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Math state test scores of high school students across video game preferences

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The thesis entitled '**Math state test scores of high school students across video game preferences**' presented by **NOAH SAMMOND and TAYLOR WOODS**, candidates for the degree of **Master of Science in Mathematics,** has been approved and is worthy of acceptance.

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Abstract

Playing video games is one of the most popular ways for modern adolescents to spend their free time. Clearly, anything that takes up potentially hundreds or thousands of hours of a young person's life is going to affect various aspects of that person's development. Some video games are more cerebrally engaging than others, requiring logical reasoning and problem-solving skills, and yet only in recent years have researchers attempted to differentiate between video games based on their content. Experiential Learning Theory implies that spending time on more cognitively stimulating video games should positively impact the cognitive abilities of the player, but the displacement hypothesis suggests that video games are more harmful because they take away from time that would otherwise be spent on more directly beneficial activities. This study gathered survey and state test data from students at two very different high schools on opposite ends of the United States in early 2024, but after issues with parental consent forms, one school had to be excluded from the study. The data from 81 students were analyzed with descriptive statistics, ANOVA, and hierarchical linear regression analysis in order to determine if the types of video games that students spend the most time on affected their performance on the mathematics portion of their state tests, after controlling for self-reported gender and the amount of time they spend playing video games on average. None of the predictors – gender, time spent gaming, nor most played type of video game – were significant in either the ANOVA or the hierarchical linear regression, and effect sizes were very small. These results coincide with most prior video-game related research insofar as they indicate that if there is any impact of gaming on academic performance, it is either minimal or highly nuanced. Future research may reveal that

some relationship does exist between gaming and academic performance, but such studies will need larger sample sizes than that of this study and/or tightly controlled experiments.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

In chapter one, the problem of study will be introduced. This includes the background of the problem, the significance and purpose of the study, the research design and theoretical framework, and term definitions for the remainder of the analysis. Chapter one will also introduce the hypotheses of the study.

1.1 Introduction

Several hundred academic studies have been performed over the past half-century in attempts to explain the various potential impacts of video games on the general public. Everything from violence in games increasing aggressive behavior (Anderson, 2004; Ferguson, 2015; Gentile et al., 2004; Li et al., 2020; Möller & Krahé, 2009) to action games improving spatial cognition (Feng et al., 2007) has gotten some level of attention from the global academic community. However, only within the past few years have researchers begun to recognize the importance of examining the more nuanced aspects of video games such as genre, the times at which people choose to play, and with whom people choose to play. This study seeks to continue expanding the understanding of how some people are affected by the video games they play by comparing the state mathematics assessment scores of high school students based on the genres of video games on which they spend the most time. The study will further explore how this relationship is moderated by the amount of time a student spends playing video games, the type of day on which a student tends to play video games (either “school days” or “days off”), the gender of the student, and the school which the student attends.

1.2 Background

Over the past twenty years, research has been very divided on whether or not playing video games affects the academic performance of adolescents. Some researchers, like Drummond and Sauer, (2014) found no statistically significant difference in academic performance among adolescents across different frequencies of video game play. Other researchers such as Hartanto et al. (2018) found that time spent gaming on weekdays was slightly negatively correlated with academic performance among adolescents, whereas time spent gaming on weekends was slightly positively correlated. The survey used in the present study includes questions about the amount of time the student spends playing games on weekdays versus weekends in order to account for this factor. Yet another group of studies, including that by Bowers et al., (2013) concluded that time spent gaming had virtually the same impact on mathematics grades as time spent doing homework outside of class, participating in extracurricular activities, or reading. However, most research has concluded that spending more time playing video games tends to correlate slightly with a decrease in overall academic performance in adolescents (King et al., 2013; Gentile et al., 2004, Swing et al., 2010).

A few studies have attempted to categorize games to analyze their varied impacts. Gentile et al. (2004), differentiated between what they classified as violent and nonviolent video games, and Aleven et al. (2013) assessed students playing a game alone, cooperatively, and competitively. Some more modern studies have begun to recognize the importance of differentiating video games based on the type of game, but only in countries besides the U.S. (Dindar, 2018), or using only a few genres (Triberti et al., 2018; West et al., 2020). Thus far, no studies have specifically examined differences in the impacts of playing various video game genres on standardized mathematics assessment scores within the United States.

1.3 Statement of the problem and significance of the study

Gaming as a hobby has gotten a bad rap in public media in the past, particularly when it comes to minors and violence (McKernan, 2013). Many parents are worried that their children are becoming addicted, or that video games are taking the place of more academic pursuits (Kutner et al., 2008). Various studies have been conducted in attempts to justify or defend against these claims.

The problem is that some parents and educators are discouraging students from playing video games based on information obtained from inadequate research. It is the opinion of the authors that the choice of games being played is an overlooked factor in the consideration of whether or not a young adult should be discouraged from playing those games. This study aims to highlight that factor by comparing the state mathematics scores of high school students based on the types of video games that they play or prefer.

1.4 Purpose of the study

This study may inspire other researchers to consider the medium of video games more thoroughly when designing future studies. At the very least, the results of this study may encourage future researchers to specify the games or types of games played by their research subjects when gaming is a focal point of the study. Furthermore, any previous studies which treat video games as a uniform entity should be carefully scrutinized. In addition, this study will enhance previous research by connecting previously studied predictor variables to the response variable of state assessment scores of high school students, specifically in the subject area of mathematics.

1.5 Primary research question

This study's primary research question is, "Are self-reported gender, amount of time spent playing video games on school days, amount of time spent playing video games on non-school days, type of video game played most, and school significant predictors of state mathematics assessment scores among high school students in the United States?"

1.6 Hypotheses

The authors hypothesize that there will be some significant relationship between mathematical skill and video game genre preferences, and that the more thoughtful and strategic genres will correlate to higher math test scores. Conversely, it is expected that the more fast-paced and action-oriented genres will appear as preferred more frequently among the lower scoring students. It is expected that the results of this study will also confirm previous findings that males perform better on mathematics assessments (Gallagher & Kaufman, 2004), and that more time spent playing generally correlates with lower scores (King et al., 2013; Gentile et al., 2004, Swing et al., 2010). Finally, this study is hoped to confirm prior studies' conclusions that time spent playing video games affects academic outcomes more negatively when that time comes from school days than from days off (Hartanto et al., 2018).

1.7 Research design

The researchers crafted a short, simple survey and shared it with students at Shasta High School in Redding, California and at Cincinnati Christian Junior/Senior High School in Cincinnati, Ohio. Each student's survey responses were collated with their state mathematics assessment score to form the data set. Since this study is looking for correlations between the

responses from singular survey questions and raw test scores, and not trying to extrapolate to find latent variables, reliability and validity are not applicable measures for the survey.

The survey included questions about how much time the student typically spends playing video games on school days and on days off, what genres of games the student plays or enjoys, and what their favorite games are. The investigators also collected basic demographic information to be used as covariates. The responses to the survey questions became the independent variables, and the students' state math assessment scores collectively constituted the dependent variable.

In early 2024, consent forms were emailed to the parents and guardians of all students enrolled in a math class at either of the two high schools. Students at Cincinnati Christian Junior/Senior High School took the Iowa Assessment in October of 2023. In April of 2024, students at Shasta High School took part in CAASPP testing. After the consent forms were signed, the survey and assent form were emailed to students whose parents or guardians provided consent. In each math class, the teacher was given several instructions. They were told to inform students that their parents may or may not have consented to them taking the survey. The students were then to be given two opportunities for extra credit: Participate in the survey if their parent or guardian gave consent, or complete an alternative assignment if consent was not received by the parent or guardian or if the student did not want to participate in the survey. The teachers were also asked to encourage students to participate in the survey, advertising the fact that it involves video games, but also pointing out that the data gathered from students who do not play video games would be helpful. Finally, the teachers were told to emphasize the fact that participation in the survey is voluntary, and if the students had any questions about the study, they could contact the investigators using the contact information in the assent form.

Using the free statistical analysis software R (R Core Team, 2023), various statistical analyses were conducted, including descriptive statistics, ANOVA, and hierarchical linear regression. Descriptive statistics were found for each survey question and for ranks of state assessment results. ANOVA was used to compare mean test score ranks across most played video game genre category. Finally, a hierarchical linear regression model approach was used to determine which of the predictor variables affected the math scores.

1.8 Ethical considerations

The strategy of connecting each student's survey responses to that student's state assessment score necessitated collecting some basic personally identifiable information. Specifically, students in the California school were asked to provide student ID numbers and students in Ohio were asked to provide their name. The survey responses were not released to anyone other than the investigators of this study. Once the survey responses were received, the state test results were obtained from the school districts as soon as possible. The data were then collated, matching the survey responses with the corresponding test scores, and then immediately cleansed of all personally identifiable information.

An application for the conduction of this study was submitted to Shawnee State University's Institutional Review Board (IRB) on October 31, 2023. The application included certifications of the researchers on ethical research involving human subjects, copies of the parental consent and subject assent forms, an image of the survey from Google Forms, and a summary of the research to be conducted. After a few minor revisions, the application was approved by the IRB on December 4, 2023.

1.9 Theoretical framework

Human behavior is complicated. There are dozens of competing (or compatible) theories that attempt to explain how humans of various ages learn and act in any given context. When it comes to learning from video games, two of the most frequently cited theories are Self-Determination Theory (SDT) and Experiential Learning Theory (Krath et al., 2021).

Self-Determination Theory is a meta-theory that claims to explain how people are motivated to action, including describing different types of motivation and their efficacies (Ryan and Deci, 2017). According to SDT, intrinsic motivation is the strongest form of motivation and occurs most readily when a person experiences feelings of autonomy, competence, and relatedness. Video games inherently facilitate autonomy, as the player is literally holding a controller (or using a mouse and/or keyboard), and can make things happen in the game at the push of a button. Many modern video games incorporate dynamic difficulty (automatically adjusting the difficulty of the game based on player performance), or at least allow the player to choose from various difficulty modifiers, in hopes of matching the difficulty of the challenges in the game to the changing skill levels of the players. Relatedness is the most conditional of the three intrinsic motivation conditions when it comes to video games. Players probably feel some sense of belonging when playing a game with other human players (though they may also feel alienated, depending on the behavior of those other players), but even the fictional characters in a single-player game may engender feelings of community under certain circumstances. Thus, video games make for suitable tools to generate strong, intrinsic motivation for the player to continue playing and improving their skills within the game.

Experiential Learning Theory is much more straight-forward than Self-Determination Theory. David A. Kolb presented this theory in 1984, and described learning as “the process

whereby knowledge is created through the transformation of experience" (Kolb, 1984). Many modern role-playing games lay bare their formulas and calculations involved in determining the outcomes of specific actions, allowing players to not only see the direct impact of decisions, but sometimes to see how a decision could affect future decisions. For example, if a character's cunning statistic is determined by multiplying that character's charisma statistic with their intelligence statistic, the player could see how equipping an item that grants an increase of four charisma points would affect their cunning score, and compare that to an item that grants three intelligence points. This scenario gives the player a context that may be important to them, encouraging them to make an effort to understand how the game works and how various scores are calculated, so they can perform better within the game.

1.10 Assumptions, limitations, and scope

The study's sample suffers from a lack of ethnic and racial diversity. The investigators involved in this study were employed at the schools involved at the time of the study, and seeking meaningful participation from other schools was considered an inefficient use of the limited time permitted by Shawnee State University in which to perform the study as part of the Master's in Mathematics degree program. A large majority of students at both schools were caucasian, however no prior studies or theories were found indicating that race or ethnicity would be a meaningful confounding variable.

It was also assumed that the decisions of parents and students to consent/assent to participation in the study, i.e. self-selection bias, would not change the outcome. Though students were told that the study is related to video games, students were encouraged to participate regardless of how much time, if any, they spend playing video games regularly.

Due to the quantitative and non-invasive nature of this study, any evidence of a correlation between video game preference and mathematical skill could not be used to affirm any causal direction. Most likely, the relationship would work both ways; playing strategic video games would improve math skills and having high math skills would increase the likelihood of someone playing strategy games, as people are generally more likely to play games in which they perform well.

The generalizability of this study depends greatly on the results when comparing the two schools involved. A study from 2014 by Drummon and Sauer found that there was statistically significant variance in the impacts of gaming on academic performance between different schools. If the conclusions drawn about each school in this study are significantly similar, then despite the aforementioned study, it could be argued that the conclusions may apply to much larger populations, perhaps even the entire United States. If, however, the two schools perform differently, then the conclusions drawn at each school would likely only apply to schools very similar to each, in line with Drummond and Sauer's findings.

1.11 Definition of terms

1. Video games: For the purpose of this study, video games are any electronic pieces of interactive entertainment involving controlled images on a screen such as on a mobile device, a handheld gaming device, a computer monitor, a tablet, or a TV.
2. Adolescents: For the purpose of this study, adolescents are high school students in grades ninth through twelfth.

3. School days: For the purpose of this study, a school day is any given day in which a student in our study attended school, and thus potentially had less time to play video games.
4. Off days: For the purpose of this study, an off day is any given day in which a student in our study did not attend school, and thus potentially had more time to play video games.
5. Statistically significant: Data is considered to be statistically significant if the results appear to be due to more than chance alone, based on various statistical analysis techniques.
6. Negatively correlated: Two variables are negatively correlated if an increase in the one variable appears to correspond with a decrease in the other variable.
7. Positively correlated: Two variables are positively correlated if an increase in the one variable appears to correspond with an increase in the other variable.
8. Descriptive statistics: The descriptive statistics of a set of data includes quantitative data that was calculated such as a mean, median, frequency, standard deviation, variance, or range.
9. ANOVA: ANOVA is a common abbreviation of "analysis of variance", which is a statistical method for comparing two means of a quantitative variable across levels of a categorical variable.
10. Multiple Linear Regression: A statistical method for creating a model that predicts the value of a quantitative dependent variable based on two or more predictor variables.
11. Hierarchical Linear Regression: A statistical process where predictor variables are added one at a time (or sometimes in blocks) to a multiple linear regression model, keeping

track of each updated model, and primarily examining the change in variance explained to assess the predictive capabilities of each block of predictors.

12. Personally identifiable information: Any information within a study that can potentially be traced back to an individual involved in the study.

1.12 Summary

In this chapter, the fundamental concepts of the study were introduced. This was accomplished by exploring the problem being investigated and explaining the purpose behind the problem at hand. It was explained what video games look like through the lens of public media in modern times and the perception video games have as a whole, both positive and negative. The results of previously conducted studies, with a variety of results, were discussed to show that there is reason to dive further into whether the act of playing video games can be positively or negatively correlated with performance in school among adolescents.

This chapter was also used to introduce the primary research question (*Are self-reported gender, amount of time spent playing video games on school days, amount of time spent playing video games on non-school days, type of video game played most, and school significant predictors of state mathematics assessment scores among high school students in the United States?*), which aims to fill a gap in contemporary research caused by overgeneralization of the medium of video games as they relate to academic performance in the United States. The design of the study was briefly described, including the survey the students answered as well as what assessment data from the students were used. The ethical considerations of the study and the IRB application were documented. Next, the theoretical framework was constructed, composed of

Self-Determination Theory and Experiential Learning Theory. Finally, the assumptions and potential limitations or drawbacks to the study were addressed.

Chapter 2: Literature Review

In chapter two, the existence of the present study will be justified through a review of prior research in the fields of education, psychology, and media. This literature review will be divided into five sections based on different themes found within the literature.

2.1 Introduction

The first topic to be discussed in the literature review will be the various effects of video games on adolescent students. Specifically, the social, cognitive, and physical effects of gaming will be explored by compiling the conclusions of previous studies.

The second section will cover research that focuses on how playing video games on different types of days (either during the school week or during "off-days") may affect high school students differently. This section will also focus on the amount of time spent playing video games by students in general and why it is important to consider in this study.

Next, there will be a thorough examination of the theoretical framework used to develop this study. A clear explanation on the meaning and relevance of Experiential Learning Theory, Self-Determination Theory, and the selection hypothesis will be given, in the context of video game usage by high school students.

There will then be a brief discussion on the recorded associations between a student's gender and their success in school. This section will also touch on some of the previous work that has been done to determine if and how the specific school a student attends affects their success in state academic assessments.

Chapter two will close with a section on the definitions and relevance of the concepts of "validity" and "reliability" presented in the context of northern California's *California*

Assessment of Student Performance and Progress (CAASPP) and Cincinnati, Ohio's *Iowa Assessments.*

2.2 Why students should or should not play video games - the social, cognitive, and physical effects

Studies assessing the impacts of video games on humans tend to look for such impacts in three categories: physiological, psychological, and academic. In terms of the proposed physiological consequences of gaming, depending on the amount of time spent gaming and when that time is spent, most findings have been slightly negative. While games involving physical activity, such as Dance Dance Revolution, Wii Fit, and Beat Saber, have shown to induce physiological responses very similar to conventional exercise (Gao et al., 2015), the vast majority of video games are inherently sedentary in nature. Despite this, multiple studies, including meta-analyses, have found little or no meaningful correlation between gaming in general and body-mass index (BMI) (Desai et al., 2010; Marker et al., 2022), though one study in Turkey found that obesity was positively correlated with gaming addiction (Oflu & Yalcin, 2019). Some studies have found that playing violent video games before bed can worsen the quality of sleep in adolescents, however, the exact mechanisms by which this connection is made are unclear (King et al., 2013).

A slew of academic journal articles have been published making connections between violent video games and aggressive behavior in adolescents and children. These articles commonly cite what's known as the General Aggression Model (GAM), "...a comprehensive, integrative framework for understanding human aggression" (Allen et al., 2018). While it is beyond the scope of this study to address the efficacy or accuracy of the GAM, studies in this

field almost universally agree that exposing minors to violent video games increases their violent and aggressive tendencies, fitting the GAM (Anderson, 2004; Gentile et al., 2004; Li et al., 2020; Möller & Krahé, 2009). However, a meta-analysis by Christopher J. Ferguson (2015) cited many of these studies as having significant shortcomings such as unstandardized measurements of aggression, lack of pretesting for aggressive tendencies, and even selective interpretations, and found the overall effect size of violent gaming on aggressive outcomes to be negligible.

The other major psychological thread of potential causality is between gaming and attention problems. A number of studies have made statistically significant connections between gaming, especially as part of a clinical gaming disorder, and attention problems (Dullur et al., 2021; Gentile et al., 2012; Swing et al., 2010). A literature review in the Journal of Psychiatric Research found substantial comorbidity between gaming disorder (characterized by excessive gaming to the detriment of the patient) and Attention Deficit Hyperactivity Disorder (ADHD) (Dullur et al., 2021). Specifically, this review found that occurrences of gaming disorder and of attention problems were highly correlated, while gaming disorder showed a much weaker correlation with hyperactivity. These findings corroborate those of older studies on this topic (Gentile et al., 2012; Swing et al., 2010).

While most studies revolving around physical health and aggression agree for the most part, no one seems to agree on how gaming affects academic performance, if it does at all. Indeed, it seems that for every study that finds that each hour an adolescent spends gaming correlates with a grade drop of two letters (Corder et al., 2015), there's one claiming that gaming improves problem solving skills (Adachi & Willoughby, 2013) and another saying gaming and academics are completely unrelated (Dindar, 2018). The majority of studies on this particular topic argue for or against a displacement hypothesis, which posits that spending time playing

video games uses up time that would otherwise be spent on more broadly beneficial pursuits including sleep, exercise, or homework (Adžić et al., 2023; Drummond & Sauer, 2014, 2020; Gentile et al., 2004, 2012; Hartanto et al., 2018, 2021; King et al., 2013; Marker et al., 2022; Tak & Catsambis, 2023; Weis & Cerankosky, 2010).

Considering the strength and consistency of conclusions regarding the effects of gaming on sleep, aggression, and attention, and given that all of these factors have been shown to moderate academic performance (Curcio et al., 2006; Polderman et al., 2010; Vuoksimaa et al., 2021), it would appear that gaming should, by every metric, worsen academic performance. Why, then, has the extant literature been so divided? Most likely, both the process of human learning and the medium of video games are simply much more complex and nuanced than even most modern research has yet considered. The present study seeks to assert one of these potential nuances in gaming, namely, the choice of game.

2.3 Types of days on which students play video games (school days versus days off), and the amount of time spent

Drummond and Sauer have made compelling arguments against the displacement hypothesis through their studies using data from the Programme of International Student Assessment (PISA). This periodically updated dataset contains information from hundreds of thousands of students from dozens of countries, including surprisingly granular reports on student video game use as well as psychometrically validated assessments of academic performance. In their initial study, Drummond and Sauer (2014) found negligible correlations between the amount of time students spent playing video games and their performance on the standardized tests. In 2020, taking into account the work of Haranto et al. (2018), Drummond

and Sauer further refined their analysis on a more recent PISA dataset by considering what proportion of gaming time occurred on weekdays versus weekends, and during what day phases (morning, afternoon, or evening). In this later iteration, they found that only students who played video games before school on weekdays had statistically meaningfully lower academic scores, while those who played video games after school or on weekends performed very similarly to those who played no games at all. In only a few years, it seems that these researchers have unveiled just one more aspect of the convoluted relationship between gaming and academics. Drummond and Sauer conclude that these findings provide evidence for a third-variable hypothesis, in which the relationship between time spent gaming and academic performance are both causally correlated with some other unmeasured variable, however they call for future research to determine what this third variable might be. The current study hopes to answer that call.

2.4 Theoretical framework: A discussion on Experiential Learning Theory, Self-Determination Theory, and the selection hypothesis

One variable which Drummond and Sauer (and indeed many past researchers) have failed to consider in seeking the impacts of video games has been the exact choice of game. Clearly, the explicit choices involved in media consumption should have some varying effects on the consumer, particularly when that consumer is still in the earlier stages of human development. A child who grows up watching religious movies like Veggie Tales is certainly not going to be affected the same way as a child who similarly watches James Bond films, and a teenager who reads historical non-fiction books would receive different benefits and detriments to one who sticks to comic books. The varying impacts of video games should be even more pronounced,

considering the passive nature of consuming television, movies, and books compared to the much more immersive and interactive nature of video games.

Only within the past decade or so have academic researchers begun making a point of identifying the specific games and types of games involved in their studies beyond simply "violent" and "non-violent". Unfortunately, most of these studies have failed to cite any particular theoretical framework justifying a link between game type and the learning process (Dindar, 2018; Oflu & Yalcin, 2019; Rehbein et al., 2016; West et al., 2020). One of the most prominently cited theories across all of gaming research is Experiential Learning Theory (Krath et al., 2021). According to the Institute for Experiential Learning, this theory, presented by David A. Kolb in 1984, claims that learning occurs more effectively through experiences rather than rote memorization or observation ("What Is Experiential Learning?," n.d.). Since video games are largely interactive activities that change and react to the player's input, this should make them particularly suitable contexts for learning and practicing skills. The question then becomes exactly what skills a player is learning, and how well those skills translate into academics and real-world situations.

Where Experiential Learning Theory is one way to explain how the choice of game might impact a learner, Self-Determination Theory and the selection hypothesis are interpretations of how the learner would impact the choice of game. Self-Determination Theory (SDT) is a broad meta-theory that attempts to explain how and why people are motivated to action (Ryan & Deci, 2017). In brief, SDT claims that intrinsic motivation is the strongest form of motivation, and that it is fostered by feelings of competence, autonomy, and relatedness. In terms of relevance to the topic at hand, if certain games incorporate skills that are academically valuable, then students who are already talented in those skills would be more motivated to play those games, as doing

so would likely induce more feelings of competence. This predisposition for any given person to choose a game or type of game based on pre-existing personal traits is precisely the selection hypothesis cited by previous video game-related papers as a potential alternative explanation for correlations between game choice and academic achievement (Adachi & Willoughby, 2013; Boot et al., 2008; Dindar, 2018; Ferguson, 2015; Möller & Krahé, 2009). Unfortunately, only experimental and/or longitudinal studies can provide meaningful evidence for or against these interpretations, but these methodologies were not feasible within the constraints of this thesis.

2.5 School and gender

Several modern studies have concluded that males generally spend more time playing video games than females (Adžić et al., 2023; Dindar, 2018; Tak & Catsambis, 2023) and that gender is a statistically significant predictor of academic performance in various subjects (Adžić et al., 2023; Ghazvini & Khajehpour, 2011). Thus, including gender as a covariate is thoroughly justified in any study involving gaming or academics.

Studies have shown mixed results in terms of whether or not the relationship between gaming and academic performance varies significantly between schools (Drummond & Sauer, 2014, 2020). This study includes students from two extremely different schools within the United States, as those were the only two schools to which the investigators had the necessary access. During statistical analysis, it will be determined whether or not it would be appropriate to combine the populations of the two schools based on their statistical similarity.

Research involving video games typically includes only participants within a singular age group, and thus do not have cause to control for age in their analyses (Hartanto et al., 2018; Tak & Catsambis, 2023). As this study follows this trend, with student outcomes only being

compared between students of significantly similar ages, age will not be considered in the analysis.

2.6 Validity and reliability of high school state mathematics assessments

Researchers have used a wide variety of metrics to assess student academic performance over the years. However, not all metrics are created equal. While the primary purpose of a class grade is to reflect the student's mastery of course content, simple grades and grade point averages (GPAs) lack the rigorous validity and reliability testing of standardized state tests (as these measures are largely unnecessary for the intended purposes of grades). As such, when attempting to empirically compare the educational efficacies of students, it is only best practice to seek out assessments with evidence of validity and reliability whenever possible.

In the world of statistical research, the validity of a test specifically refers to the extent to which a test accurately measures what the test is intended to measure for a given population. For example, a state mathematics test designed to measure arithmetic skills of elementary school students should be considered psychometrically valid if elementary school students who perform well on that exam necessarily excel at arithmetic.

Reliability, on the other hand, refers to the consistency of an exam. An exam is considered psychometrically reliable if, when that test is administered multiple times to members of the same population, the results are statistically similar. Clearly, both reliability and validity are necessary qualities for any metric to be considered academically rigorous.

Most standardized state tests in the United States have at least some form of validity and reliability evidence (*Technical Methods Report*, n.d.). In California, high school students in their 11th year of schooling are tasked with the California Assessment of Student Performance and

Progress (CAASPP), an adaptive electronic assessment based on the Smarter Balanced Assessment system (California Assessment of Student Performance and Progress Smarter Balanced Summative Assessment 2021–22 Technical Report, 2023). This test has an abundance of validity and reliability evidence that shows that it effectively measures students' understanding of the Common Core State Standards (CCSS). The CCSS, in turn, has its own reports containing validity and reliability evidence, allowing researchers to conclude that if a student thoroughly understands Common Core mathematics, then they are well prepared for higher education or vocational school (Conley et al., 2011).

In Ohio, high school students in 9th and 10th grade, as well as select students in 11th and 12th, are given the Iowa Assessment, which is also an online state achievement assessment that covers several core subjects, including mathematics. The Iowa Assessments thankfully also have ample evidence of validity and reliability as an assessment of Common Core proficiency and readiness for postsecondary education in high school students (Hoover et al., 2015). Thus, both the CAASPP and the Iowa Assessments make for suitable means to measure high school achievement in mathematics.

2.7 Conclusion

The process of learning and the medium of video games are both so vast and complex that research could continue expanding on this one connection for millenia. One important aspect of the connection between these two fields that this study seeks to clarify is how the specific genre of video games that adolescent students play may impact their ability to master mathematical concepts and the resulting effects on their state assessment scores.

There is plenty of research concerning the physical and psychological impacts of gaming on adolescents, but less exists related to the field of academic performance. The research that does exist linking video game play with academic performance tends to focus on other variables such as the relative timing of the gameplay or the indirect relationship between gaming and academics that manifests from the previously mentioned physical and psychological impacts.

Unfortunately, many studies involving the outcomes of playing video games lack any explicit theoretical framework. This is likely because, again, both the process of learning and interactive entertainment are simply not fully understood. This chapter attempted to justify the search for what may be an intuitive connection between applying logic and reasoning in video games and scoring highly on standardized tests that measure related constructs.

Based on the evidence presented in this chapter, it is clear that the results of the Iowa Assessments (taken by students attending Cincinnati Christian Schools) and the California Assessment of Student Performance and Progress (taken by students at Shasta High School) are legitimate candidates for the response variable of this study, as they have been proven to be psychometrically valid and reliable for the purpose of assessing meaningful math skills in high school students.

Chapter 3: Methodology

In order for a study to be academically rigorous, it must be replicable. This chapter seeks to meet that requirement by explaining in great detail how the data used in this study was collected and analyzed. It will be up to future researchers to assess and judge the effectiveness with which these methods measure the relationship between gaming and academic performance.

3.1 Setting and participants

The surveys for this study were provided to students at two schools: Shasta High School in Redding, California, and Cincinnati Christian Junior/Senior High School in Cincinnati, Ohio, both on opposite edges of the United States. Steps taken to obtain parental consent, student assent, survey responses, and state test scores were made as similar as possible between the two schools, but some differences did arise, particularly in the timing of events.

Cincinnati Christian Schools (CCS) is a private school district with two buildings in Cincinnati, Ohio. In total, during the 2023-2024 school year, CCS held a total of 705 students between kindergarten through 12th grade. The survey for this study was conducted in the Junior High/Senior High building containing 7th grade through 12th grade students. A majority of these students attended the associated elementary school (which hosts kindergarten through 6th grade students). As it is a private school, Cincinnati Christian Schools costs a significant amount of money for students to attend. Speaking with the director of admissions, it was found that of the 705 students enrolled in the 2023-2024 school year, roughly 79% of them were on a scholarship to attend the school. Of these 705 students, 62 were in 9th grade, 76 were in 10th grade, 71 were in 11th grade, and 47 were in 12th grade.

Shasta High School (SHS) is a public high school that is known to serve a disproportionately large number of socioeconomically disadvantaged students. According to measurements taken in 2023, within the approximately 1,300 students attending SHS, the percentage of students who were classified as socioeconomically disadvantaged was 45.4% (Kikut, 2024), whereas California was reported to have 12.2% of its population being categorized as impoverished (Kikut, 2024; *U.S. Census Bureau QuickFacts*, 2023).

Because this study included students from two very different schools on opposite ends of the United States, it is the aim of the researchers to generalize the conclusions of this study to all high school students within the U.S. However, there have been studies that found some slight variation between schools in the relationship between the amount of time students spend playing video games and their academic performance (Drummond & Sauer, 2014). This will be addressed in chapters four and five.

3.2 A Priori power analysis

An a priori power analysis was conducted using the free statistical software *G*Power 3.1* (Faul et al., 2007). Considering the fact that hierarchical regression uses the F-statistic, the "F tests" family of statistical tests was chosen. Then, the specific statistical test, "Linear multiple regression: Fixed model, R^2 increase" was selected because that name corresponds to hierarchical regression (Gupta, 2021). A priori power analysis was chosen from the next list of options, and finally the parameters of the power analysis were entered to obtain the statistically preferred sample size.

The average effect size of time spent gaming on academic performance was estimated to be between .02 and .20 by a comprehensive meta-analysis (Ferguson, 2015). In 2014,

Drummond and Sauer found, with a very large data set, effect sizes of gaming time on academic performance between 0.08 and 0.18. In 2020, those same researchers found further similar results, with all effect sizes below .20. In addition, because prior research in the field of video games has shown that gaming tends to have very small effect sizes in terms of the impact on academic performance (Adachi & Willoughby, 2013; Adžić et al., 2023; Hartanto et al., 2018), the estimated effect size input to G*Power for this analysis was .02.

The industry standard values of .05 for alpha and .80 for desired power level were then input into the program. Since the final model would be primarily assessing the impact of a single time-related variable and three dummy variables representing preference for different video game genre groups, the number of "tested predictors" was set to four, and the total number of predictors was set to five, to include the dichotomous variable of gender. According to G*Power 3.1.9.7, these parameters would require a sample size of 602 students in order to be fully realized.

However, as stated by Field et al. (2012), a sample size numbering 15 subjects for each predictor variable is sufficient to establish model efficacy in multiple regression analysis. Since hierarchical regression is a type of multiple regression, this rule of thumb applies. This study had a total sample size of 81. The full model had a total of five variables, so the sample size of this study was adequate.

3.3 Instrumentation

The survey used in this study (see Appendix B) was created in Google Forms by the investigators at the start of the 2023-24 Shawnee State University mathematics thesis program, specifically for the purpose of the study. The authors simply determined the variables needed to

perform the desired analysis (time spent playing video games, video game genre preference, most played video game genre, etc.) and asked the survey taker to provide that information. The survey also included a question which prompted the student to list their three favorite video games and briefly describe why they enjoy those games. The primary purpose of this question was to attempt to verify that the student understood the video game genres presented. For example, if a student said that they only play role-playing games, but then listed multiple fighting games as their favorites, that student's data would likely be discarded as there was clearly some miscommunication through the survey or mistake from the student filling it out. The question on the survey asking the student to check a box indicating all video game genres they typically enjoy was originally intended to allow for further analysis. However, because the responses would have to be coded with a large number of dummy variables, the unfortunately small sample size made such analysis ineffectual.

The survey was never intended to assess some underlying constructs or latent variables within survey takers, so validity and reliability are moot points. However, it is still worth considering how accurately a person, particularly a minor, is willing and able to answer the questions as they were presented, as simple as they were.

Preferences in video games and time spent on video games can vary significantly over time, as with most leisure activities. Furthermore, despite the fact that genre options were provided with brief descriptions and several popular and quintessential examples of games from that genre, there is no way to fully verify that any student's selections reflected their actual preferences or time spent with each genre. Many video games also combine features of multiple genres, making the choice of a single favorite or most played genre that much more difficult for students. Studies have also revealed that a person's perception of time very readily dilates while

playing video games, distorting the amount of time that the person feels has passed (Igarzábal, 2019). However, the authors had no way of recording the amount of time any student spent playing video games. So while the accuracy of these survey questions is difficult to assess, there were simply no better options for acquiring this data.

Fortunately, other measures of mathematical aptitude were available to the researchers for this study. Both the Iowa Assessments and the CAASPP have multitudinous works representing both validity and reliability evidence in their appropriateness for measuring student academic outcomes in high school in the U.S. (2020-21 Summative Technical Report, 2022; California Assessment of Student Performance and Progress Smarter Balanced Summative Assessment 2021–22 Technical Report, 2023; Hoover et al., 2015; Conley et al., 2011).

3.4 Data collection

The data set of this study was initially intended to be formed as a combination of both Shasta High School and Cincinnati Christian Schools. However, due to the rise of several issues with the data from Shasta High School, it was decided in early April, 2024, to disregard all data collected from Shasta High School and focus the study on Cincinnati Christian Schools.

In section 3.4.1, the collection of data for the initial plan is detailed. In section 3.4.2, the removal of Shasta High School and the various reasons for doing so are explained.

3.4.1 Initial data

In December of 2023, the study was submitted for a full review and approved by the Shawnee State University Institutional Review Board (IRB) (See Appendix A). Within the same month, slight modifications of the consent and assent forms were made, and approval was

applied for once again and was received. Thus, the following gives the procedures completed for the study that comply with the IRB's rigorous regulations.

The students in Ohio took the Iowa Assessments in October of 2023. These assessments were taken by the students on their school-issued iPads over the course of one to two mornings depending on the number of subjects on which the students were required to test.

For this study, a list of all parents and guardians of high school students (grades 9th through 12th) was created using a school communications website called Facts (formerly known as Renweb) resulting in a collection of roughly 450 email addresses. In January, 2024, these email addresses were issued instructions on how to use DocuSign (an electronic signature software) as well as a brief explanation of the study. At the same time, a link through DocuSign containing the electronic parental consent form (see Appendix C-2) was dispersed to the same email addresses. After about one week of waiting for responses to come in and for the rate of responses to decrease, a list of student names was compiled from the properly filled out consent forms.

Next, a meeting was conducted with all of the Cincinnati Christian Senior High mathematics teachers to discuss the logistics of having students partake in the survey. In February, 2024, all students that had been given parental consent were sent the subject assent form (see Appendix C-3). Of these students, those who signed the assent form were asked to complete the survey. Those who accomplished both of these tasks earned one extra credit point in their mathematics course. Students who did not both sign the assent form and complete the survey were given an alternative extra credit bonus problem to work on, based on their respective math courses. This gave all students the opportunity to earn extra credit in their class, and not feel pressured one way or the other to sign the assent form and/or fill out the survey.

After receiving 111 Google Form survey responses, 7 were either duplicates or had not signed the assent form, leaving 104 valid responses from CCS students for this study. Of these 104 students, 23 did not have assessment data available, leaving 81 total data points from CCS students for this study.

Unlike students in Ohio, who took their yearly state assessments in the fall, Californian high school students took the CAASPP in early April. For this study, teachers of the math department at Shasta High School were addressed at a staff meeting in January, 2024, to request their assistance with the thesis study process. Shortly thereafter, a message was sent out through the communication platform ParentSquare (see Appendix C-1), to the email addresses of the 1,959 parents that the school had on file for enrolled students. This message included a Google Form which asked the parents to provide their name and email address directly to the researchers, indicating agreement to receive the electronic consent form. Ninety parents correctly filled out the Google Form, resulting in 90 electronic consent forms being sent out through DocuSign in early February. After one week, signed consent forms were inspected, resulting in a total of 36 students for whom proper parental consent was acquired.

Because the students' email accounts were tied to and controlled by the school district, they were not allowed to receive emails from outside sources, so paper assent forms were used instead of DocuSign. The paper forms with the students' names on them were given to the 36 students' math teachers and the teachers were asked to provide these papers to the corresponding students for reading and signing. It was emphasized to the teachers that no form of coercion to participate would be accepted throughout the study. Thirty-two students chose to sign their assent forms so that they could take the survey.

In mid March, the teachers were given a link to the survey Google Form. They were asked to either email the link directly to the students for whom consent and assent was verified, or to post the survey on their Google Classrooms, a web-based system to which the students had access. The teachers were then to set aside five to ten minutes for the students who provided assent to take the survey. The teachers were also told to give all students the choice to complete a short, simple assignment, the details of which were left up to each teacher, for those who chose not to or could not complete the survey. Teachers were instructed to make both the assignment and completing the survey worth equal amounts of extra credit points, so that there was no coercion to participate in the study. Ultimately, 25 Shasta High School students properly filled out the survey. However, one student responded to the question of gender with "prefer not to say", and while inclusivity of minorities is extremely important in research, a single data point is simply insufficient to draw any meaningful conclusions through data analysis, so this student's information was not included.

Finally, in the second and third weeks of April, 2024, 11th-grade students at Shasta High school completed CAASPP tests in their English and mathematics classes, while lower grade levels participated in practice tests called "interim assessments". Results of the tests were released to the school district in May, and the mathematics test results were then provided to the investigators for analysis.

None of the questions in the survey were invasive or controversial by any metric. Additionally, students were thoroughly informed that they could cease participation in the survey at any time and for any reason. The survey results did include school-based student ID numbers, which was necessary in order to pair survey responses with the corresponding mathematics assessment scores. This technically constitutes personally identifiable information, though only

someone with access to the school district's records would be able to identify any given student from the data gathered. Regardless, all data was collected while the students were under observation from school employees who were involved in or assisting the research, and all data was stored only in the researchers' Google Drives and personal devices. As such, despite the fact that there was no realistically probable scenario in which anyone would seek out this data, be able to acquire it, and decipher any meaningful information from it, the maximum reasonable security protocols were maintained throughout data collection and storage.

3.4.2 Data modification

Unfortunately, for students at Shasta High School, meaningful mathematics assessment data was only generated for students who took the real CAASPP, those being 11th-grade students, and only eight juniors completed the survey at Shasta High School. Furthermore, the data generated for those students was only valid for comparing those students to others within the same school district, and would not be appropriate for use in comparing students from Shasta High School to those in another state. Thus, the decision to exclude Shasta High School entirely from the data analysis was made. Data collected from Ohio proceeded to analysis.

Since the study no longer included two disparate high schools, the primary research question had to be modified. Furthermore, the small sample size significantly limited the allowed complexity of analysis that could be justified, and it was decided to discount the variation associated with the different time factors. Specifically, the final analysis would only make use of the overall average daily time spent playing video games, not the individual variables of time spent on school days or days off.

Previously, the primary research question was, "Are self-reported gender, amount of time spent playing video games on school days, amount of time spent playing video games on non-school days, type of video game played most, and school significant predictors of state mathematics assessment scores among high school students in the United States?" Due to the lack of variety in school, it seemed appropriate to adjust the scope of generalization to only private schools. The geographical scope of potential generalizability is also much more dubious, but it will be addressed in chapter five. Based on all these changes to the study, the new primary research question is as follows: "Are self-reported gender, amount of time spent playing video games, and most played type of video game significant predictors of state mathematics assessment scores among students of private high schools in the United States?"

3.5 Data processing and analysis

3.5.1 Data preparation

After all survey responses were received, the data were converted into a CSV (Comma Separated Values) file and inspected for anomalous survey answers. A few students indicated in the “time spent gaming” and “favorite game” questions that they do not play video games, but still chose favorite genres in later questions. These answers were modified to align with what the student actually indicated. Video game genre preferences were then coded with dummy variables (as detailed in section 3.5.3.1). The state mathematics test results were appended to the data, with each student’s survey responses being associated with that student’s ranking. Finally, the data were wiped clean of personally identifiable information and students were randomly assigned ID numbers from 1 to 81. The resulting data was input to the free statistical analysis software, R.

3.5.2 Hierarchical regression

The primary statistical analysis technique chosen for this study was hierarchical regression, a type of multiple linear regression (MLR). MLR attempts to create a linear model based on an equation of the form

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k$$

where $\hat{Y}$ represents the predicted value of the quantitative dependent variable, b_0 represents the intercept, each b_i represents the *i*th predictor variable's coefficient (the amount by which it increases the dependent variable's value for each unit), each X_i represents the *i*th predictor variable's value, and k is the number of predictor variables (Siegel & Wagner, 2022).

Hierarchical regression in particular involves creating multiple, separate, MLR models, starting with only a chosen subset of the available predictors, then adding more predictors and determining if the overall model becomes more effective at predicting the response variable. It is common practice to group the predictors based on how relevant they are to the actual purpose of the study, and most modern implementations of hierarchical regression begin with a model containing only the variables for which the researchers wish to control, then add the treatment variables in proceeding models (Arshad et al., 2023; Sipahioğlu et al., 2023; Yıldız & Körpeoğlu, 2023).

In this study, the focus was determining the relationship (or lack thereof) between the genre of video game a high school student plays most and their performance on standardized mathematics assessments. As cited previously, there is evidence that the gender of a student may have some association with both gaming activity and academic performance, though this factor was not the target of this study, so it was considered a control variable and added to the initial

model. The variable representing time spent on gaming was clearly related to the research goals, but it was still not the primary focus, so it was added in a second model. Finally, the most central predictor variable, the student's most played genre of video game, was added in a third model.

To create a linear regression model in R, one can represent non-numeric variables numerically. This is commonly achieved using "dummy variables" (*Including a Dummy Variable Into a Regression*, 2018). For a given categorical variable, one level is chosen to be the "reference", and every other level is assigned a dummy variable which can take on a value of zero or one. A data point corresponding to the reference value would have zeroes entered for each of the dummy variables representing levels of the original categorical variable; a data point in one of the other categories would have only a one corresponding to that category's dummy variable, and zeroes elsewhere. For dichotomous variables, the choice of reference is arbitrary, though the decision determines the interpretation of the final results. For this study, although the question of gender in the survey was left as free-response, the vast majority of surveys completed included explicitly "male" or "female" responses. As stated previously, one student gave a response that could not be clearly attributed to "male" or "female", which was discarded due to insufficient data points for a third category. Thus, gender was rendered dichotomous, and "Male" was arbitrarily coded as the reference.

For categorical variables with more than two levels, the reference must be chosen more thoughtfully, as each regression model coefficient only compares outcomes between the reference category and one other category, not between two non-reference categories (*Dummy Variable | Interpretation and Examples*, n.d.). Since the hypotheses focus on the effect of strategic and logic-based games, that collection of genres was coded as the reference category in the genre preference variables.

The model summaries in R described the significance, or lack thereof, of each model, allowing for interpretation of how effective the predictor variables were, collectively, at predicting the response variable. Because this study used hierarchical regression, it was important to look at the change in the R^2, which represents the amount of variance collectively explained by the included predictor variables. The change in R^2 was assessed using ANOVA (analysis of variance) commands on each pair of consecutive models to determine whether or not the change in variance explained was statistically significant.

Finally, the effect sizes of the models were calculated. The effect size for each model in the steps of the hierarchical regression is the value Cohen's f^2, which is calculated by the following formula:

$$f^2 = \frac{R^2_{AB} - R^2_A}{1 - R^2_{AB}}$$

R^2_A is the coefficient of determination of a given regression model with the set of predictor variables A, and R^2_{AB} is that of the model where a set of predictor variables, B, are added to the first model. An effect size of f^2=0.02 is considered a small effect, while 0.15 is a medium effect and 0.35 is a large effect (Dierker, et al., 2012).

3.5.3 Variables

The predictor variables chosen for this study were gender, average daily time spent gaming, and most played video game genre. As stated in the previous section, gender was coded dichotomously, with male as the reference category.

3.5.3.1 Video game genres

Since genres of video games, like genres of books and movies, are decidedly nuanced and frequently overlap in practice, effectively coding a student's most played genre was a challenge. The survey presented students with a total of 15 different genres, chosen in an attempt to minimize overlap without excluding any types of games. Each of these genres, however, has defining characteristics to distinguish them from one another. For example, role-playing games have players controlling one or more characters who experience some form of growth throughout the game, most often represented using "experience points" and "levels". Puzzle games require thoughtful action, analysis, and logic. Fighting games involve two or more characters engaged in direct combat, and typically require skills in timing and precision. However, as different as these genres are, many modern games try to blend multiple genres in a single experience, making categorizing any given game that much more difficult.

Unfortunately, the more predictor variables are involved in multiple linear regression, the larger the sample size is required in order for resulting conclusions to be academically rigorous. As such, it was deemed unreasonable to keep all 15 genres separate, which would have necessitated 14 additional dummy variables. Instead, to highlight the expected differences caused by students playing the different genres, the genres were grouped into three categories: highly strategic, logical, and thoughtful games; highly action-oriented and motor-function-focused games; and, games that significantly involve both strategy and action. This categorization required two dummy variables for analysis, though one additional dummy variable was included for students who indicated that they do not play video games. As stated previously, the category of strategic games was made the reference in order to align with the hypotheses of the study.

Much discussion was had between the investigators to ascertain the most appropriate segregation of video game genres into the three overarching categories. The three categories were given the titles of "Logic and Reasoning", "Action", "Mixture". Of the fifteen genres listed on the survey (see Appendix A), five were assigned to the Logic and Reasoning category, five were denoted as Action, and five were considered Mixtures.

One small note: Two students indicated in the "favorite game" short-answer question that they don't play video games, and listed their average gaming time as zero hours per day, but still indicated preferred genres in the "most enjoyed" and "most played" genre questions. Since this was most likely the result of the researchers neglecting to include an option in each question to indicate that the survey taker does not play video games, these students were coded as not playing video games rather than with the genres they arbitrarily selected.

For the purposes of this study, genres that fall under the "Logic and Reasoning" category are those that prioritize logic and planning to overcome challenges. Usually these games allow the player time to think about their decisions and to formulate strategies before engaging in tasks or in combat.

Genres such as "puzzle" and "turn-based strategy" clearly fall into this category, as their names give away exactly what those games entail. In addition, "turn-based RPGs" (turn-based role-playing games) are games that allow the player to make decisions on how to proceed in combat without any sort of time pressure, before allowing their opponent to do the same, somewhat akin to a board game. These genres absolutely favor thoughtful planning and strategy over timing, precision, and reflexes, and so belong in the "Logic and Reasoning" category for this study.

MMORPGs (massively multiplayer online role-playing games) are highly social games that typically take place on centralized servers, which players join and can interact with each other in real time. These games almost universally have combat which does require some level of timing and speed among the players, though much less so than many other genres of game. At the higher levels of play, MMORPGs necessitate that players not only work together, but coordinate, plan, and prepare for larger-scale fights and events. Many MMORPGs can also be extremely complicated, to the point that any successful player must have spent some amount of time doing some research, experimentation, or analysis in order to determine how to maximize their odds of success on the battlefield. All these factors substantially overwhelm the minimal action-based aspects of the genre, earning it a place in the "Logic and Reasoning" category.

Exploration and narrative games are largely devoid of action-focused game mechanics that would land them in one of the other genres. These games are typically fairly relaxed, but may still contain various challenges. These could include environmental puzzles or complex social interactions with non-player characters, but rarely have any hazards or fail states. This makes exploration and narrative games largely cerebral in nature, and thus best suited to be labeled "Logic and Reasoning".

Action games in this context were characterized by a distinct lack of thoughtful planning and reasoning, with a much larger focus on precision in timing or complex motor function. Some genres, almost by definition, fit squarely into this category, such as rhythm games and fighting games. Rhythm games very rarely involve any planning or logic, and only require that the player practice certain movements to train muscle memory and reflexes. Fighting games, at higher levels of play, can require a skilled player to use psychology to read and predict an opponent, but

still rely on in-the-moment decision making and rapid button presses in intricate combinations, rather than developing and executing a broad strategy.

It would be easy for a casual onlooker to assume that first-person and third-person shooter games, racing games, and sports games could also be readily categorized as lacking any strategy or logic. However, many shooters are intended to be played with friends, and thus may encourage players to work together and strategize, and some racing and sports games have menus in which players can modify their vehicle or team, employing logic and analysis in order to maximize their effectiveness in future races and matches. Despite these relatively common, modern aspects that push their respective genres closer to being arguably categorizable as "mixtures" between action and logic, the core gameplay elements are still primarily relying on a player's ability to time inputs precisely and react to visual and audio feedback. As such, rhythm, fighting, shooter, racing, and sports games were labeled as "Action" games for the purpose of this study.

As stated previously, nearly every genre has at least some games that could easily be described as containing large numbers of both logical and action-oriented mechanics. However, most of the genres assigned here to the "Mixture" category are inextricably linked to both styles of gameplay. Real-time strategy (RTS) games, as their name would imply, involve making strategic decisions, planning, and executing on plans in real time, so it fits pretty clearly into this category. Similarly, action RPGs (action role-playing games) critically incorporate timing and precision as well as juggling numbers and strategy.

Platformers, by their nature, involve precision and dexterity, and sometimes even speed, in order to be played effectively, but the vast majority of platformer games also incorporate some puzzle-solving elements into their gameplay. The "puzzle-platformer" is also a substantial

sub-genre of platformers, and so it would be naive to simply relegate this genre to the "Action" category.

Simulation games are an oddball genre, as anything from farming, to flying a plane, to business management can be made into a commercially successful video game. While few of these games meaningfully make use of both action-focused gameplay mechanics as well as thoughtful strategy or logic, there are simply too many simulation games that focus on either type of engagement to easily pigeon-hole the entire genre as either "Action" or "Logic and Reasoning".

Action-adventure games are characterized, as their name would suggest, by both action and adventure. It is prototypical for an action-adventure game to have highly action-focused combat, interlaced with careful exploration, social interaction with non-player characters, and environmental puzzles. With such a wide variety of common gameplay elements, action-adventure as a genre was deemed to belong in the "Mixture" category.

Ideally, each of these genres, and perhaps even further sub-genres, would be analyzed independently. Unfortunately, such an analysis would require a much larger dataset than that which was available for this study.

3.5.3.2 Time spent playing video games

Some clarity is required regarding the measures of time students spent playing video games. In the survey, two of the questions posed to students were: "On average, how many hours do you spend playing video games on a school day?" And, "On average, how many hours do you spend playing video games on a day off from school?" Combining these responses using the expression $\frac{5A + 2B}{7}$, where A is the response to the first question and B is the response to the

second question, a value can be generated that represents the average amount of time that the student spends playing video games in a given day. This process has been used to find values to represent this quantity in similar studies in the past (Dindar, 2018).

3.5.3.3 State mathematics assessment scores

Students at Cincinnati Christian Schools took the Iowa Assessments and received two scores – a "Math Total Score" and a "National Percentile Ranking" (NPR). It was chosen for this study to track the NPR as a basis for mathematics assessments score in order to simplify calculations and interpretation of the results as the NPR is a number from 1 to 99. For example, if a subject's math score in this study was "90", that would indicate that the given student scored better than 90% of all students who took the assessment. Since the Iowa Assessments have been established as valid and reliable for interpreting the mathematical prowess of high school students, they were a suitable measure for the purposes of this study.

3.5.3.4 Descriptive statistics and ANOVA

In addition to hierarchical regression, descriptive statistics for the data used in this study were generated, including means and standard deviations of the quantitative variables such as assessment score and hours played. Qualitative data was also arranged in tables to show the breakdown of gender, grade level, age, and most played genre of video game.

Analysis of variance (ANOVA) was also performed in order to give further context to the primary analysis, with the independent variable being video game genre category and the dependent being state mathematics test scores. The statistical assumptions assessed for ANOVA

were normality of the dependent variable, homogeneity of variance between groups, and independence of cases.

3.5.4 Hierarchical linear regression assumptions

In a multiple regression model (which is the type of model being analyzed at each step of the hierarchical regression process), there are various assumptions made about the data and variables that are necessary in order for academically substantiated conclusions to be drawn from the final results. Some of these are simple, such as having a quantitative response variable that is continuous in value, the inclusion of at least two independent variables, and a lack of major outliers (Fein et al., 2022). However, there are a few statistical assumptions that require analysis to be done either by hand, or as was done here, using statistical computing software such as R. The four major assumptions that must be assessed for MLR are independence of subjects, low multicollinearity of the predictor variables, homoscedasticity, and normality of the residuals (Fein et al., 2022).

Independence is typically evaluated or established qualitatively. In other words, if researchers have substantial reason to believe that individual cases did not influence each other in data collection, then the independence assumption is considered to be satisfied. In this study, there is a small concern for independence as the data were collected from students who were grouped in classrooms. However, students were observed while filling out the survey to ensure that no meaningful interaction occurred between them while they answered the questions. Similarly, students taking the Iowa Assessments did so in secure testing environments, and so were not allowed to interact at the time. Thus, there is no reason to believe that any measurements unduly influenced any others.

The second assumption to test is multicollinearity. A multiple regression model is considered to have multicollinearity if two or more of the predictor variables are highly correlated with each other (Fein et al., 2022). The optimal result in a multiple regression model is to have little to no multicollinearity, as this ensures that the amount of variance explained by each predictor is correctly attributed to that predictor alone. If a specific predictor variable is highly correlated with other independent variables in the multiple regression model, then it becomes much more difficult to determine which of the independent variables is meaningfully related to the dependent variable (Fein et al., 2022). According to *Statistics How To*, the variance inflation factor (VIF) "estimates how much the variance of a regression coefficient is inflated due to multicollinearity," (*Variance Inflation Factor*, 2015) and is found using the equation $VIF_i = \frac{1}{(1-R_i^2)}$ where R_i^2 is "the unadjusted coefficient of determination for regressing the i^{th} independent variable on the remaining ones" (The Investopedia Team, 2023). Most modern statisticians agree that a VIF greater than 10 is cause for concern, though as with many aspects of statistical analysis, it is ultimately a matter of context and subjectivity (*Variance Inflation Factor*, 2015).

Homoscedasticity, or homogeneity of variance, is the assumption that residuals are, on average, the same between different values of a given independent variable (*Assumptions of Multiple Linear Regression*, 2021). The veracity of this assumption can be established by plotting standardized residuals against predicted values, with homoscedasticity coming into question only if a pattern is visible within the data. If there is a cone-shaped pattern in the scatter plot, researchers may need to apply a transformation to the dependent variable to salvage viability of the analysis (*Assumptions of Multiple Linear Regression*, 2021).

The final assumption in MLR is that of residuals being approximately normally distributed. This can be checked with the Shapiro-Wilk normality test (*Normality*, 2021). An alternative means of determining normality among residuals would be a histogram, which could be visually inspected to verify that the error values follow an approximately normal distribution curve (Fein et al., 2022). The analysis of a quantile-quantile (Q-Q) plot is also useful to test for normality of the residuals (*Regression Diagnostics with R*, 2023).

Regression lines may be significantly influenced by the presence of outliers. A common way to identify outliers within a dataset is to look for unusually high or low standardized residuals in the analysis. Any cases which yield a standardized residual greater than three are generally considered to be outliers, and may be removed from the analysis in order to create a more reliable model. (*Z Score for Outlier Detection - Python*, 2020).

Each of the variables considered here has been used in some form in prior research. Gender is included in virtually every piece of academic literature on gaming or academic performance (Ferguson, 2015; Hartanto et al., 2018; Marker et al., 2022). State tests are designed to meaningfully measure overall competence in each subject, and so have been used to measure academic performance many times (Corder et al., 2015). Finally, gaming data is almost universally self-reported through surveys or similar methods (Desai et al., 2010; Drummond & Sauer, 2014, 2020; Hartanto et al., 2018).

3.6 Summary

The purpose of this chapter was to maximize transparency and replicability for the study at hand. The data collection took place at two very different high schools on opposite ends of the United States, though Shasta High School's data was deemed insufficient and was discarded. A priori

power analysis was performed using industry standard practices, with the exception of a low effect size, the choice of which was prompted by prior research findings. Custom-made surveys were provided to students for whom parental consent and student assent could be attained. Once the state test scores were paired with the proper student's survey responses, the data were expunged of personally identifiable information, and prepared for analysis. The resulting dataset was analyzed with hierarchical regression and ANOVA to determine the change in variation explained by the predictor variables before and after the central variables were added to the model. The output of the analysis is presented in chapter four.

Chapter 4: Results

In chapter four, the results of the statistical analysis will be conducted and reported on, as outlined in the methodology. Results of descriptive statistics and ANOVA tests will be presented in this chapter as well to give more context to the data set being used. The statistical assumptions for all model types used are tested and presented in this chapter. The model comparisons between each step in the hierarchical regression are presented in this chapter as well.

4.1 Purpose of study and hypotheses

The primary research question of the present study was, "Are self-reported gender, amount of time spent playing video games, and most played type of video game significant predictors of state mathematics assessment scores among students of private high schools in the United States?" The researchers hypothesized that all three variables would be significant, albeit minimally impactful, predictors.

The researchers hypothesized that students who most frequently play more strategic or cerebral games would have a more positive correlation between time spent gaming and mathematics assessment score. The researchers also expected to find evidence to support prior academic research conclusions that playing video games on school days is generally more detrimental to academic performance than is playing video games on days off. However, as stated in chapter 3, the unforeseen small sample size prohibited proper analysis to assess the individual time variables. The results of the analysis are presented in this chapter.

Using the available survey responses of 81 high school students from Cincinnati Christian Junior/Senior High School, and their corresponding state mathematics test scores, this study sought to determine the extent to which video game genre preferences moderate the effect

of time spent gaming on mathematical proficiency. Hierarchical linear regression analysis was performed in search of answers to these research questions.

4.2 Descriptive statistics

Of the students sampled (N = 81), 47 (58.0%) self-reported their gender as male, and 34 (42.0%) as female. Ages ranged from 14 to 17 years old, with a mean age of 15.89 years old and a standard deviation of 0.99 years. Fifteen students (18.5%) were in 9th grade, 28 (34.6%) were in 10th grade, and 38 (46.9%) were in 11th grade. Additional descriptive statistics for quantitative variables are presented in Table 1 below.

Table 1: Quantitative descriptive statistics

Variable	Mean	Std. Dev.	Median	Range	IQR
Age (Years)	15.89	0.99	16	3	2
Math Score (NPR)	81.37	15.51	87	61	26
School-day gaming time (Hours)	1.14	1.55	1.00	10	2
Day-off gaming time (Hours)	2.96	2.83	2	13	3
Total average daily gaming time (Hours)	1.66	1.79	1.29	10.86	2.00

None of the students surveyed chose “Turn-Based RPGs” or “MMORPGs” as either their most played or most enjoyed video game genre. “Turn-Based Strategy” was never chosen as “most played genre”, and “Simulation” was never chosen as “favorite genre”. Furthermore, seven students (8.6%) indicated that they do not play any video games. The genre of “Shooter”

was by far the most played (35.8%) and most enjoyed (27.2%) among the sample. The chosen genres' frequencies and proportions are presented in Table 2 below.

Table 2: Frequencies (and proportions) for preferred video game genre among high school students surveyed at CCS

Genre	Most Enjoyed	Most Played
Action-Adventure	8 (9.9%)	5 (6.2%)
Action RPG	2 (2.5%)	2 (2.5%)
Exploration/Narrative	4 (4.9%)	4 (4.9%)
Fighting	3 (3.7%)	2 (2.5%)
Platformer	4 (4.9%)	5 (6.2%)
Puzzle	6 (7.4%)	5 (6.2%)
Racing	7 (8.6%)	5 (6.2%)
Real-Time Strategy	3 (3.7%)	3 (3.7%)
Rhythm	3 (3.7%)	2 (2.5%)
Shooter	22 (27.2%)	29 (35.8%)
Simulation	0 (0.0%)	1 (1.2%)
Sports	11 (13.6%)	11 (13.6%)
Turn-Based Strategy	1 (1.2%)	0 (0.0%)

Table 3 presents frequency and proportion values for most enjoyed genre category, and most played genre category. Only one male indicated that they prefer a genre within the "Logic and Reasoning" category (specifically, the Exploration/Narrative genre), and only one male stated that they do not play video games.

Table 3: Frequencies (and proportions) for which a genre in each category was chosen as most enjoyed or most played among high school students surveyed at CCS

Genre Category	**Most Enjoyed**			**Most Played**		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
Logic and Reasoning	1 (2.1%)	10 (29.4%)	11 (13.6%)	1 (2.1%)	8 (23.5%)	9 (11.1%)
Mixed	12 (25.6%)	5 (14.7%)	17 (21.0%)	8 (17.0%)	8 (23.5%)	16 (19.8%)
Action	33 (70.2%)	13 (3.8%)	46 (56.8%)	37 (78.7%)	12 (35.3%)	49 (60.5%)
No Gaming	1 (2.1%)	6 (17.6%)	7 (8.6%)	1 (2.1%)	6 (17.6%)	7 (8.6%)

4.3 ANOVA

4.3.1 Testing statistical assumptions for ANOVA

The first assumption of ANOVA is that the dependent variable is approximately normally distributed. Both Shapiro-Wilk ($W = 0.894$, $p < .001$) and a visual inspection of a histogram plainly indicate that the data are not normally distributed. According to Laerd Statistics (*One-Way ANOVA*, n.d.), this is only cause for concern if the data show platykurtosis, meaning that the distribution has unusually flat tails (*Skewness and Kurtosis in R Programming*, 2020). However, using a statistical software package, “moments” (Komsta & Novomestky, 2022), the kurtosis of the math test scores was calculated to be approximately 2.282. This qualifies the dependent variable as having platykurtosis, and as such, Laerd Statistics advises pivoting to a corresponding non-parametric test, such as the Kruskal-Wallis rank sum test.

Kruskal-Wallis is a very similar test to ANOVA, with the only significant differences being lower statistical power and more lenient assumptions. Kruskal-Wallis does not require that the dependent variable be normally distributed, only that each group has at least five cases. Since

this new assumption is satisfied, as can be seen in the final column of Table 3 above, Kruskal-Wallis is appropriate.

4.3.2 Results of Kruskal-Wallis Rank Sum Test

The results of the Kruskal-Wallis rank sum test were not significant ($\chi^2(3) = 1.062$, $p = .786$), so the null hypothesis cannot be rejected. This implies that the median mathematics test score ranks are similar across students grouped by their most played video game genre category.

4.4 Testing statistical assumptions for hierarchical linear regression

In order for conclusions drawn from hierarchical linear regression analysis to be academically rigorous, the data and model must satisfy some assumptions. These assumptions are independence of the data points, homoscedasticity and linearity of the regression line, low multicollinearity, and roughly normally distributed residuals.

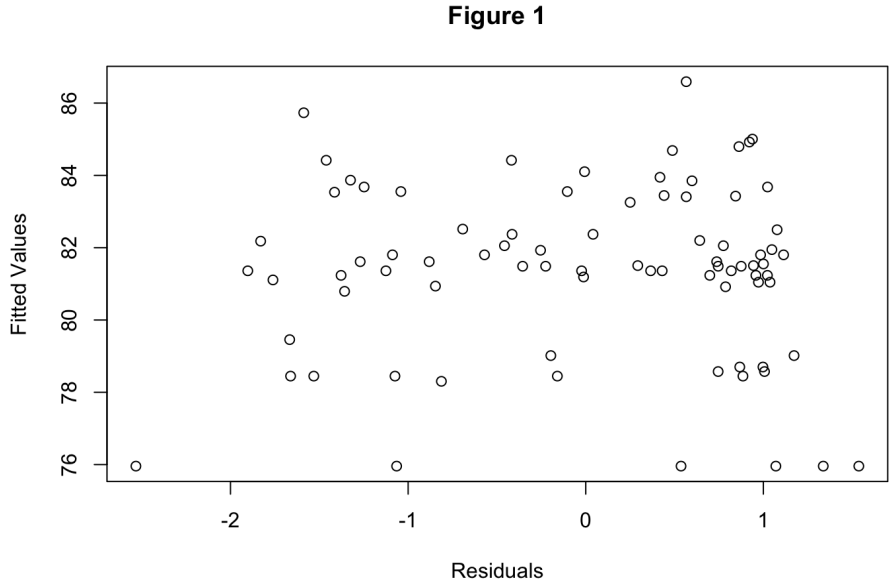
4.4.1 Independence

As stated in chapter 3, independence of cases is typically established qualitatively. Students were observed by school employees both while taking the Iowa Assessments and the survey for this study. While other environmental factors such as shared classes and friendships may very well have had some variable impacts on subsets of students, researchers had no cause to conclude that any students had meaningful, measurable, undue influence upon each others' data. Thus, the assumption of independence was sufficiently satisfied.

4.4.2 Homoscedasticity/linearity of the regression line

Equal variance, also known as homoscedasticity, and linearity of the regression line were both assessed using a scatter plot comparing standardized residuals to fitted values. Since no visually apparent pattern is obvious in the scatter plot, presented as Figure 1 below, the assumptions of homoscedasticity and linearity were satisfied.

Figure 1: Scatter plot of standardized residuals versus fitted values for the final model (Step 3)



4.4.3 Multicollinearity

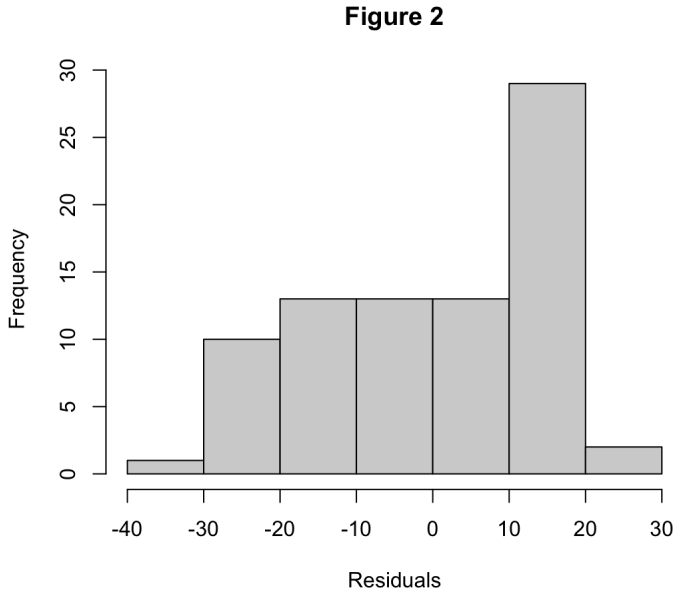
Multicollinearity, the extent to which independent variables are correlated with each other, is assessed by examining variance inflation factors (VIFs). Using R, the VIFs were calculated to be approximately 1.39 for gender, 1.18 for gaming time, and 1.48 for game genre. Since none of the VIFs were greater than 5, multicollinearity was no concern.

4.4.4 Normality of residuals

Normality of residuals can be determined through the Shapiro-Wilk test of normality. The results of this test were statistically significant ($W = 0.91$, $p < .001$), so the null hypothesis of normally distributed residuals was rejected.

In addition, a histogram of the residuals is included in Figure 2 below. The graph is clearly skewed to the left, and thus the normality assumption was violated.

Figure 2: Histogram of the residuals of the final model (Step 3)



4.5 Hierarchical regression models

As explained in chapter three of this manuscript, hierarchical regression analysis is a process of creating multiple, separate, Multiple Linear Regression (MLR) models, starting with a lower number of predictor variables and increasing the amount in a stepwise manner. At each step, it is determined whether the new variables have a significant impact on the model in terms of predicting the response variable.

In this study, the first model of consideration was the null model (the intercept-only model). The predictor variables were then added to successive models in the following order: gender, average daily amount of time spent playing video games, and most played category of video game genre.

Two outliers were detected using standardized residuals, studentized residuals, and Cook's distances. However, removal of these cases did not meaningfully change the outcomes of the analysis, and so the models containing all 81 data points are presented here. The results of the hierarchical linear regression analysis are presented in Table 4 below.

Table 4: Hierarchical linear regression analysis results using gender, average daily time spent gaming, and most frequently played video game genre as predictors of state mathematics assessment scores among surveyed students at CCS

Step **Independent Variables**	***B***[a]	***SE***[b]	***t***	***p***	R^2	ΔR^2
Step 1					.004	.004
Gender[1]	-1.906	3.508	-0.543	.589		
Step 2					.009	.006
Gender	-1.293	3.638	-0.355	.723		
Average Daily Gaming Time	0.674	1.011	0.666	.507		
Step 3					.024	.015
Gender	-2.404	4.197	-0.573	.568		
Average Daily Gaming Time	0.460	1.078	0.427	.571		
Most Played Game Genre Category[2]						
Mixed	-2.938	6.856	-0.429	.669		
Action	-5.242	6.321	-0.829	.410		
No Gaming	-7.530	8.089	-0.931	.355		

[1] Male used as reference category

[2] Logic and Reasoning used as reference category

[a] Estimated regression coefficient

[b] Standard error

Gender (t = -0.543, B = -1.906, 95% CI [-10.765, 5.957], p = .589) alone explained only 0.4% of the variance in the test scores. Including average daily gaming time (t = 0.666, B = 0.674, 95% CI [-1.688, 2.607], p = .507) added further, negligible explanation of variance (0.9%), particularly when accounting for the fact that merely adding variables to a regression model inherently inflates R^2. Comparing the test scores of students who reported most frequently playing strategic video games to those who reported playing more mixed (t = -0.429, B = -2.938, 95% CI [-16.597, 10.721], p = .669), or action-focused (t = -0.829, B = -5.242, 95% CI [-17.834, 7.350], p = .410) games, or to those who reported playing no video games at all (t = -0.931, B = -7.530, 95% CI [-23.644, 8.584], p = .355) yielded similarly negligible increases in effectiveness of the model (1.5%).

4.6 Model comparisons

The Cohen's f^2 effect sizes from step 1 to step 2 ($f^2 = 0.005$), from step 1 to step 3 ($f^2 = 0.020$), and from step 2 to step 3 ($f^2 = 0.015$) were all very small (Dierker et al., 2012).

Despite a total lack of significant predictors in any of the regression models, ANOVA commands were executed in R in order to assess whether the changes in explained variance between the models were statistically significant. The output of the ANOVA commands is presented in table 5 below.

Table 5: Output of ANOVA commands comparing steps in the hierarchical regression

	df [a]	***F***	***p***
Null Model to Step 1 (adding Gender[1] to the intercept only model)	79	0.295	.589
Step 1 to Step 2 (adding Average Daily Gaming Time to the previous model)	78	0.444	.507
Step 2 to Step 3 (adding Most Played Game Genre Category[2] to the previous model)	75	0.378	.769

[1] Male used as reference category
[2] Logic and Reasoning used as reference category
[a] Degrees of freedom

The effect sizes as well as the ANOVA command outputs indicate an extremely weak or non-existent relationship between the proposed predictors and mathematics test scores.

4.7 Statistical conclusions

The assumptions of independent samples, homoscedasticity/linearity, and low multicollinearity were satisfied. However, normality of the residuals was severely violated. Fortunately, research has shown that violation of this particular assumption in multiple linear regression doesn't meaningfully affect hypothesis testing interpretations (Osborne & Waters, 2002).

The investigators hypothesized that the predictors chosen would be statistically significant, and that students who prefer to play genres of games under the "Logic and Reasoning" category would perform better in mathematics than those who prefer to play genres of games under the "Action" and "Mixed" categories (as well as those who do not play video games). The results of the hierarchical linear regression analysis did not support either of these hypotheses as none of the *p*-values were below .05.

Chapter 5: Summary

Chapter five will summarize the interpretations and consequent conclusions of the statistical analysis conducted in chapter four. A summary of the findings from chapter four are presented and are interpreted in relation to the study's primary research question. Implications of this study on further research in this area are discussed in this chapter. Limitations of this study in addition to suggestions for said future research are discussed in this chapter as well.

5.1 Introduction

The authors set out hoping to combat some of the rampant over-generalization in research around the sociological impacts of video games on high school students. With how dense and diverse the industry of video games is in modern times, it seems naive and irresponsible to assume that all types of video games are going to have an identical impact on a person playing them. This study categorized games based on some of their most defining characteristics (as represented by video game genres), and assessed their impact on standardized mathematics test scores among private high school students in Ohio.

Chapter five summarizes the findings and implications of the study. First, the most important results from chapter four and their interpretations will be re-emphasized. Then, the ways in which the results relate to the theoretical framework, as well as any potential consequences of the research, will be discussed. Next, the limitations and drawbacks of this study will be documented, followed by recommendations for any future research to improve upon this study, or take it in new directions. Finally, the manuscript will conclude with the highlights of the study.

5.2 Summary of the findings

The primary research question of this study was as follows:

Are self-reported gender, amount of time spent playing video games, and most played type of video game significant predictors of state mathematics assessment scores among students of private high schools in the United States?

Since none of the p-values for any predictors were .05 or below, at any step in the hierarchical regression analysis, it would seem that the answer to this question is a steadfast and sweeping, "no". However, with such a small sample size from a relatively narrow population, this conclusion is even less unassailable than most statistical research. The only reasonably defensible inference one could make from this study alone is that, if there is a meaningful correlation between any of the included predictor variables and mathematics state test scores, then that correlation would likely be very weak.

5.3 Interpretation of the findings

No reasonable academic could look at these data and claim that playing video games comprehensively improves or worsens mathematical skills among high school students. However, with such a small sample size, it is also not necessarily true that playing video games has no impact on mathematics state test scores. Again, both video games and the entire process of learning itself are vastly complex topics, as there are literally millions of video games, and several hundred modern theories on how humans process and assimilate information (Krath et al., 2021).

As implied in chapter 2, there are countless confounding variables that could, and ideally should, be controlled for in a study that expects to find statistically significant associations

between gaming and academic outcomes. In an attempt to keep this thesis focused, and to avoid any and all controversial topics that could dissuade parents from signing the consent form required for academic research involving minors, the investigators designed the study conscientiously not including measures of aggression, addiction, socioeconomic status, parental interaction, prior academic achievement, or biological gender. However, prior research has indicated that most of these aspects of a person have some bearing on either their gaming habits and preferences, their academic performance, or both (Anderson, 2004; Drummond & Sauer, 2014; Dullur et al., 2021; Gentile et al., 2004, 2012). It was ultimately fortunate, then, that the decision was made not to include these metrics, as they certainly would have reduced the already abysmal sample size, and having additional predictor variables would have made any quantitative, statistical analysis indefensible.

Unfortunately, while the original plan was to include analyses of the effect that gaming time has on math test scores based on whether that time was spent on school days or days off, the lack of survey responses (which came about mostly as a result of lacking parental consent) made such comparisons impossible for the researchers to justify statistically, on top of the already complex hierarchical linear regression model. Although studies have shown that this distinction in when games are played is consequential (Drummond & Sauer, 2020), the researchers were forced to simply add such an interaction to the laundry list of unaccounted confounding variables.

5.4 Implications for theory and research

The fact that there is not a clear, strong, positive correlation between playing logic-based video games and mathematics test scores may imply one of several things. Based on Experiential

Learning Theory, playing video games that require logical reasoning and problem solving should improve those skills, but the issue is that these skills may or may not be transferable to learning mathematics. Learning math could certainly be seen as a series of puzzles to be solved – being shown some rules or systems to understand, then giving new, but similar scenarios in which to apply those rules. Many video games, particularly those categorized here as "Logic and Reasoning", use this exact sequence of events to challenge players. However, understanding and solving a block puzzle (a common video game puzzle involving pushing blocks around a grid) might not translate to understanding and solving an equation.

It is also possible that the effects of addiction or displacement sometimes counteract what would otherwise be benefits of playing video games. Moderation is critical in nearly all aspects of life, and with modern games only becoming more and more addictive by design, it is understandable that minors, still developing self-control and inhibition, may overindulge in playing video games, causing academic performance to suffer.

Since all the data collected, aside from the test scores, were survey responses, and thus self-reported, there is of course the possibility that students simply responded to questions inaccurately, intentionally or otherwise. Games can be wildly complex, and span multiple genres, so it may be difficult choosing just one genre as the most time consuming in a student's life. Furthermore, with so many different genres, it is possible that the "most frequently played" genre only consists of 10% of the student's gaming time, with the other 90% split among other genres. In these cases, the effects of any one genre could easily be misrepresented.

Because no correlation was found between any gameplay and mathematics performance, Self-Determination Theory and the selection hypothesis were not explicitly supported. Based on these theories, students who excel at math would be more likely to play video games that make

use of their strongest skills, as doing so would likely induce a sense of competence and success. A lack of a significant association between any video game genre category (or not playing video games) and mathematics test scores implies that either none of the genres effectively employ the same skills that make a student successful in math, or there are just too many other factors at play, influencing the games that students choose to play.

5.5 Implications for practice

The worlds of video gaming and education are much more involved than they may first appear. There are countless potentially confounding variables and aspects of humanity that cannot easily be quantified yet. So, in order to find any meaningful pattern within all the noise, research in either of these fields, or both fields, must be decidedly rigorous. A massive sample size, on the order of several thousand, including students/gamers from geographically, biologically, and culturally diverse populations, is one aspect of research that would likely be sufficient for valid inference of studies in these fields. Alternatively, tightly controlled, experimental research may eliminate enough interference to reveal trends, though this would be extremely difficult to verify, as seemingly any part of a human's psychology or history could have significant impacts on how they process information or how they engage with video games.

Since this study was so limited in scope, and the results so vague, the only far-reaching take-away is to not underestimate the complexity of these fields. If any future, budding researchers, with wide eyes and no budget, find this study in their literature review while beginning any sort of similar study, there is a high likelihood that it would best to pivot, to adjust the topic or the methodology to something a bit less involved.

5.6 Limitations

At the outset of this thesis, the sample populations were chosen primarily out of convenience. The two researchers were employed at two very different schools on opposite ends of the United States, with one having nearly 2,000 students. It was assumed that this diversity and these numbers would be enough to satisfy both the requirements of the thesis program and the historically validated minima needed for statistical analysis. What the researchers did not anticipate was the substantial red tape surrounding asking high school students about video games they play, and how the necessary parental consent forms would absolutely cripple the final sample size.

Because one of the two high schools had to be cut from the study, resulting in a dismal sample size of only 81 students, the data also lack geographical and cultural diversity. It is entirely possible that the absence of a meaningful association between video game preference and mathematical performance is unique to private Christian high schools in Ohio, but it is just as likely that this conclusion applies to high schools across the entire globe. Without the second school, there is simply no way to determine the scope to which the found non-association applies.

The digital age is making it easier for gamers to keep some sort of record on how much time they spend on each video game they play. Cloud-based gaming platforms like Steam, as well as the operating systems of modern consoles like PlayStation 5, allow players to see roughly how much time has been logged on each game by each person's profile. Game companies and other researchers would do well to make use of this data, if possible, to draw more accurate conclusions than those which would otherwise be drawn from self-reported information as in this study. However, genuine preferences and some activities in which players engage while playing

video games are much more difficult to precisely track and quantify, and thus more difficult to gather with any method beyond self-report surveys.

While this study looked for correlations between gaming and state mathematics test scores, the fact that state tests are standardized does not automatically lend to them being perfect metrics of mathematical skill. Moreover, even if playing certain video games does not help a student become more successful in mathematics overall, that does not preclude it from helping some aspects of learning math. For example, playing a puzzle game might not help a student improve their arithmetic skills, but it might make it easier for them to understand mathematical proofs. More granular metrics of how well students understand individual topics may give future researchers a clearer picture of how playing certain games may affect an adolescent's ability to learn mathematical concepts.

5.7 Recommendations for future research

Considering millions of minors spend dozens, hundreds, or even thousands of hours playing video games each year, it is difficult to imagine that such a mentally engaging activity has no impact on a brain's development. However, with the immense variety of video games available, it is also difficult to imagine a single experiment or study that could adequately capture any one aspect of exactly how playing one or more video games affects a growing child. Thankfully, with the hobby of video games being so prevalent today, there is no shortage of minors to be studied, so long as the parents/guardians are willing to give consent. As such, the most likely avenues for future research to produce meaningful results would involve massive samples, as well as a wide variety of potentially confounding variables being measured as accurately and directly as possible.

While it is tough to say exactly which features of gaming are most probable to have a meaningful, measurable effect on a child's academic performance, previous research has indicated a decent likelihood that addiction and violence are good places to start (Gentile et al., 2012; Li et al., 2020). Once these relationships are better understood, it may be worthwhile to examine more closely how video game facets like genre, multiplayer versus single-player, controller type, or difficulty can influence the progression of minors' academic performance. Of course, any relationships sought must be steeped in theoretical backing, and established with large and diverse samples.

An alternative approach to fine-tune a study such as this would be to control for students' prior academic achievement or interest in mathematics or video games. To verify that a correlation between gaming and academic achievement is causal in one direction or the other, an experimental and/or longitudinal study would be required. If a student plays video games and performs well in mathematics, it is impossible to tell purely through observation whether one significantly influenced the other. However, ethically compelling non-gamer children to spend substantial time playing video games and then testing for changes in academic performance would be one methodologically viable solution.

5.8 Conclusion

In summary, it is clear that this study can be worked on in the future by a more fortunate or ambitious group of researchers in regards to their sample size. However, there were still meaningful and relevant outcomes of this study. For example, it has been shown that Experiential Learning Theory may not apply as a bridge from Logic/Reasoning categories of video game genres that students play to the scores the same students achieve on standardized mathematics

assessments. In addition, it is clear that gaming is still extremely prevalent among adolescents, as more than 90% of students surveyed stated that they spend some amount of time playing video games each week. Thus, studying how gaming can affect the development of a child is still a worthwhile pursuit. It has also been laid out that there are plenty of different approaches that could be used in this type of study, such as controlling for the students' previous achievement in mathematics courses, as well as their interest in them.

None of the coefficients of the models in this study were significant, and so little to no relationship seems to exist between the variables measured. Thus, at least among private high school students in Ohio, it seems there is no meaningful connection between the types of video games that students play most and their performance on state mathematics assessments. The extent to which this lack of correlation applies on a larger scale remains unclear.

Although this study showed no significant association between gaming and math test scores, it is still entirely feasible that such a connection exists and is merely weak. The fact of the matter is that it will take a larger sample size, and more control of confounding variables, in order to isolate such a relationship. It is the hope of these authors that future researchers will continue the growing trend of taking video games seriously, and considering the medium with the depth and complexity it requires.

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Appendix A: Proof of IRB Approval

This document shows proof of the IRB application process and approval for the study.

Shawnee State University Study # 2023-55

Full Review Application

Title of Research Project:

Video Game Preferences and Mathematics Performance Among Adolescents

Name of Principal Investigator	Email Address	Phone Number
Douglas Darbro	ddarbro@shawnee.edu	749-351-3441

Department(s)/Division/Agency: Graduate Mathematics Program

Name(s) of Co-Investigators:	Email address:	Faculty	Student	Other
Taylor Woods	woodst8@mymail.shawnee.edu	☐	☒	☐
Noah Sammond	sammondn@mymail.shawnee.edu	☐	☒	☐
		☐	☐	☐
		☐	☐	☐
		☐	☐	☐
		☐	☐	☐

*Please place an asterisk by the investigator name(s) whose Training certificate(s) is/are already on file with the IRB, if the certificate is less than 3 years old.

1. Describe the key demographics (age, SES, ethnicity, geographic locations, gender, etc.) of the sample that you wish to obtain.

High school students at Shasta High School in Redding, CA, and at Cincinnati Christian Junior/Senior High School in Cincinnati, OH.

1a. What is the greatest number of participants that will be recruited? 2000

1b. How will participants be recruited?

We will email consent forms to legal guardians of students who will be taking state exams at our schools this academic year. We will email assent forms and the survey to students whose legal guardians gave consent.

1c. Check the type of populations listed below that will be included in the study.

__X__ Children (under the age of 18)
_____ Prisoners
_____ Participants with diminished cognitive ability (unable to provide consent)
_____ Pregnant women and/or fetuses
_____ No vulnerable populations will be included

2. Will participants be remunerated for their participation? Yes No x

2a. If so, how will participants be remunerated? Please indicate the type of remuneration and the amount. For instance, the participants will be given a $10 Amazon Gift Card for participation or the participants will receive 3% of their final grade in extra credit in their Introduction course.

2b. If participants do not complete the study, will partial or full remuneration be given? Please describe how that will be determined

3. What direct benefits (other than remuneration) exist for the participants who participate?
The participants will have the satisfaction of knowing that they helped further statistical research on the impacts of video games, and they will have an opportunity to briefly write about some of the their favorite games (if applicable).

4. What direct risks could the participants potentially face? Check all that apply.

__x__ Risk of breach of confidentiality or privacy

_____ Risk of coercion by researcher(s)

_____ Risk of psychological harm

_____ Risk of physical harm

_____ Other potential risk: _____

4a. Please describe the specific risk(s).
In order to associate each student's survey data with their state exam scores, some personally identifiable information must be collected with both pieces of data. As with any data that is transmitted over the Internet, there is always a risk of that data being compromised.

4b. What measures will be taken to limit or minimize the risks?
We will be using standard cybersecurity practices including secure protocols and software, and we will cleanse the data of all personally identifiable information immediately once the survey data and state score

5. What are the expected benefits of the research to the scientific community or the common good?
If we find a statistically significant correlation between the gaming preferences of adolescents and their performance in mathematics, then parents and educational professionals would be better able to predict a child's affinity for mathematics based on the types of games they prefer.

6. Does the methodology require that participants be deceived about any aspect of the study?

Yes No X

6a. If so, please justify the use of deception and describe the debriefing procedures that will be used (Please attach the debriefing form and/or a script of the debriefing information).

7. How will the participants be informed of the risks and benefits of the study?
Through the reading of the assent form.

7a. How will consent be obtained from participants (or their legal guardian)?
Through the reading and signing of the consent form.

7b. Will participants be involved who cannot give legal consent? Yes X No

7c. If so, how will assent be obtained from the participants?
Through the signing of the assent form.

SSU IRB Approved BR 12/4/2023 | 11:36 PM

Shawnee State University

Study # 2023-55

In submitting this form and the corresponding documents, I acknowledge that I have completed Human Research Participants training and that I understand and will uphold the rights of human participants. I also verify that all information contained in this form and any other corresponding documentation is correct based on my knowledge. I understand that I may not have contact with any research participants until the Shawnee State University IRB has given me their approval. I also understand that I must file an ***Amendment/Modification Form*** if my project extends beyond a year from my approval date and I must file a ***Final Study Form*** with all consent forms once the study is complete.

DocuSigned by: Douglas Darbro
Signature of Principal Investigator 1

DocuSigned by: Taylor Woods
Signature of Co-Investigator 2

DocuSigned by: Nabil Sammoud
Signature of Co-Investigator 3

Signature of Co-Investigator 4

Signature of Co-Investigator 5

Signature of Co-Investigator 6

Date of Submission: 12/2/2023 | 1:04 PM EST

Please compile attachments into one document for each category. If any forms below are not applicable, please attach reasons why.

Human Research Training Certificates:

Data Collection Questions and Forms:

Research Summary:

Consent Forms:

Assent Forms:

Advertisements:

Revisions Requested Yes X No IRB Chair Signature

Date sent for revision (if applicable): 12-3-2023

Please attach revisions requested with changes clearly marked Changes marked

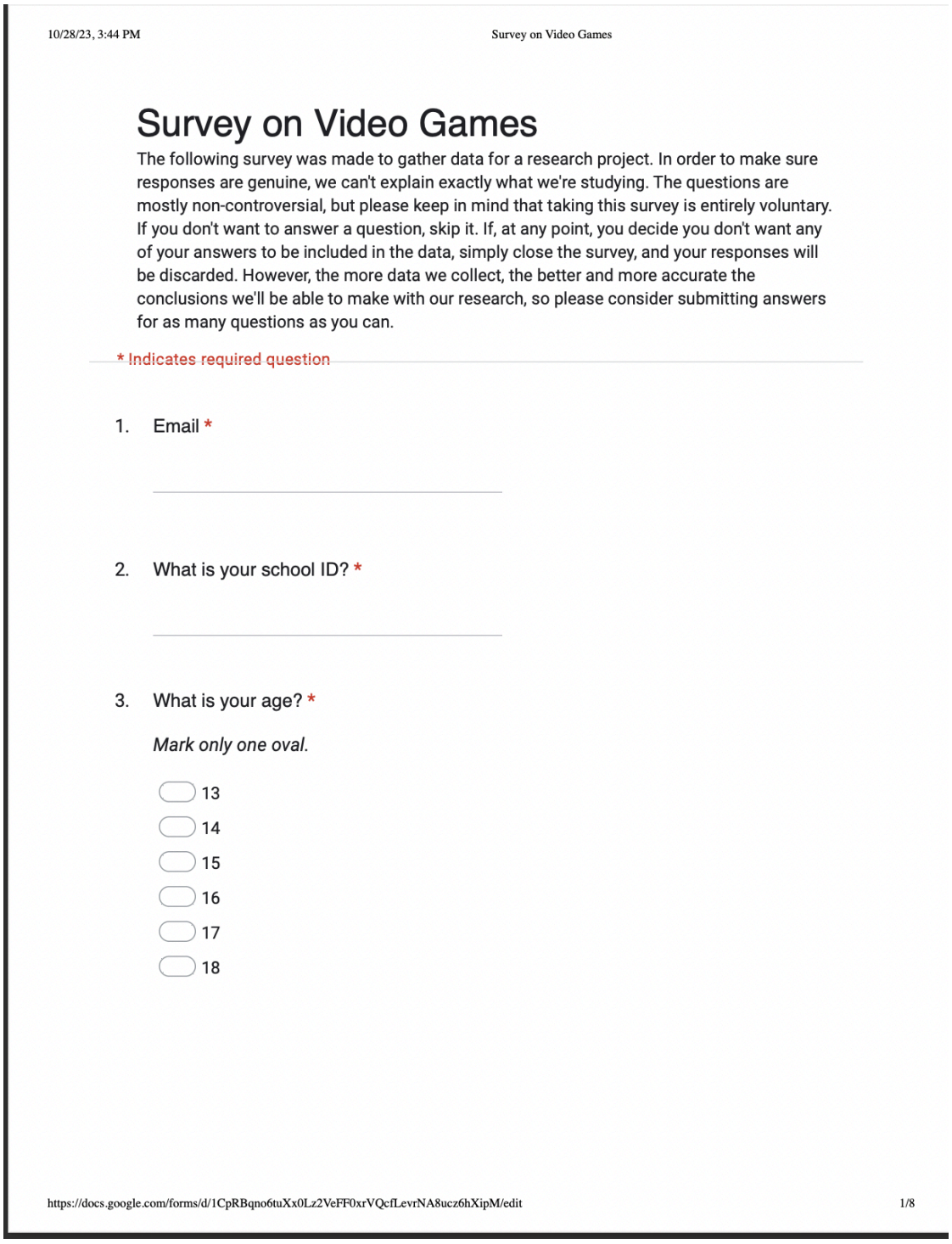
Please attach revised assent form discussed in email on 12/3/23. Thanks!

Final copy

DS DDD

Appendix B: Google Forms Survey

This is the survey sent to students who signed the assent forms. This information was used to create the study's data.



10/28/23, 3:44 PM Survey on Video Games

Survey on Video Games

The following survey was made to gather data for a research project. In order to make sure responses are genuine, we can't explain exactly what we're studying. The questions are mostly non-controversial, but please keep in mind that taking this survey is entirely voluntary. If you don't want to answer a question, skip it. If, at any point, you decide you don't want any of your answers to be included in the data, simply close the survey, and your responses will be discarded. However, the more data we collect, the better and more accurate the conclusions we'll be able to make with our research, so please consider submitting answers for as many questions as you can.

* Indicates required question

1. Email *

2. What is your school ID? *

3. What is your age? *

Mark only one oval.

- 13
- 14
- 15
- 16
- 17
- 18

https://docs.google.com/forms/d/1CpRBqno6tuXx0Lz2VeFF0xrVQcfLevrNA8ucz6hXipM/edit 1/8

4. What grade are you in? *

Mark only one oval.

- 9th
- 10th
- 11th
- 12th

5. What is your gender? *

6. On average, how many hours do you spend playing video games on a school day? *

Mark only one oval.

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24

7. On average, how many hours do you spend playing video games on a day off from school? *

Mark only one oval.

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24

8. What are your favorite video games? (List up to 3) *

Please briefly explain why for each.

What are your favorite things to do in each these games?

9. Which of the following genres of games do you typically enjoy playing? (Check all that apply) *

Check all that apply.

- [ ] Shooter (first-person or third-person) - Involves aiming and shooting at things. Examples: Halo, Borderlands, Overwatch, Rainbow Six, Gears of War
- [ ] Racing - Involves trying to travel a distance in the shortest amount of time. Examples: Mario Kart, Forza, Gran Turismo, DiRT
- [ ] Fighting - Involves close-quarters combat from a side-on perspective. Examples: Super Smash Bros., Street Fighter, Mortal Kombat
- [ ] Puzzle - Involves using logic and deduction to solve problems or achieve a goal. Examples: Candy Crush, Portal, The Witness, Tetris
- [ ] Exploration/Narrative - Focuses on exploring an environment and/or telling a story. Examples: Firewatch, Ace Attorney, What Remains of Edith Finch
- [ ] Action-adventure - Involves reflex-based combat and exploration. Examples: The Legend of Zelda, God of War, Tomb Raider, Grand Theft Auto
- [ ] Turn-based Strategy - Involves outwitting an opponent while taking turns to act. Examples: XCOM, Civilization, Total War
- [ ] Real-time Strategy - Involves outwitting an opponent while all players are able to act at any time. Examples: Starcraft, Age of Empires, Command & Conquer, Homeworld
- [ ] Turn-based RPG - Involves improving the traits and characteristics of one or more characters through turn-based conflicts. Examples: Undertale, Fire Emblem, Baldur's Gate
- [ ] Action RPG - Involves improving the traits and characteristics of one or more characters through conflicts in which characters act freely. Examples: Elden Ring, Skyrim, Diablo, The Witcher
- [ ] MMORPG - Involves creating an avatar and improving their traits and characteristics through conflict along with other players online. Examples: World of Warcraft, Final Fantasy XIV, RuneScape
- [ ] Rhythm - Involves performing actions along with the rhythm of music. Examples: Dance Dance Revolution, Crypt of the Necrodancer, Karaoke Revolution, Beat Saber
- [ ] Platformer - Focuses on controlling a character to jump and move around an environment. Examples: Super Mario Bros., A Hat in Time, Banjo-Kazooie, Sonic the Hedgehog
- [ ] Simulation - Attempts to model some objects or scenarios found in real life. Examples: The Sims, Flight Simulator, Farming Simulator, Power Wash Simulator
- [ ] Sports - Involves gameplay based on real or fictional sporting events. Examples: WWE Wrestling, Fifa, NBA 2K, Tony Hawk's Pro Skater

10. Which of the following genres of games do you *enjoy playing the most*? *

Mark only one oval.

- ◯ Shooter
- ◯ Racing
- ◯ Fighting
- ◯ Puzzle
- ◯ Exploration/Narrative
- ◯ Action-adventure
- ◯ Turn-based Strategy
- ◯ Real-time Strategy
- ◯ Turn-based RPG
- ◯ Action RPG
- ◯ MMORPG
- ◯ Rhythm
- ◯ Platformer
- ◯ Simulation
- ◯ Sports

11. Which of the following genres of games do you *spend the most time playing*?

Mark only one oval.

- ◯ Shooter
- ◯ Racing
- ◯ Fighting
- ◯ Puzzle
- ◯ Exploration/Narrative
- ◯ Action-adventure
- ◯ Turn-based Strategy
- ◯ Real-time Strategy
- ◯ Turn-based RPG
- ◯ Action RPG
- ◯ MMORPG
- ◯ Rhythm
- ◯ Platformer
- ◯ Simulation
- ◯ Sports

Appendix C-1: Communication through Parent-Square

This is a message sent to parents at Shasta High School:

Dear Parent/Guardian,

My name is Taylor Woods, and I'm a paraprofessional at Shasta High School. I'm currently working on a Master's Degree in Mathematics through Shawnee State University, Ohio, and I need the help of Shasta High's students to complete my master's thesis. My project is trying to find connections between video game preferences and math skills, and as with any study, the more participants, the better.

All I need from your child is to take a short survey about what kinds of games they like (this will be done in their math class later this semester). All I need from you is to read and sign the parental consent form to permit your child to participate. In order to send the consent form to you, I need you to provide your name and email address through the Google Form linked below. I know this all seems unnecessarily convoluted, but these are the steps legally required for any research that involves minors.

If you and your child can do these things for me, I would be extremely grateful. If you have any questions whatsoever about the process or the study, you'll find my contact information in the Google Form and the forthcoming consent form. Please don't hesitate to reach out to me.

Thank you for your time,

Taylor Woods

Appendix C-2: Parental Consent Form

This is the document signed by parents/guardians to allow their students to sign the assent for which allows the students to participate in the survey and have their assessment data used.

Research Survey Parental Consent Form

Study Title: To minimize response bias in the survey, the title of this study will not be revealed to participants.

Study location: Shasta High School in Redding, CA, and Cincinnati Christian Junior/Senior High School in Cincinnati, Ohio

Investigators: The following investigators are available for questions about this study: Taylor Woods, (530) 339-0257, woodst8@mymail.shawnee.edu, available weekdays after 5PM PST, weekends after 8AM PST Noah Sammond, (513) 330-2662, sammondn@mymail.shawnee.edu, available weekdays after 3PM EST, weekends after 12PM EST

Purpose of study: We are trying to find a connection between the types of video games that high school students play and their academic performance.

Population to be studied: High school students at both Shasta High School and Cincinnati Christian Junior/Senior High School

Number of participants: Up to 2000

Study procedures: Your child will be asked to fill out a survey containing questions about the amount of time they spend playing video games, what kinds of games they play, as well as basic demographic information.

Benefits: You and your child will know that you helped further statistical research on the impacts of video games, and your child will have an opportunity to briefly write about some of their favorite games (if applicable).

Risks: We will be handling the resulting survey data as well as state test scores for your child, and as with any data that is collected, there is always a small chance that a data breach occurs and the data is made public. We will be removing any information that could link the survey results or the state scores to your child as soon as possible, and we will use only secure storage

and data transmission methods to minimize the risk of data being compromised. There is also a small risk that the survey questions could make your child feel uncomfortable.

Right to refuse: Participants may choose not to participate in the survey, and even after beginning the survey, the participants may choose to stop or cancel their participation at any time with no repercussions.

Privacy: The statistical results of the study may be published, but no personally identifiable information will be included in the publication. Participation in this study will remain entirely confidential.

Signatures: I verify that I am 18 years of age or older. The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators listed above. If I have questions about my child's rights or other concerns, I can contact the Associate Provost, Institutional Review Board, Shawnee State University (740) 351- 3299. I agree to allow my child to participate in the study described above and acknowledge that I can take a screenshot of this consent form for my own records.

Name(s) of the student(s) in your care that you are allowing to participate:

_____

Signature of Parent/Guardian: _____

Date_____

Appendix C-3: Subject Assent Form

This is the document signed by students to agree to take part in the survey and have their assessment data used.

Research Survey Subject Assent Form

Study Title: To make sure we get the most truthful answers, we can't reveal the official title of our study.

Location of Study: Shasta High School in Redding, CA, and Cincinnati Christian Junior/Senior High School in Cincinnati, Ohio

Investigators: The following investigators are available for questions about this study:
Taylor Woods, (530) 339-0257, woodst8@mymail.shawnee.edu,
available weekdays after 5PM PST, weekends after 8AM PST
Noah Sammond, (513) 330-2662, sammondn@mymail.shawnee.edu,
available weekdays after 3PM EST, weekends after 12PM EST

Purpose of the Study: We are trying to find a connection between the types of video games that high school students play and their academic performance.

Population to be Studied: High school students at both Shasta High School and Cincinnati Christian Junior/Senior High School

Number of subjects: Up to 2,000

Study Procedures: You will be asked to complete a survey.

Benefits: You know that you helped further statistical research on the impacts of video games, and you will have an opportunity to briefly write about some of your favorite games.

Risks: Whenever you send something over the Internet, there is always a chance that information could be made public, but we'll do everything we can to make sure that doesn't happen with your survey answers and any school information we collect. There is also a very small chance that taking the survey makes you uncomfortable. In addition, we will be handling the resulting survey data as well as your state test scores and as with any data that is collected, there is always a small chance that a data breach occurs and the data is made public. We will be removing any information that could link the survey results or the state scores to you as soon as possible, and we will use only secure storage and data transmission methods to minimize the risk of data being compromised.

Right to Refuse: You may choose not to participate or to stop taking the survey at any time without any consequences. If you answer some questions but don't submit the survey, nothing you put in the survey will be used in the study.

Privacy: The overall results of our study may be published, but no specific information about you or your survey answers will be included in the publication. We also won't include information about who did or did not participate in the study.

Signatures: By signing below, I verify that I have read the information provided regarding this study and all my questions about the study have been answered. I may direct additional questions regarding study specifics to the investigators listed above. If I have questions about my rights or other concerns, I can contact the Associate Provost, Institutional Review Board, (740) 351-3299. I agree to participate in the study described above and acknowledge that if I want to keep a copy of this assent form, I can save a screenshot of it.

Signature of Participant: _____

Date: _____

Bibliography of Researcher #1

Noah Sammond

Candidate for the Degree of

Master of Science Mathematics

Thesis: MATH STATE TEST SCORES OF HIGH SCHOOL STUDENTS ACROSS VIDEO GAME PREFERENCES

Major Field: Mathematics

Personal Data: Born, raised, and live in Cincinnati, Ohio. Currently a high school mathematics teacher at a private Christian school.

Work Experience: Four years of tutoring K-12 in mathematics at Mathnasium in West Chester, Ohio. Three years of teaching high school mathematics (Honors Algebra II, College Algebra, Precalculus, Honors Precalculus, CCP Calculus I, CCP Calculus II, and CCP Statistics I) at Cincinnati Christian Schools in Cincinnati, Ohio.

Prior Education: Bachelor of Science in Secondary Education Mathematics, Salt Lake City, Utah, in 2022.

Completed the requirements for the Master of Science in Mathematics, Portsmouth, Ohio in 2024.

ADVISER'S APPROVAL: 7/12/2024

Bibliography of Researcher #2

Taylor Woods

Candidate for the Degree of

Master of Science Mathematics

Thesis: MATH STATE TEST SCORES OF HIGH SCHOOL STUDENTS ACROSS VIDEO GAME PREFERENCES

Major Field: Mathematics

Personal Data: Has lived entirely in California, primarily in Redding.

Work Experience: Seven years working as a math-specialized educational paraprofessional in the Shasta Union High School District in Redding, CA.

Prior Education: Bachelor's Degree in Computer Science from the University of California, Davis.

Completed the requirements for the Master of Science in Mathematics, Portsmouth, Ohio in 2024.

7/4/2024

ADVISER'S APPROVAL: