868***
I would prefer to do an assignment in math than to write an essay.	0.752***
I really like mathematics.	0.907***
I am happier in a math class than in any other class.	0.743***
Mathematics is a very interesting subject.	0.781***
I am comfortable answering questions in math class.	0.801***
I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math	Removed

Notes: *** $p < 0.001$

In the final revised model, it was found that there was a high correlation ($r > 0.9$) between the enjoyment and motivation latent variables. A chi-square difference test was used to determine if there would be any difference between a three-factor model, with enjoyment and motivation modeled as a single latent variable, or if the four factor model was still a better fit. The model fit did not improve with the three-factor model ($\chi^2(461)$ = 1283.12, p < 0.01, *CFI* = 0.888, *RMSEA* = 0.084 [90% CI = 0.078, 0.089]) and the chi-square difference test showed that the four-factor model was a significantly better fit ($\Delta\chi^2_{diff}(3)$ = 58.63, p < 0.01) (Schermelleh-Engel, Moosbrugger, & Muller, 2003). Thus, the four-factor model was used for the components of the structural analysis.

Table 4

Standardized Loadings for CFA Model (Motivation)

Item	Loading
I am confident that I could learn mathematics.	0.783***
I am willing to take more than the required amount of mathematics.	0.860***
I plan to take as much mathematics as I can during my education.	0.844***
The challenge of math appeals to me.	0.897***
I would like to avoid using mathematics in college	Removed

Notes: *** $p < 0.001$

Table 5

Scale Reliabilities for CFA Model

Latent Variable	Number of Items	Cronbach's Alpha
Self-Confidence	10	0.957
Value	10	0.926
Enjoyment	8	0.935
Motivation	4	0.909

Path Analysis

Structural Model One

Before analyzing the first structural model, a reliability test using Cronbach's alpha was performed on the 17 items included as a part of the cognitive math variable (α

= 0.833). A latent variable, “math ability,” was generated with a single indicator represented by the percentage score on the math exam. The error variance of this latent variable was set to the reliability found between the items on the exam.

Paths were drawn from the calculated gameplay score to all of the latent variables in the *ATMI* as well as the math ability variable. Additionally, all of the latent variables from the *ATMI* were considered predictors of math ability, so these paths were drawn to match the image shown in Figure 1. Standardized direct and indirect effects of this path analysis were analyzed with the model ($\chi^2(520)$ = 1842.68, p < 0.01, *CFI* = 0.823, *RMSEA* = 0.100 [90% CI = 0.095, 0.105]). The structural model with significant standardized coefficients is shown in Figure 4. The standardized indirect effects were determined by multiplying the direct effects along the indirect paths through the latent variables of the *ATMI* and are given in Table 7.

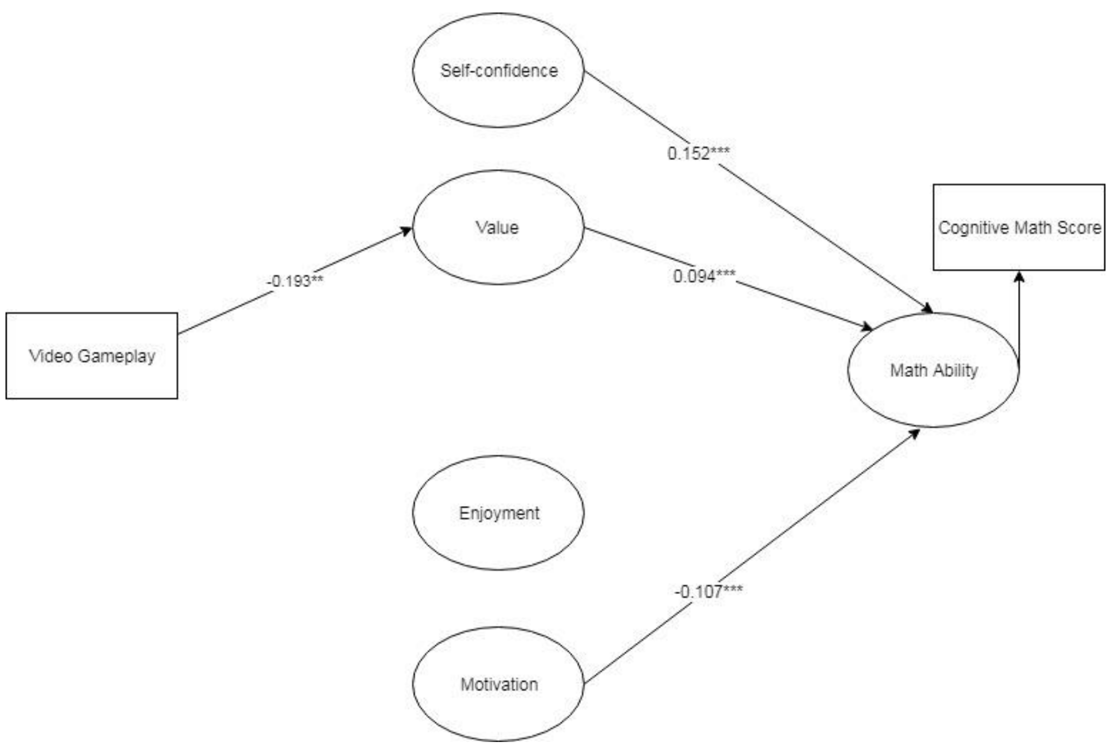


Figure 4. Structural Model 1

Table 6 shows the standardized direct effects of video gameplay on the latent variables and math ability from the first structural model. The direct effect of video gameplay on the latent variable “value” is statistically significant (β = -0.193, $p < 0.01$) while the direct effects on self-confidence (β = -0.099, p = 0.119), enjoyment (β = -0.102, p = 0.112) and motivation (β = -0.089, p = 0.173) were not significant. The direct effect of video gameplay on math ability was also not statistically significant (β = -0.019, p = 0.166).

Table 6 also shows the standardized direct effects of the latent variables on math ability. Self-confidence (β = 0.152, $p < 0.001$), value (β = 0.094, $p < 0.001$), and motivation (β = -0.107, $p < 0.001$) were all statistically significant while the direct effect of enjoyment on math ability was not significant (β = -0.022, p = 0.109).

Table 6

Direct Effects (Model 1)

Predictor	Variable	Regression Weight
Gameplay	Self-Confidence	-0.099
Gameplay	Value	-0.193**
Gameplay	Enjoyment	-0.102
Gameplay	Motivation	-0.089
Gameplay	Math Ability	-0.019
Self-Confidence	Math Ability	0.152***
Value	Math Ability	0.094***
Enjoyment	Math Ability	-0.022
Motivation	Math Ability	-0.107***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7 shows the standardized indirect effects of video gameplay on math ability. These effects were calculated based on the indirect paths. Direct effects were multiplied to determine the mediating effect. Significance of the indirect effects were determined based on the significance of the two direct paths related to the effect. Only the indirect effect related to the path between video gameplay, the latent variable "value", and math ability was significant ($\beta = -0.018$) while the other indirect effects were not significant.

Table 7

Indirect Effects of Gameplay on Math Ability (Model 1)

	Thru	Math Ability
Gameplay	Self-Confidence	-0.015
	Value	-0.018***
	Enjoyment	0.002
	Motivation	0.002

Notes: * *p < 0.05, *** *p < 0.01, **** *p < 0.001*

Structural Model Two

In the second structural model, demographic characteristics were included as predictors of the given variables. Because it is expected that the age of the participant may influence the level of gameplay as well as the cognitive math score, it was included as a predictor of each of these variables. Likewise, gender and college major were included as predictors of both the latent variables related to the *ATMI* as well as the cognitive math score. Because gender is a dichotomous variable, it was dummy-coded to compare males to females. In order to account for college major, business, education and psychology, health and nursing, and other majors were dummy-coded and compared to liberal arts majors.

Again the standardized direct and indirect effects of this model were analyzed ($\chi^2(708) = 2202.42$, $p < 0.01$, $CFI = 0.808$, $RMSEA = 0.091$ [90% CI = 0.087, 0.095]). The structural model with significant standardized coefficients including these demographic variables are shown in Figure 5. The standardized indirect effects,

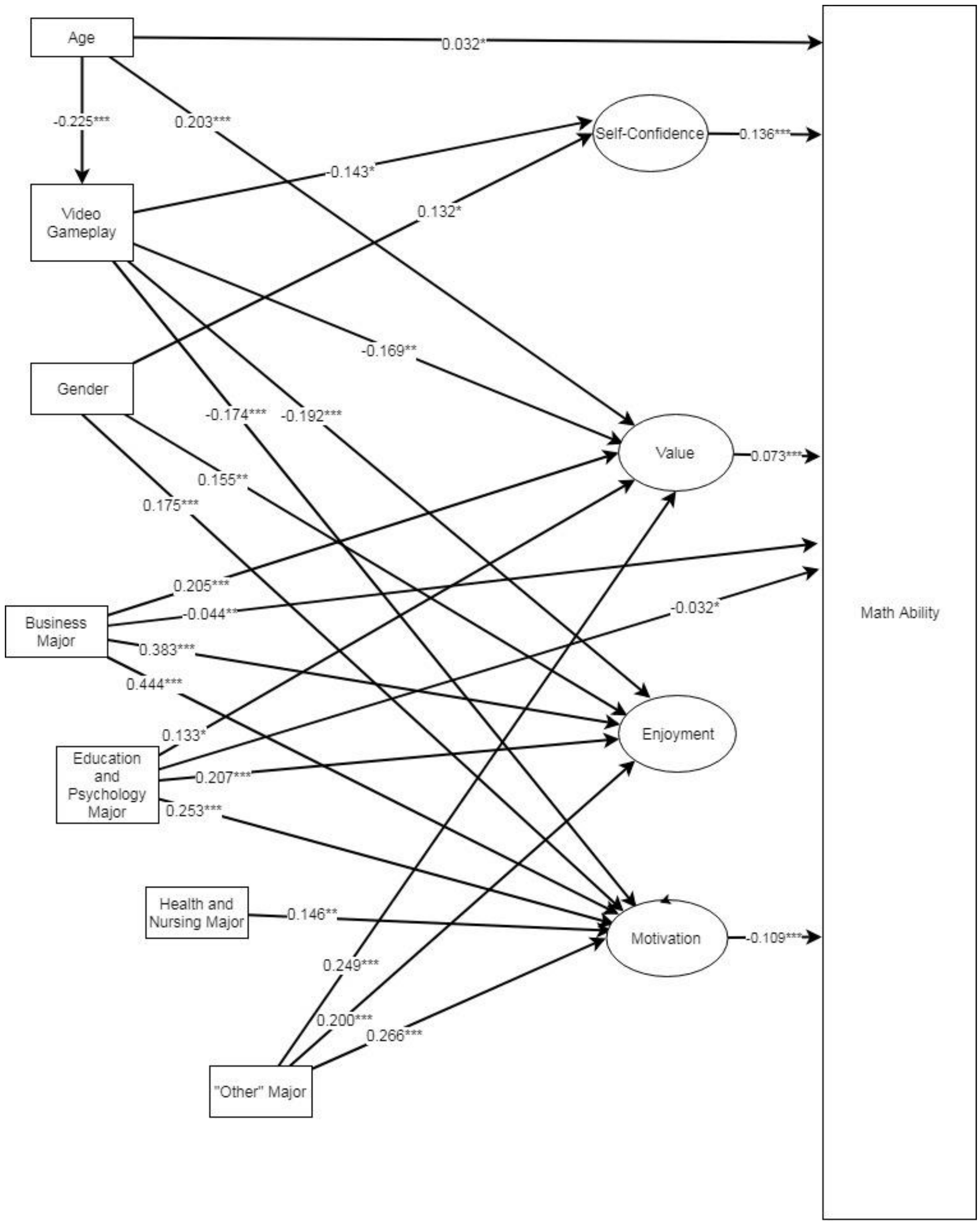


Figure 5. Structural Model 2

Notes: * *p < 0.05*, ** *p < 0.01*, *** *p < 0.001* determined by multiplying the direct effects along the indirect paths, are given in Tables 11 - 14.

Figure 5 shows the direct effects related to the second structural model. This model included demographic characteristics (age, gender, academic major). Figure 5 also shows significant direct effects between age and video gameplay (β = -0.225, p < 0.001), age and the latent variable "value" (β = 0.203, p < 0.001) as well as age and math ability (β = 0.032, p < 0.05). The direct effects between age and the latent variables of self-confidence, enjoyment, and motivation were all found to not be significant and are given in Table 8.

Table 8

Direct Effects (Model 2)

Predictor	Variable	Regression Weight
Age	Gameplay	-0.225***
Age	Self-Confidence	-0.061
Age	Value	0.203***
Age	Enjoyment	-0.091
Age	Motivation	-0.052
Age	Math Ability	0.032*
Gameplay	Self-Confidence	-0.143*
Gameplay	Value	-0.169***
Gameplay	Enjoyment	-0.192***
Gameplay	Motivation	-0.174***
Gameplay	Math Ability	-0.009
Gender	Self-Confidence	0.132*
Gender	Value	0.054
Gender	Enjoyment	0.155***
Gender	Motivation	0.175***
Gender	Math Ability	0.016

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 5 also shows statistically significant direct effects between video gameplay and the latent variables of self-confidence (β = -0.143, p < 0.05), value (β = -0.169, p <

0.001), enjoyment (β = -0.192, $p < 0.001$), and motivation (β = -0.174, $p < 0.001$). The direct effect of video gameplay math ability remains insignificant in the second model (β = -0.009, $p = 0.492$) as shown in Table 8.

Additionally, Figure 5 shows the significant direct effects between gender and the other latent variables. There is a statistically significant effect between gender and self-confidence (β = 0.132, $p < 0.05$), gender and enjoyment (β = 0.155, $p < 0.001$) and gender and motivation (β = 0.175, $p < 0.001$). As shown in Table 8, neither the direct effect between gender and value nor the direct effect between gender and math ability were statistically significant.

Finally, Figure 5 shows the significant direct effects between academic major and the other variables in the model. There are significant direct effects between an academic major of business and value (β = 0.205, $p < 0.001$), enjoyment (β = 0.383, $p < 0.001$), motivation (β = 0.444, $p < 0.001$) and math ability (β = -0.044, $p < 0.001$). There are also significant direct effects between an academic major of education and psychology and value (β = 0.133, $p < 0.05$), enjoyment (β = 0.207, $p < 0.001$), motivation (β = 0.253, $p < 0.001$), and math ability (β = -0.032, $p < 0.05$), and a significant direct effect between an academic major of health and nursing and motivation (β = 0.146, $p < 0.01$). Additionally, Figure 5 shows a significant direct effect between an academic major of "Other" and value (β = 0.249, $p < 0.001$), enjoyment (β = 0.200, $p < 0.001$), and motivation (β = 0.266, $p < 0.001$). All other paths were not statistically significant and are given in Table 9.

Table 9

Direct Effects of Academic Major (Model 2)

Predictor (Academic Major)	Variable	Regression Weight
Business	Self-Confidence	0.066
Business	Value	0.205***
Business	Enjoyment	0.383***
Business	Motivation	0.444***
Business	Math Ability	-0.044**
Education/Psychology	Self-Confidence	0.057
Education/Psychology	Value	0.133*
Education/Psychology	Enjoyment	0.207***
Education/Psychology	Motivation	0.253***
Education/Psychology	Math Ability	-0.032*
Health/Nursing	Self-Confidence	-0.036
Health/Nursing	Value	0.107
Health/Nursing	Enjoyment	0.097
Health/Nursing	Motivation	0.146**
Health/Nursing	Math Ability	-0.017
Other	Self-Confidence	-0.036
Other	Value	0.249***
Other	Enjoyment	0.200***
Other	Motivation	0.266***
Other	Math Ability	0.013

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Likewise, Table 10 shows the direct effects of the latent variables on math ability in the second structural model. In this model the paths between self-confidence and math ability ($\beta = 0.136$, $p < 0.001$), value and math ability ($\beta = 0.073$, $p < 0.001$) and motivation and math ability ($\beta = -0.109$, $p < 0.001$) were statistically significant while the path from enjoyment to math ability was not significant.

Table 11 through Table 14 show the indirect effects associated with the second structural model. These effects were calculated similarly to the first model and significance was determined in the same way as the first model. Many of the effects were very small (β < 0.001) and these are noted in the tables, however some of the indirect paths were found to be significant. Table 11 shows the indirect path from age to value to math ability (β = 0.014, p < 0.001) to be significant. Likewise, in Table 12, the indirect paths from video gameplay to math ability through self-confidence (β = -0.019, p < 0.001), through value (β = -0.012, p < 0.001), and through motivation (β = 0.019, p < 0.001) were found to be significant. In Table 13, the paths from gender to math ability through self-confidence (β = 0.018, p < 0.001) and motivation (β = -0.019, p < 0.001) were also found to be significant. In Table 14, the paths from an academic major of business to math ability through value (β = 0.015, p < 0.001) and through motivation (β = -0.048, p < 0.001) were significant. The paths from an academic major of education and psychology to math ability through value (β = 0.010, p < 0.001) and through motivation (β = -0.028, p < 0.001) were also significant. Similarly, the path from an academic major of health and nursing to math ability through motivation (β = -0.016, p < 0.001) was significant and the paths from an academic major of "other" to math ability through value (β = 0.018, p < 0.001) and through motivation (β = -0.029, p < 0.001) were significant.

Table 10

Direct Effects of ATMI Variables on Math Ability (Model 2)

Predictor	Variable	Regression Weight
Self-Confidence	Math Ability	0.136***
Value	Math Ability	0.073***
Enjoyment	Math Ability	0.004
Motivation	Math Ability	-0.109***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11

Indirect Effects of Age on Math Ability (Model 2)

Predictor	Thru	Effect
Age	Gameplay	0.002
Age	Self-Confidence	-0.008
Age	Value	0.014***
Age	Enjoyment	< 0.001
Age	Motivation	0.005
Age	Gameplay, Self-Confidence	< 0.001
Age	Gameplay, Value	< 0.001
Age	Gameplay, Enjoyment	< 0.001
Age	Gameplay, Motivation	< 0.001

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12

Indirect Effects of Video Gameplay on Math Ability (Model 2)

Predictor	Thru	Effect
Gameplay	Self-Confidence	-0.019***
Gameplay	Value	-0.012***
Gameplay	Enjoyment	< 0.001
Gameplay	Motivation	0.019***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13

Indirect Effects of Gender on Math Ability (Model 2)

Predictor	Thru	Effect
Gender	Self-Confidence	0.018***
Gender	Value	0.004
Gender	Enjoyment	< 0.001
Gender	Motivation	-0.019***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14

Indirect Effects of Academic Major on Math Ability (Model 2)

Predictor (Academic Major)	Thru	Effect
Business	Self-Confidence	0.009
Business	Value	0.015***
Business	Enjoyment	0.002
Business	Motivation	-0.048***
Education/Psychology	Self-Confidence	0.008
Education/Psychology	Value	0.010***
Education/Psychology	Enjoyment	< 0.001
Education/Psychology	Motivation	-0.028***
Health/Nursing	Self-Confidence	-0.005
Health/Nursing	Value	0.008
Health/Nursing	Enjoyment	< 0.001
Health/Nursing	Motivation	-0.016***
Other	Self-Confidence	-0.005
Other	Value	0.018***
Other	Enjoyment	< 0.001
Other	Motivation	-0.029***

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

CHAPTER V – DISCUSSION

The concept of quantitative literacy can be summarized as a person's cognitive mathematical abilities and their attitude about and toward mathematics. In order to understand how playing video games can impact a person's quantitative literacy, this research was designed to investigate the relationship between playing video games and a person's ability to answer particular math questions, as well as the influence of playing video games on a person's attitudes toward mathematics in general. The chapter will discuss the results of this research, which provides some insight into these questions, as well as the general limitations of this study. Finally, the possibilities for future research will be examined.

Discussion of the Results

Effects of Video Gameplay on Cognitive Math Ability

The results of the study show that there is a minimal effect on the cognitive math abilities of participants based on their level of video gameplay. The first evidence of this is given by the weak negative direct correlation between the level of video gameplay and the scores on the cognitive math assessment. Though the relationship is statistically significant, the value of the correlation is close to zero, implying that there is no relationship between playing video games and the level of mathematical abilities. Even though the correlation is negative, implying that playing video games may actually reduce or impede a person's mathematical abilities, the weak correlation concurs with previous research that have shown there are no negative impacts on math ability from playing video games (Drummond & Sauer, 2014).

This evidence is supported by the results of the path analyses, which included all the components of quantitative literacy. When the latent variables of the *ATMI* are included in the analysis, the direct effect of video gameplay on cognitive math ability is essentially zero and not statistically significant (β = -0.019, p = 0.166). Because of the lack of statistical significance, this relationship is shown to be no different from zero. Further, when demographic characteristics are included in the second model, the effect continues to be no different from zero (β = -0.009, p = 0.492).

These results are in agreement with previous studies in which the data show that playing video games does not directly improve a person's mathematical ability. For example, Unsworth et al. (2015) and Collins and Freeman (2014) showed from their studies that there is little difference in cognitive abilities between those who played video games and those who did not. However, there is also something to be said about the negative effects of playing video games as well. Drummond and Sauer (2014) showed that frequent video gameplay did not have any negative effects on the academic performance of participants. The second structural model of this current study backs up this finding, showing that even though the resulting correlation is negative, it is not statistically different from zero when multiple factors are included. This would suggest that even though playing video games does not improve a person's math abilities, it also does not impair their math abilities.

In general, the data show that there is not a direct relationship between playing video games and cognitive math ability. All the direct relationships between playing video games and cognitive math ability were found to be no different from zero. Though there is a possibility that playing video games could still impact the non-cognitive aspects of quantitative literacy, the evidence provided by this study shows that there is no direct cognitive impact unless the effect is so small that it would need to be exposed by a further, more in-depth study.

Effects of Video Gameplay on Attitudes Toward Mathematics

The results of this study also show that there are minimal direct effects on the attitudes of a person related to their reported level of video gameplay. In the first structural model, the direct effect of video gameplay on math ability is not statistically significant, as shown in Table 6. Based on the model there is essentially no relationship between playing video games and a person's attitude toward mathematics. The only result that is statistically different from zero was the effect of video gameplay on the perceived value of mathematics. In this case, the relationship was negative, implying that for higher reported levels of video gameplay, the reported value of mathematics was reduced. In other words, those who play video games more often may find that they do not value mathematics as much as those who play less often.

When demographic characteristics are included in the structural model, shown in Figure 5, the negative effects of video gameplay on the attitudes toward mathematics are statistically significant as well as more prominent. As shown in Table 8, for every one-hour of additional gameplay reported, the results show a reduction of self-confidence (14%), value (17%), enjoyment (19%), and motivation (17%). These findings suggest that a person that plays video games more often may find that their attitudes toward mathematics are significantly reduced.

Though many previous studies did not find a direct cognitive relationship between video gameplay and math ability, most did show that there was an improvement in other components of quantitative literacy such as motivation. Multiple studies have shown that there is an increase in the level of motivation due to playing video games (Beserra et al., 2010; Hoffman & Nadelson, 2010; Ranalli & Ritzko, 2013). However, the findings of this study are not in agreement with previous research because the data show that there are some negative impacts to motivation as well as other factors as a result of playing video games more often. The results of this study imply that those who play video games more often actually are less self-confident in their mathematical abilities, less motivated toward experiencing mathematical situations, see less intrinsic value in the use of mathematics, and do not enjoy the use of mathematics. Previous literature does not show this same relationship, but limitations of the sample may have led to this discrepancy. These limitations are discussed further in a following section.

The result related to the value of mathematics should be considered because it is statistically significant in both the structural models. It is possible that those who play video games often do not find any value in the use of mathematics. This may come from the self-reporting of video gameplay, primarily those who reported that they did not play any games from the list and instead provided their own list of games. Though the specific games included in the study were chosen because of their inherent mathematical situations, other video games that were reported by participants added to their measured level of video gameplay but may have lacked these mathematical situations. Of particular interest were those who reported higher levels of cell-phone games, such as *Candy Crush*, that do not include the use of mathematics whatsoever. These video game players may not recognize the functional value of mathematics compared to those who played other types of games. Future studies described below could further expose these differences and lead to more tangible results.

Effects of Attitudes Toward Mathematics on Math Ability

The structural models of the current research show that there are some direct effects of the reported attitudes toward mathematics on a person's cognitive math abilities. Most of these results were statistically significant, except for those related to the enjoyment of mathematics. Based on the results of the first structural model, a one-unit increase in reported self-confidence suggests a 15% improvement in cognitive math ability while a one-unit increase in the reported value of mathematics suggests a 9% increase in math ability. Conversely, a one-unit increase in the reported level of motivation implies a decrease in the measure of math ability by 10%. In the second structural model, which includes the demographic characteristics, these values all remained statistically significant, however the increase in cognitive ability due to an increase in self-confidence and value were slightly reduced (14% and 7% respectively). There was essentially no change in terms of the motivation variable.

The first two results seem to align with expectations. If a person is more confident in their mathematical abilities or if they see a greater value toward mathematics, then they are likely to be better at mathematics overall, as shown by the positive relationship between disposition and quantitative literacy in previous research (Wilkins, 2010). The interesting result here is again the factor related to motivation. Those more motivated toward mathematical situations seem to perform poorly compared to those less motivated. Again, this effect is small, but it would seem to disagree with previous research. Though it is expected that those who play video games would be more motivated (Abrams, 2009;

Hoffman & Nadelson, 2010; Gerber et al., 2014), it is also expected that more motivation would imply better cognitive mathematical outcomes (Wilkins, 2010). This was not the case, based on the current study and in fact, other studies have shown that there is little to no difference related to cognitive outcomes even when factors such as motivation are improved (Ranalli & Ritzko, 2013). It may be the case that those who are more motivated are so because they lack some necessary mathematical skills and not because they are better at mathematics in general. Thus, this may be representing the portion of the sample that were motivated to improve their mathematical skills.

Effects of Demographics on Math Ability and Attitudes Toward Mathematics

In the second structural model, demographic characteristics, including age, gender, and academic major, provided some insight into the relationships between those characteristics and the other variables within the study. Each of these relationships is examined below.

Ages of participants were measured in groups of 7 years, beginning with 18 to 24 year olds and increasing in groups up to 45 year olds. Those 46 years old and above were treated as one group. Based on these groups, age was shown to be a significant predictor of a person's level of video gameplay. This is expected based on information given by the Entertainment Software Association (2015) which shows that those who play video games are primarily of a younger age. As the age group of participants increased, the study showed a statistically significant decrease in the reported level of video gameplay. For each increase in age group, the reported gameplay was reduced by almost 23%.

A significant relationship was also found between the age of the participant and their reported value of mathematics as well as their cognitive ability. As the age group of the person increased, there was a 20% increase in the reported value of mathematics. This shows that as a person ages, they find that mathematics becomes more important in everyday situations. Likewise, as a person ages it is also expected that the person would become better at mathematics, which accounts for the approximately 3% increase in cognitive math abilities based on the age group of the participant.

The relationships found between age and the other attitudes measure in the *ATMI* were not statistically significant, implying that although older participants showed an improvement in math ability, there was no difference in the level of self-confidence, enjoyment and motivation toward mathematics. As a person ages, they may find no change in their self-confidence, enjoyment of mathematics, or motivation toward mathematics even though their math ability is shown to improve slightly.

In terms of gender, males were compared to females in the structural analysis. There were some statistically significant results, specifically in terms of the latent variables measured by the *ATMI*. The data show in Table 8 that on average males report a higher level of self-confidence (13%), enjoyment (15%), and motivation (18%) than females. This agrees with research that has shown that males report a higher level of self-confidence related to mathematics (Tariq, Qualter, Roberts, Appleby, & Barnes, 2013). Even with this difference between the reported attitudes of males and females, there was no statistical difference between the cognitive math scores based on gender. This is again in line with some previous research that shows there is very little difference between the cognitive math abilities of males and females (Hyde et al., 2008; Catsambis, 1994).

Finally, the academic major of participants was also included in the second structural analysis. In this case, all majors (business, education and psychology, health and nursing, and other) were compared to liberal arts majors. This was done because of the relatively minimal mathematics requirements for those students who are liberal arts majors.

Business majors reported a significantly higher level of value (21%), enjoyment (38%), and motivation (44%) than their liberal arts counterparts, while they exhibited a slightly lower level of math ability (4%) than their liberal arts counterparts. This trend was similar for education and psychology majors. Education and psychology majors reported higher levels of value (13%), enjoyment (21%), and motivation (25%) compared to liberal arts majors but scored lower on the measure of math ability (3%). Health and nursing majors also reported significantly higher levels of motivation (15%) than liberal arts majors. Finally, those who reported “other” as a major reported significantly higher levels of value (25%), enjoyment (20%), and motivation (27%). There were no other significant relationships between academic major and any of the other variables in the study.

The results with respect to academic major show that the students who find at least some utility in mathematics (business, education and psychology, health and nursing, other) report higher levels of some of the attitudes related to mathematics, but there is little difference in their overall cognitive ability. While participants associated with these academic majors may see the overall usefulness of mathematics, there is essentially no difference between their cognitive abilities and those who are liberal arts majors.

Indirect Effects of Video Gameplay on Math Ability

Finally, the indirect effects of the path analyses were investigated. The statistical significance of these indirect effects was established based on the significance of the paths associated with the indirect effects. Table 7 shows the indirect effects associated with the first structural model, where the only path with any significance was with respect to the path from video gameplay to the value of mathematics to the cognitive math ability. Those who reported a higher level of video gameplay reported a lower level of the intrinsic value of mathematics, but those who reported a higher level of the value of mathematics reported a higher cognitive ability. Therefore, it would seem that a person who plays more video games will have a less positive view of the value of mathematics and thus a decrease in their cognitive math ability of approximately 2% for each additional hour of video gameplay reported. As mentioned before, this could again relate back to those who reported playing cellphone video games, where the usefulness of mathematics is minimized.

When demographic characteristics are included, the number of paths increase and there are additional indirect effects that were statistically significant. In Table 11, it can be seen that the older a person, the greater their attitude toward the value of mathematics, which will in turn show a slight improvement in mathematical ability (1%). Because the age groups of participants were separated into only five groups, this improvement appears minimal. The paths related to video gameplay through self-confidence, value, and motivation to math ability were also significant, but as with age above, the effect is very small. Those who played video games more often showed a reduction in self-confidence and value leading to a reduction in math ability of 2% and 1% respectively.

Those who played video games more often showed a lower level of motivation toward mathematics, which in turn related to an approximately 2% higher level of math ability. Though these effects are small, the data show that there are some small effects relating video gameplay to math ability, but only in the way that video gameplay effects attitudes toward mathematics and not directly toward a person's cognitive ability.

Males reported a higher level of self-confidence and thus had a slightly higher level of math ability (2%), while they reported higher levels of motivation which, based on the data, implied an approximately 2% lower level of math ability. Business majors reported higher levels of value and motivation than liberal arts majors, which had opposite effects on their overall cognitive ability. Business majors who reported higher levels of value performed slightly better than liberal arts majors (2%), but they performed somewhat worse when they reported higher levels of motivation (5%). Education and psychology majors were again similar to business majors, in that as they reported higher levels of value they scored slightly higher in cognitive math abilities (1%), but higher levels of motivation were again related to lower cognitive math abilities (3%). Health majors also found that an increase in motivation led to a decrease in math ability, causing them to have a score reduction of approximately 1%. Finally, those who report "other" as a major were similar to business and education majors as a higher reported level of value implied higher math scores (2%) but higher levels of motivation implied lower levels of math ability (3%).

In general, these indirect paths show the interaction between each of the variables and overall effects that occur when all of the variables are included in the analysis. Because an increase in motivation is tied to lower scores on math ability, each group who reported higher levels of motivation saw a reduction in their overall scores. These reductions were very small compared to the direct effects due to some of these variables, but they were significant in that the small effect could be determined.

It seems that most academic majors reported higher levels of motivation compared to liberal arts majors, but scored slightly lower on the cognitive math instrument. Again, this could be related to those majors recognizing the usefulness of mathematics, but not scoring as high as one would expect. Overall, the differences are minimal in that another sample may not have shown the same relationships or perhaps inverse relationships. These and other considerations appear below in terms of the limitations of the study.

Limitations of Results

Limitations of Sample

Upon first analysis of the results, it can be seen that the sample for the study was a relatively even split between males and females while the sample was limited by some differences between age groups and the academic majors represented. It is somewhat expected that there would be a difference in the ages of the participants, particularly because there are fewer video game players in higher age groups (ESA, 2015).

There were also some limitations based on the main method of data collection, using the online Amazon Mechanical Turk. This system was likely influential on the type of sample that was collected. It is more likely that this system is used by those who are experienced with computers and therefore more likely to play video games. This could lead to increase in the level of reported video gameplay but may not have entirely captured a true sample of those who play video games in general. This would also lead to a sample that was primarily younger, which is shown by the fact that a great portion of the sample (74.3%) were under the age of 38. Thus, older groups were generally underrepresented in this study. Likewise, the system may favor those who were in particular academic majors, leading to a difference in the number of each of the academic majors collected overall. In future studies, a sample collected that was evenly distributed among all age groups and academic majors would likely produce more generalizable results.

Limitations of Analysis

The confirmatory factor analysis process broke down the different latent variables based on the indicators from the *ATMI*. This instrument had been previously developed and contained items that were constructed as both positive and negative items related to the four latent variables of interest (Tapia, 1996). Though the data showed a reasonable fit related to this instrument, many of the indicators were either all positive or all negative. Only one latent variable had both positive and negative indicators in the final model, self-confidence, and only one item was different from the others. This item was shown to have the lowest factor loading of all the items and likely would have improved the model further if this had been removed.

The lack of both positive and negative items as indicators of each latent variable implies that there may have been an issue with the collection of the sample. It is possible that even with timing the participants and the use of attention filters there was some amount of the participants that did not accurately answer each of the questions. This issue could have influenced all of the data in the study and had some influence on the results. This also could have led to the apparent high correlation between two of the latent variables, even though the chi-square difference test showed that the four-factor model remained an improvement over the three-factor model. Improving or editing the *ATMI* would likely influence the results, providing more reliable data overall.

Implications for Further Research

One major success of this research study was to show the direct and indirect effects related to each of the variables in the structural analyses. Many studies have looked at how one component of quantitative literacy can be influenced by playing video games, but no study has been able to isolate each of the different components as a way of determining what effects may lie hidden within each of the different factors. The results of this study show there are some relationships that exist between video gameplay and the cognitive and attitudinal aspects of quantitative literacy. In order to build on this study, future research could be performed that would improve the individual aspects of the study that may have influenced the results.

One such method that would improve and expand the results of this study would be to collect a larger sample in order to obtain a deeper look at the very small indirect effects that were present in this initial study. Many of the significant indirect effects found were small and the others were not statistically difference from zero. A larger sample may distinguish between those that were not significant because of there being no relationship and those that were not significant because the sample size was not available.

Another way to improve on the current research would be an experimental design that placed a participant in a controlled setting and also determined which video games were played and for how long. This study was limited as it was only able to use a self-reported measurement of gameplay. Though this measurement was more advanced than previous studies, by asking about the type of game and the number of hours played per week, it was not directly controlled by the research and was left to the participant to report. A controlled experiment would likely have a much smaller sample, but could investigate the direct effects of video gameplay on cognition and attitudes toward mathematics more accurately.

Yet another way to analyze these relationships would be to make changes to the instrument that was used for the determination of cognitive math ability. The items included in the instrument focused on simple math abstractions and was reduced to 17 items to account for the time required to complete the survey, but a longer and more difficult instrument may further separate the results of the assessment. The instrument had a high standard deviation overall and this could have impacted the overall results of the study.

Summary of Research

Overall, this research intended to look at the impact of playing video games as it related to the cognitive math abilities and attitudes toward mathematics of the participants. The results showed that there was little impact on cognitive math ability and mixed effects on the attitudes toward mathematics. Some of these results were in line with previous research, particularly the results showing video games have no effect on overall cognitive math scores, while other results strayed from published research in that the motivation of participants was not bolstered by an increase in the level of playing video games. Further research could delve into the more intricate details of the results and provide a greater insight to the effects of playing video games on the components of quantitative literacy.

APPENDIX A – Cognitive Math Exam

The 17 items below have been extracted from the web-based questionnaire. Subheadings have been added for context. Attention filters have been removed.

Ratios

1. A warehouse stores 495 different inventory items, of which 1/5 are perishable. How many of the items are perishable?

- 98 items
- 99 items
- 102 items
- 247 items

2. A statistician has readings that take 2/3 minute to each read and record. How many readings can be completed in 36 minutes?

- 12 readings
- 14 readings
- 24 readings
- 54 readings

3. A cookie recipe calls for 1/3 of a cup of sugar and makes 1 dozen cookies. How many dozen cookies can you make if you have 7 cups of sugar and want to use it all?

- 1/21
- 3/7
- 7/3
- 21

4. A baseball team ended its season with a ratio of losses to wins of 2 to 3. What fraction of their games did they win?

- 3/5
- 5/3
- 3/2
- 2/3

<u>Rates</u>

5. Determine the best buy based on cost per unit: Brand X: 8 oz for $2.00 Brand Y: 20 oz for $3.80 Brand Z: 24 oz for $5.28

- Brand X
- Brand Y
- Brand Z
- Not enough information

6. Determine the best buy based on cost per unit: Brand A: 10 cans for $3.55 Brand B: 16 cans for $5.01 Brand C: 26 cans for $7.46 Brand D: 34 cans for $10.10

- Brand A
- Brand B
- Brand C
- Brand D

7. Jeremy's car got 240 miles (highway) on 8 gallons of gasoline. What was the average number of miles expected per gallon?

- 29 mpg
- 30 mpg
- 31 mpg
- 32 mpg

<u>Percentages</u>

8. According to a recent poll, 1752 out of the 8760 people in a particular city were classified as obese. What is the relative frequency of obesity according to this poll?

- 10%
- 20%
- 40%
- 80%

9. Of the 2330 respondents to a survey, 1030 claimed to be worried about their health. What is the likelihood that a person selected at random will not be worried about their health? Round to two decimal places.

- 43.78%
- 44.21%
- 55.79%
- 2399.90%

10. Sales of frozen pizza for a club fundraiser increased from 500 one year to 695 the next year. What was the percent of increase?

- 28.1%
- 39%
- 61%
- 71.9%

11. The price of a printer was reduced from $400 to $240. What was the percent of decrease?

- 40%
- 45%
- 60%
- 66.7%

Real Number Addition

12. A football team gained 35 yards on one play, lost 14 years on another, and gained 38 yards on the last play of the first half. They had already gained 400 yards during the half. What was the total yardage gain for the first half?

- 341 yards
- 459 yards
- 473 yards
- 487 yards

13. The temperature at the South pole was -24^{o}C at 8 am. At 3 pm it was 26^{o}C. By how many degrees did the temperature rise?

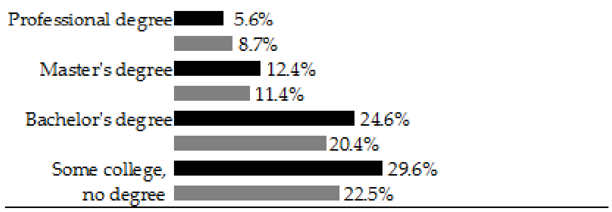
- -2^{o}
- 2^{o}
- -50^{o}
- 50^{o}

14. There is a 3-degree drop in temperature for every thousand feet that an airplane climbs into the sky. If the temperature on the ground is 48 degrees, what will be the temperature when the plane reaches an altitude of 17,000 feet?

- -31 degrees
- -3 degrees
- 3 degrees
- 31 degrees

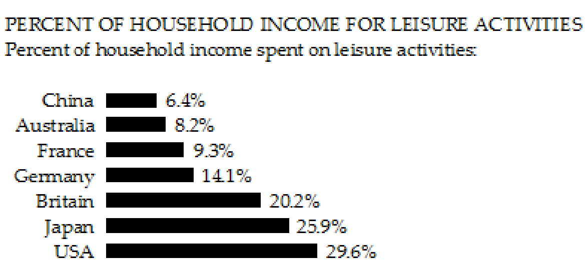
Graphs and Charts

15. The following graph shows the educational attainment of residents of a certain town (in black) compared to the state average (in gray). For which educational level is the town below the state average?



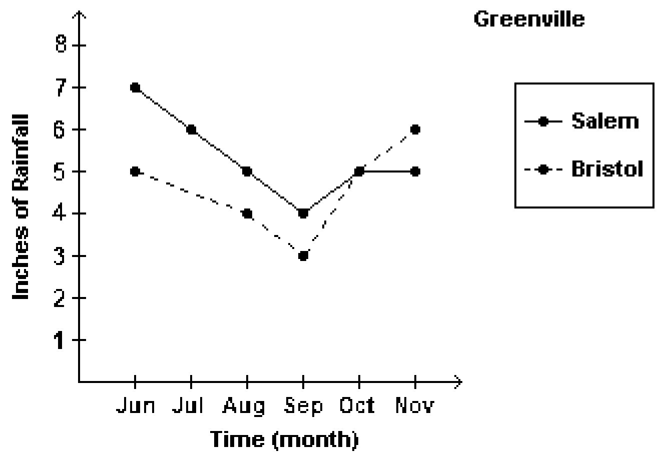
- Some college, no degree
- Bachelor's degree
- Master's degree
- Professional degree

16. Assuming income is spread evenly over all 365 days of the year, how many days each year will the average adult in France have to work in order to pay for leisure activities? Round to the nearest day.



- 34 days
- 93 days
- 331 days
- 3395 days

17. In what month does Bristol receive its highest level of rainfall?



- June
- August
- September
- November

APPENDIX B USM IRB Approval Letter

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 18021401
PROJECT TITLE: Mathematical Literacy and Video Games
PROJECT TYPE: Doctoral Dissertation
RESEARCHER(S): Craig Carrigee
COLLEGE/DIVISION: College of Education and Psychology
DEPARTMENT: Educational Research and Administration
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Exempt Review Approval
PERIOD OF APPROVAL: 02/21/2018 to 02/20/2019
Lawrence A. Hosman, Ph.D.
Institutional Review Board

APPENDIX C PRCC IRB Approval Letter

PEARL RIVER
COMMUNITY COLLEGE

Pearl River Community College
Institutional Review Board Decision Letter

The Institutional Review Board (IRB) has completed its review of the following project:

Principal Investigator: Craig Carrigee
Pearl River Community College

On-Campus Liaison*: Dr. Jennifer Seal
Telephone. 601-403-1146 Email: jseal@prcc.edu

Project Title: Mathematical Literacy and Video Games

Funding Agency: N/A

Proposal Number (if applicable): N/A

The determination of the board is that:

√ This project complies with the institution's policy and procedures regarding use of human subjects in a grant-funded research project (Common Rule Section 101, subsection b). The project may be conducted as planned subject to continuing review as outlined in the Board's procedures.

You are authorized to implement this study as of the date of the final approval. This approval is valid for one year. If the project continues beyond this time frame, the IRB will request continuing review and update of the project. After receiving initial approval of your project, any proposed changes that may affect the format, implementation, or exempt status of your project and/or any unanticipated or serious adverse events involving risk to the participants requires that notification must be received, and approval must be granted by the PRCC IRB before the implementation of the project.

As stated and agreed upon in your petition to the Pearl River Community College Institutional Review Board, **study findings must be shared with the PRCC IRB.** Copies of the report may be shared with both internal and external personnel associated with the College who have an interest in the topic and results. In addition, **permission of the PRCC IRB is required prior to publication of your study.** Approval is at the sole discretion of the Board.

*Please note that you must discuss your project and implementation plans with the On-Campus Liaison (indicated above) to ensure that your plans can be implemented as you requested.

This project does not comply with the institution's policy and procedures regarding use of human subjects in a grant-funded research project. Concerns of the Institutional Review Board are outlined in an attached document. The Principal Investigator has the right to modify and re-submit the proposal for another review.

Chair, Institutional Review Board

11-17-17
Date

6/13

101 Highway 11 North • Poplarville, Mississippi 39470 • 601-403-1000 • www.prcc.edu

REFERENCES

Abrams, S. S. (2009). A gaming frame of mind: digital contexts and academic implications. *Educational Media International*, *46*(4), 335 – 347.

Ackland, A. (2014). More… or less? Towards a critical pedagogy of adult numeracy. *Adults Learning Mathematics: An International Journal*, *9*(2), 7 – 21.

Almy, K. & Foes, H. (2017). *Math Lit: A Pathway to College Mathematics, 2nd Edition.* Boston: Pearson.

Beserra, V., Nussbaum, M., Zeni, R., Rodriguez, W., & Wurman, G. (2014). Practising Arithmetic Using Educational Video Games with an Interpersonal Computer. *Journal of Educational Technology & Society*, *17*(3), 343-358.

Buelow, M. T., Okdie, B. M., & Cooper, A.B. (2015). The influence of video games on executive functions in college students. *Computers in Human Behavior*, *45*(2015), 228 - 234.

Burdette, A. M. & McLoughlin, K. (2010). Using Census Data in the Classroom to Increase Quantitative Literacy and Promote Critical Sociological Thinking. *Teaching Sociology*, *38*(3), 247 – 257.

Bowers, A. J., & Berland, M. (2013). Does recreational computer use affect high school achievement?. *Educational Technology Research and Development*,*61*(1), 51-69.

Carr, J. (2012). Does Math Achievement h'APP'en when iPads and Game-Based Learning are Incorporated into Fifth-Grade Mathematics Instruction?. *Journal of Information Technology Education: Research*, *11*(1), 269-286.

Catsambis, S. (1994). The path to math: Gender and racial-ethnic differences in mathematics participation from middle school to high school. *Sociology of Education*, 199-215.

Collins, E. & Freeman, J. (2014). Video game use and cognitive performance: Does it vary with the presence of problematic video game use? *Cyberpsychology, Behavior, and Social Networking*, *17*(3), 153 – 159. Doi: 10.1089/cyber.2012.0629

De Freitas, S. & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated?. *Computers & Education*, *46*(3), 249 – 264.

Drigas, A. S., & Pappas, M. A. (2015). On Line and Other Game-Based Learning for Mathematics. *International Journal of Online Engineering*, *11*(4).

Drummond, A., & Sauer, J. D. (2014). Video-games do not negatively impact adolescent academic performance in science, mathematics or reading. *PloS ONE*, *9*(4): e87943. Doi:10.1371/journal.pone.0087943

Dumford, A. D., & Rocconi, L. M. (2015). Development of the Quantitative Reasoning Items on the National Survey of Student Engagement. *Numeracy*, *8*(1), 1 – 17.

Entertainment Software Association (ESA). (2015). *Essential Facts about the Computer and Video Game Industry: 2015 Sales, Demographic and Usage Data.* Retrieved from http:// www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf

Ferguson, C. J., Garza, A., Jerabeck, J., Ramos, R., & Galindo, M. (2013). Not worth the fuss after all? Cross-sectional and prospective data on violent video game influences on aggression, visuospatial cognition and mathematics ability in a sample of youth. *Journal of youth and adolescence*, *42*(1), 109-122.

Frith, V., Jaftha, J., & Prince, R. (2004). Evaluating the effectiveness of interactive computer tutorials for an undergraduate mathematical literacy course. *British Journal of Educational Technology*, *35*(2), 159-171.

Gal, I. (2002). Adults' Statistical Literacy: Meanings, Components, Responsibilities. *International Statistical Review, 70*(1), 1 – 51.

Gerber, H. R., Abrams, S. S., Onwuegbuzie, A. J., & Benge, C. L. (2014). From Mario to FIFA: what qualitative case study research suggests about games-based learning in a US classroom. *Educational Media International*, *51*(1), 16-34.

Goodman, M., Finnegan, R., Mohadjer, L., Krenzke, T., & Hogan, J. (2013). Literacy, Numeracy, and Problem Solving in Technology-Rich Environments among US Adults: Results from the Program for the International Assessment of Adult Competencies 2012. First Look. NCES 2014-008. *National Center for Education Statistics*.

Grubb, J. (2016, January 14). 2015 NPD: The 10 best-selling games of the year. Retrieved from http://venturebeat.com/2016/01/14/2015-npd-the-10-best-selling-games-of-the-year/

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and math. *SCIENCE-NEW YORK THEN WASHINGTON-*, *320*(5880), 1164.

Hoffman, B., & Nadelson, L. (2010). Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research and Development*, *58*(3), 245-270.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science*, *321*(5888), 494-495.

Kaiser, G., & Willander, T. (2005). Development of mathematical literacy: Results of an empirical study. *Teaching mathematics and its applications*, *24*(2-3), 48-60.

Kim, S., & Chang, M. (2010). Computer games for the math achievement of diverse students. *Journal of Educational Technology & Society*, *13*(3), 224-232.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and Development.* Englewood Cliffs, NJ: Prentice Hall.

Kühn, S., Gleich, T., Lorenz, R. C., Lindenberger, U., & Gallinat, J. (2014). Playing Super Mario induces structural brain plasticity: gray matter changes resulting from training with a commercial video game. *Molecular psychiatry*, *19*(2), 265-271.

Linder, A. M. (2012). Teaching Quantitative Literacy through a Regression Analysis of Exam Performance. *Teaching Sociology, 40*(1), 50 – 59.

Martin, G. (2016, Dec 8). *The 25 Best Videogames of 2016*. Retrieved from https://www.pastemagazine.com/articles/2016/12/the-25-best-videogames-of-2016.html

Matteson, S. M. (2006). Mathematical literacy and standardized mathematical assessments. *Reading psychology*, *27*(2-3), 205-233.

Ozgen, K. (2013). Self-efficacy beliefs in mathematical literacy and connections between mathematics and the real world: The case of high school students. *Journal of International Education Research (JIER), 9*(4), 305 – 316.

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students* (Vol. 2). San Francisco, CA: Jossey-Bass.

Plass, J. L., O'Keefe, P. A., Homer, B. D., Case, J., Hayward, E. O., Stein, M., & Perlin, K. (2013). The impact of individual, competitive, and collaborative mathematics game play on learning, performance, and motivation. *Journal of Educational Psychology*, *105*(4), 1050 – 1066.

Primi, C., Busdraghi, C., Tomasetto, C., Morsanyi, K., & Chiesi, F. (2014). Measuring math Anxiety in Italian college and high school students: Validity, reliability and gender Invariance of the Abbreviated Math Anxiety Scale (AMAS). *Learning and Individual Differences, 34,* 51 – 56. doi: 10.1016/j.lindif.2014.05.012

Ranalli, J., & Ritzko, J. (2013, October). Assessing the impact of video game based design projects in a first year engineering design course. In *Frontiers in Education Conference, 2013 IEEE* (pp.530-534). IEEE.

Scott, M., Bailey, T., & Kienzl, G. (2006). Relative Success? Determinants of College Graduation Rates in Public and Private Colleges in the U.S. *Research In Higher Education*, *47*(3), 249-279. doi:10.1007/s11162-005-9388-y

Scherger, N. (2013). The redesign of a quantitative literacy class: student responses to a lab-based format. *Teaching mathematics and its applications, 32*, 206 – 213.

Schermelleh-Engel, K., Moosbrugger, H., & Muller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online, 8* , 23–74. Available from http://www.dgps.de/fachgruppen/methoden/mpr-online/

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research*, *99*(6), 323-338.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and Quasi-experimental Designs for Generalized Causal Inference.* Belmont, CA: Cengage.

Stacey, K. (2012, July). The international assessment of mathematical literacy: PISA 2012 framework and items. In *12th International Congress on Mathematical Education* (pp. 8-15).

Tapia, M. (1996). *The attitudes toward mathematics instrument.* Paper presented at the annual Meeting of the Mid-South Educational Research Association, Tuscaloosa, AL (ERIC Reproduction Service No. ED 404165).

Tapia, M., & Marsh, G. E. (2004). The relationship of math anxiety and gender. *Academic Exchange Quarterly, 8*(2), 130 – 134.

Tariq, V. N., Qualter, P., Roberts, S., Appleby, Y., & Barnes, L. (2013). Mathematical literacy in undergraduates: role of gender, emotional intelligence and emotional self-efficacy. *International Journal of Mathematical Education in Science and Technology, 44*(8), 1143-1159.

Unsworth, N., Redick, T. S., McMillan, B. D., Hambrick, D. Z., Kane, M. J., & Engle, R. W. (2015). Is playing video games related to cognitive abilities? *Psychological Science, 26*(6), 759-74. doi:10.1177/0956797615570367

Verge Staff. (2015, Dec. 19). *The 10 Best Video Games of 2015*. Retrieved from https://www.theverge.com/2015/12/19/10130146/best-video-games-2015-xbox-one-playstation-ps4-nintendo

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin*, *140*(4), 1174.

Wade, B. & Goodfellow, M. (2009). Confronting statistical literacy in the undergraduate social science curriculum. *Sociological Viewpoints*, *25*, 75 – 90.

Wilkins, J. L. (2000). Special Issue Article: Preparing for the 21st Century: The Status of Quantitative Literacy in the United States. *School Science and Mathematics*, *100*(8), 405-418.

Wilkins, J. L. (2004). Mathematics and science self-concept: An international investigation. *The Journal of Experimental Education*, *72*(4), 331-346.

Wilkins, J. L. M. (2010). Modeling Quantitative Literacy. *Educational and Psychological Measurement*, *70*(2), 267 – 290.

Wilkins, J. L. & Ma, X. (2003). Modeling change in student attitude toward and beliefs about mathematics. *The Journal of Educational Research*, *97*(1), 52-63.