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Video Games and Brain Aging

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Abstract

This research was conducted to assess the relative impact of video game play on cognitive and motor skills. Prior research has shown that video game play facilitates cognitive and motor skills, while other research has focused on the negative outcomes of the activity, such as addiction, aggression, obesity, repetitive strain injuries, and the gradual loss of interest in other activities. In a pre-post video game manipulation compared against participants in a comparable control condition, this study's findings support prior research on the positive impacts of video game play on memory, but not motoric response time enhancement. Future iterations of this research and its limitations are discussed.

Keywords

Short-Term Memory, Cognitive, Concentration, Perception, Reaction Time, Brain Aging, Level of Involvement, Motor, Repetition

1. Introduction

This paper investigates whether video games have beneficial effects on adolescent and adult cognition and motor functions. Specifically, the authors theorize that games harness concentration and motor planning that has the ability to affect changes in reaction time and short-term memory. Outcomes such as these can also potentially be moderated by emotions, stress, age, and other factors.

In a study of 3305 people aged 16 to 44 years, researchers found that the response time of the brain begins to decline at age 24 (Shalby, 2014). As we age, our reflexes slow down due to physical changes in our nerve fibers as well as a loss of neuronal connections in the brain. In spite of this, the effects of age on reflexes and reaction time vary greatly between individuals. However, any mentally stimulating activity that requires manual dexterity and mental effort, such as video games, should assist most people in brain activity.

Whether a video game will have beneficial and positive effects on other activities has been a very controversial topic, debated over 30 years. There is far more media attention given to alleged negative effects of video games such as addiction, aggression, obesity, repetitive strain injuries, and the gradual loss of interest in other activities (Prescott, Sargent, & Hull, 2018). However, this experiment tries to support the theory that individuals who play an appropriate amount of interaction-rich video games prior to a memory or motor task can benefit from the practice of enhanced concentration and quicker reaction times. Studies have shown that video games can be used for educational and therapeutic purposes, as well as for improving reaction times, hand-eye coordination, and ambidexterity. For instance, playing video games has been shown to improve spatial perception abilities, such as the ability to mentally rotate and manipulate two or three dimensional objects (Griffiths, 2022). This is potentially due to the increase in brain connectivity that influences muscle control, memories, perception, and spatial navigation. A recent study by Bejjanki and colleagues demonstrated other benefits of video game play (2014). The fast-pace, while playing action video games, helps improve perception, attention, and cognition as players constantly repeat motor responses.

1.1. Cognitive Basis for Benefits of Video Game Play

Historic research has shown that an increase in the level of involvement with a task enhances the ability to recall information. In seminal work by Craik and Lockhardt, different levels of processing of verbal information enhanced individual's ability to recall information (Craik & Lockhart, 1972) (**Figure 1**). Their theory states that repetition of information improves memorization only when it is done in-depth and with the purpose of semantically processing the information. Memory retention is better long-term with deep processing than short-term with shallow processing.

This type of memory encoding is similar to our interaction with stimuli. Passively interacting with a stimulus requires less cognitive and motor processing than does interacting with the stimuli. Increasing cognitive and motoric processing increases brain activity and reinforces specific skill sets beyond passive observation.

1.2. Neural Bases for Benefits of Video Game Play

Over the course of several weeks or longer, the gray matter of the human brain shows changes in volume and density. Gamers develop cognitive maps or mental

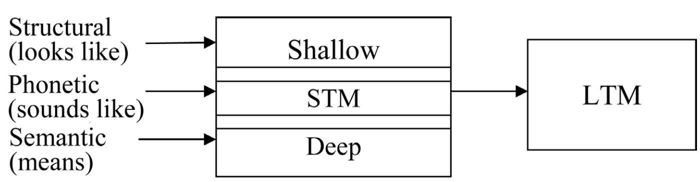

Figure 1. Levels of processing theory "Shallow to Deep".

representations of the virtual environment they explore when they play games (Osmond, 2018). Several studies and functional magnetic resonance imaging (fMRI) suggests that the stimulation of hippocampus increases functional metabolic activities in the brain, as well as increases the volume of the gray matter associated with neural processing (Osmond, 2018).

1.3. Experimental Methodology Rationale

Based on the evidence discussed above with respect to prior published cognitive and neuroscience-based research, this study tests the hypothesis that video game play will improve short-term memory by increasing a person's concentration following video game play as well as decrease response times by increasing a person's cognitive and motoric dexterity following video game play.

The following hypotheses are tested in the current research.

- H0a There will be no significant differences in memorization scores as a function of video game play.
- H1 There will be significant differences in memorization scores as a function of video game play.
- H1a There will be significant increases in memorization scores as a function of video game play.
- H0b There will be no significant differences in response time scores as a function of video game play.
- H2 There will be significant differences in response time scores as a function of video game play.
- H2a There will be significant decreases in response time scores as a function of video game play.

2. Methods

2.1. Experimental Procedure

This experiment and survey is not limited by age group. The data was collected through survey questions; these will include a self-evaluation of each participant's experience with emotional, stress level changes, and short-term memory VS long-term memory. The experiment was comprised of 52 participants. This experiment required a subset of 15 participants to play the Google snake game-for 15 minutes (see **Appendix A**, **Figure A1** for depiction of video game. In a pre-post study design, this group completed a short-term memory test and a reaction time test twice, once prior to playing the game and once again after game play). A separate subset of 10 participants served as a control groups and, rather than play an interactive video game, they passively watched a clip of a nature documentary for 15 minutes (see **Appendix A**, **Figure A2** for depiction of nature video documentary). These individuals were also given the pre-post short term memory and reaction time tests. Twenty-seven participants completed only the pre-manipulation condition to serve as a manipulation check with the rationale being that these individuals would not have scores on either the memory or reaction time test that differ significantly than the pre-manipulation scores for either those participants in the game play condition or those in the nature documentary condition. See Figure 2 for the study design.

2.2. Data Sources

This research paradigm collected both qualitative and quantitative data, through both self-report inventory (10 questions related to emotional and stress levels as well as a memory-based (spatial recall of items) and a response-time task (speed to make selection of target)).

2.3. Participants

Participants were comprised 73.3% female and 26.7% male. Their ages ranged from 19 to 50. See Table 1 for participant breakdown by experimental condition. Participants were randomly assigned to experimental and control groups without any inclusion or exclusion criteria.

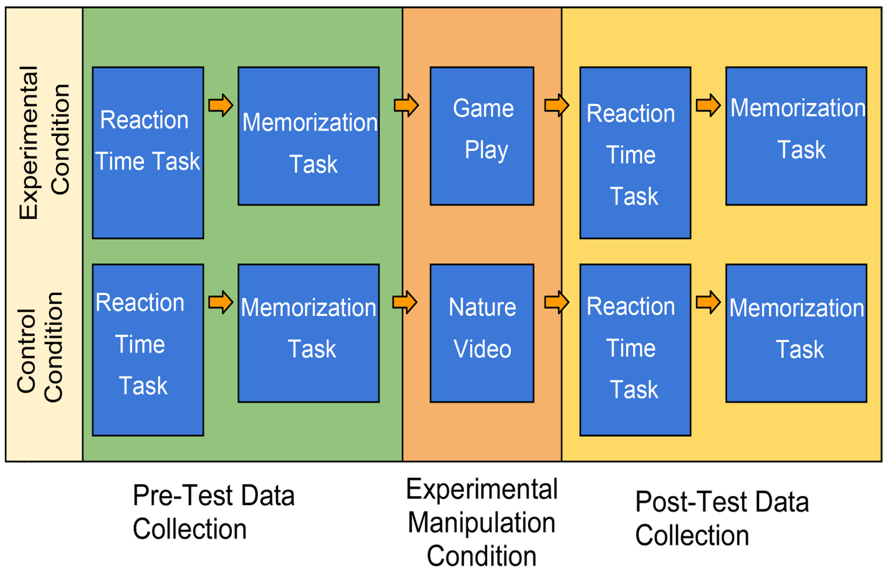

Figure 2. Experimental procedure.

Table 1. Breakdown of participants by gender and experimental condition. Study condition C refers to those participants in the control group (nature video or pre-manipulation check) and E refers to participants in the game play condition.

Frequencies of "Gender"				
"Gender"	Study Condition	Counts	% of Total	Cumulative %
F	C	24	46.2%	46.2%
	E	11	21.2%	67.3%
M	C	13	25.0%	92.3%
	E	4	7.7%	100.00%

2.4. Materials, Procedure, and Scoring

All participants completed a survey through Google forms before performing the experiment. The survey begins with a consent form stating that all responses in the test are anonymous and the information for each participant is de-identified. The survey consisted of 11 questions having either Likert scales, short answer or multiple choice self reports. This data was collected on each individual participant's habits and beliefs about game play and anxiety in order to determine the extent to which these factors may serve to moderate scores across experimental conditions.

3. Results

Prior to the primary hypothesis on the positive impact on some cognitive tasks following game play, a manipulation check was performed on two independent groups for both the memorization and the response time task. Because this experiment was conducted using a pre-post measure of cognitive functions across two gamified tasks, it is expected that the response times and memorization scores in each group would not significantly differ in the pre-manipulation phase of the experiment, but would in the post manipulation score averages and distributions due to the relative influence of game play.

3.1. Reaction Time Task Pre-Manipulation Check

An independent sample t-test was performed on the pre-test reaction time task for both the experimental and control manipulation check group. The reaction time scores significantly different between groups $t(50) = -2.62$, $p < 0.012$ with an effect size of −0.84 with the average reaction time for the control group being significantly faster ($\bar{x} = 266$, s.d. = 44.3) than that in the experimental condition ($\bar{x} = 303$, s.d. = 43.55). Please see Figure 3 for differences.

Alternatively, an increase in the sample size of the experimental condition (N = 15) may provide a more representative sample with scores distributed more similarly with those in the initial manipulation control condition, composed of N of 37 participants.

3.2. Memorization Task Pre-Manipulation Check

A second independent sample t-test was performed on the pre-test memorization task for both the experimental and control manipulation check group. The pre-test memorization scores did not differ significantly across groups $t(50) = -0.933$, $p = 0.356$ with the average memorization score for the control group not differing significantly ($\bar{x} = 9.90$, s.d. = 1.92) than that in the experimental condition ($\bar{x} = 10.6$, s.d. = 3.09).

3.3. Comparison of Pre-Post Test Response Times by Condition

To assess the primary hypothesis that there is a significant impact of video game play on motor function, a repeated measures analysis of variance was conducted

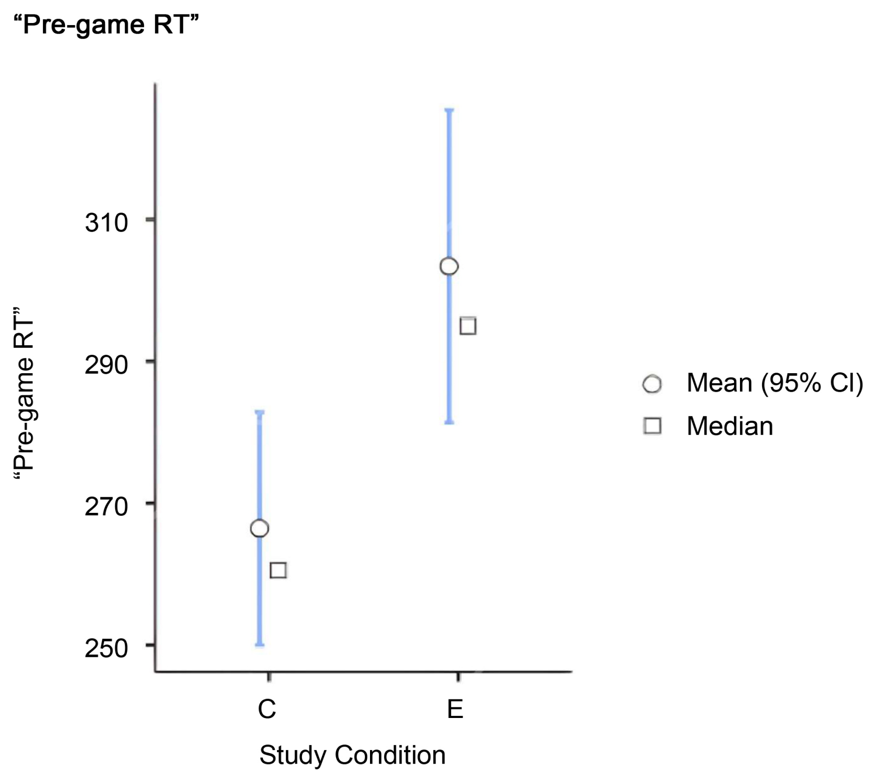

Figure 3. The mean response times by experimental condition for the initial manipulation check of the reaction time task performed in pre-test.

with response time and as a factor each having two levels (pre-post) by condition. No significant differences were found in response time score change from pre to post manipulation as a function of experimental condition F(1,23) = 0.216, $p < 0.647$. Please refer to the Repeated Measures Anova Table 2 below. Unexpectedly, individuals in the control condition were significantly faster at pre and post response times on average ($\bar{x}$ = 266 ms, s.d. = 44.3) than were participants in the experimental pre post ($\bar{x}$ = 303, s.d. = 310). Please see Figure 4 for estimated marginal means for response time scores pre and post manipulation by experimental condition.

Repeated Measures ANOVA

Table 2. Results of the repeated measures task for analysis of variance of response time pre-post manipulation by condition.

Within Subject Effects					
	Sum of Squares	df	Mean Square	F	P
Response Time	51.3	1	51.3	0.0557	0.816
Response Time * Study Condition	198.5	1	198.5	0.2155	0.647
Residual	21178.9	23	920.8		

Note. Type 3 sums of squares.

Between Subject Effects					
	Sum of Squares	df	Mean Square	F	P
Study Condition	14,672	1	14,672	2.88	0.103
Residual	117,127	23	5092		

Note. Type 3 sums of squares.

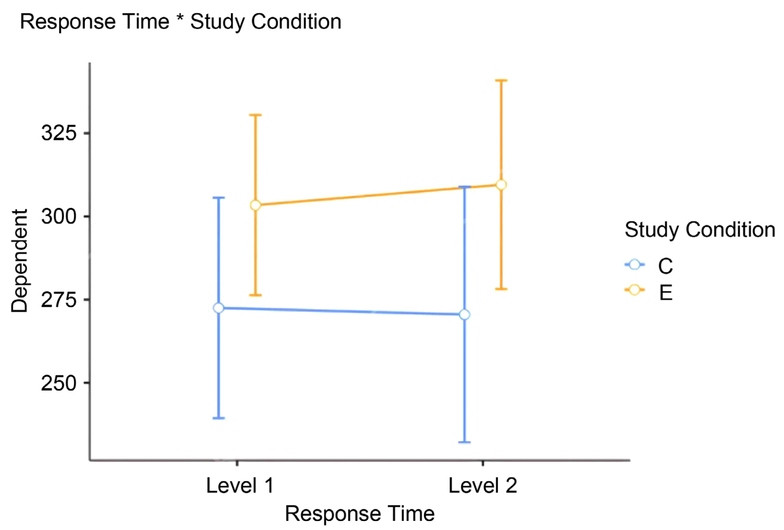

Figure 4. Estimated marginal means for response time task by experimental condition.

The significant result in the pre-manipulation condition for the reaction time task suggests this test may not be sensitive enough as a post-manipulation assessment as compared to the memorization task in the pre-manipulation condition.

This in the control group was faster at the response time task in both the pre and post manipulation condition. Those in the video game play experimental condition were slower at the response time task following video game play, possibly due to motor fatigue.

3.4. Comparison of Pre-Post Test Memorization Scores by Condition

To assess the primary hypothesis that there is a significant impact of video game play on cognitive function, a repeated measures analysis of variance was conducted on pre-post memorization accuracy scores by condition. While a main effect was found on the pre-post scores, $F(1,23) = 4.34$, $p = 0.048$ with a small effect size of $\eta p^2 = 0.59$, no significant interaction was found on pre-post memorization scores by condition (see Figure 5). Please see Table 3 for estimated marginal means for memorization scores pre and post manipulation by experimental condition.

3.5. Relationships in Reported Trait-Oriented Stress

A Subset of study participants (N = 15) were asked a number of self-report

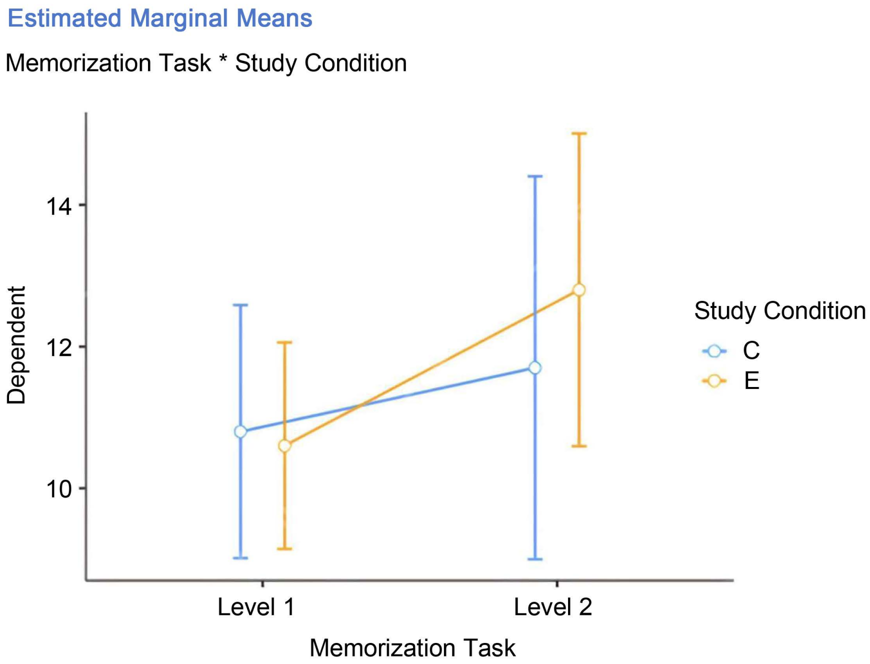

Figure 5. Estimated marginal means for memorization task by experimental condition.

Table 3. Estimated marginal means for memorization scores pre and post manipulation by experimental condition. Participants memorization scores increased in the post manipulation condition compared to the pre-manipulation condition.

Estimated Marginal Means - Response Time * Study Condition					
				95% Confidence Interval	
Study Condition	Response Time	Mean	SE	Lower	Upper
C	Level 1	272	16.0	239	306
	Level 2	271	18.6	232	309
E	Level 1	303	13.1	276	330
	Level 2	310	15.2	278	341

inventories related to their levels of stress. The following questions were asked of each participant:

- "How well do you think you take stress?"
- "On average, how many times a week do you feel acute stress?"
- "What do you think an acute stress is to you? (ex. studying for exam)"

Self-reported stress was measured to understand the relative impact of trait-based stress levels on response time and memorization scores. This was done to ensure that stress would not serve as a strong moderating variable potentially impacting scores beyond the initial videogame treatment (see **Figure 6**).

A correlation matrix was performed to assess the extent to which reported stress levels had with each other and with the performance measures. A near significant difference in Pearson's r value was found for pre-game response times by reported ratings for participants' ability to handle stress r(13) = −0.498, p = 0.059. See Figure 7 for the scatterplot of pre manipulation response time scores by reported ability to handle stress (1 = handle poorly; 5 = handle very well). The less participants reported handling stress, the slower their pre-manipulation response times indicating a negative bivariate correlation between these two variables. This effect was not found in the post manipulation response times.

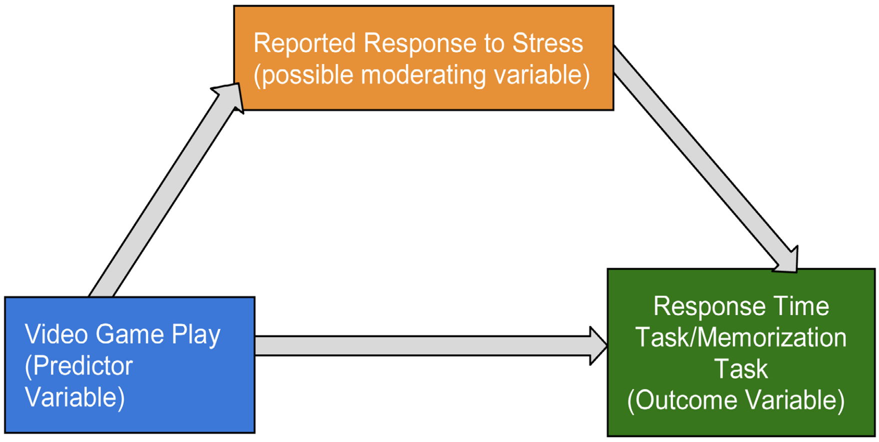

Figure 6. Model to demonstrate potential moderating effects of self-reported levels of participant stress on speed and accuracy tasks.

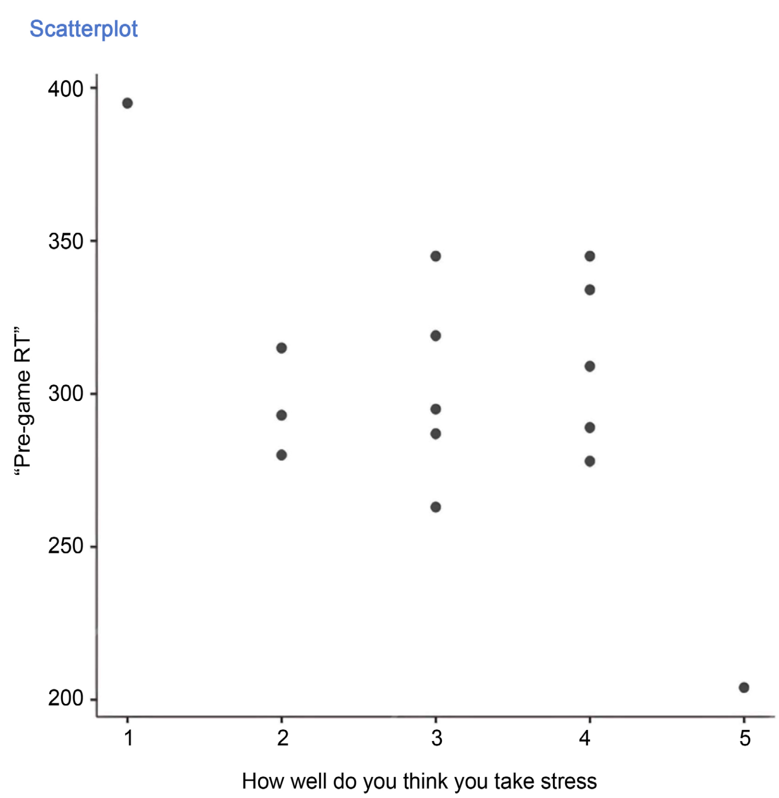

Figure 7. Scatterplot of the near significant bivariate correlation of pre-manipulation response time scores by reported ability to handle stress.

4. Discussion of Future Research

Overall, the results showed no interactions, however, this study's findings support prior research on the positive impacts of video game play on memory, but not motoric response time enhancement. This effect was not found overall for response time scores, and video game play did not appear to facilitate memorization or reaction times. This may be due to a number of factors, such as a ceiling effect lowering the sensitivity of finding positive effects of game play on concentration or response times potentially due to the participants' starting scores being already high, exceeding those scores may have proven a limitation. Another potential moderating effect could be due to distractions; as noted in the survey, many participants believed that gaming before memorization might be distracting and lead to less productivity.

In future experiments, an equal number of adults and adolescents balanced for gender would be examined. A recent research study found gender differences in the adolescent brain, a time of increased divergence between males and females in physical characteristics. According to functional imaging studies, male and female brains employ different strategies for achieving similar cognitive abilities (Lenroot & Giedd, 2010). That said male and female brains can show different patterns of activation without differences in performance. In comparison to males, females showed statistically significant increases in short-term memory. Males showed a non-significant increase in perceptual ability compared to females. Females carry out episodic memory tasks more efficiently than males when the tasks are verbal in nature, as opposed to spatial. Generally, females are able to access their memories more quickly and date them more precisely than males. In addition to a memorization and reaction time task, additional measures of more holistic cognitive abilities could be integrated into the study design to assess emotional dynamic, such as changes in reported aggression or implicit response time tasks to evaluate changes in specific associations with emotion-related words.

5. Limitations

This study included a small sample size, with only a few adults in the total participants, and a limited number of adolescents. In addition, previous research has shown that some addiction control games could benefit the cognitive brain. However, the current study does not fully demonstrate that playing video games can enhance memory and reaction time and counter brain aging. Future studies should expand surveys to include more participants from different age groups and should be separated into different groups for further comparison.

Furthermore, the type of video game used and the duration of time spent playing the video could possibly have influenced the results. Different levels of cognition demand could affect the participants' performance based on their level of involvement. An excessive amount of screen time can result in fatigue, and a difference could not be created if the exposure was too little.

Finally, the memorization and gaming tasks chosen as dependent measures in the study could be considered instrumentation threats to the internal validity of a potential beneficial cause and effect relationship of video game play on motor and cognitive functioning. The assessments selected for this study may have lacked sensitivity to measure the influence of video game play on cognition and response times.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix A

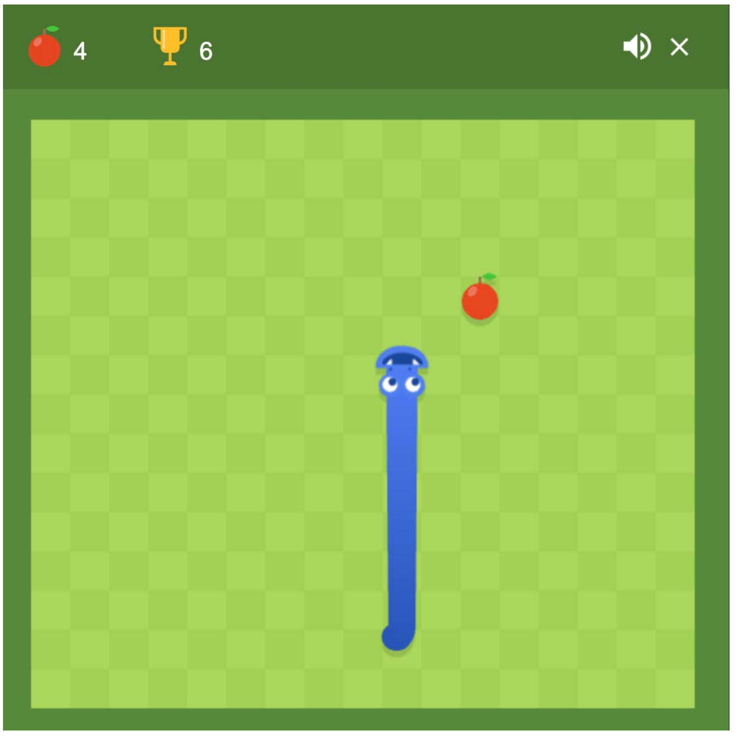

Figure A1. Image of the game for experimental manipulation.

Figure A2. Image of the nature video for experimental manipulation.