An Exploration of Gaming, Problem Solving, Spatial Skills, and Persistence

Niamh Daly Ryan

N00114783

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Declaration

This Thesis is entirely my own work, and has not been previously submitted to this or any other third level institution.

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Signature:

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Acknowledgements also to my partner in crime for putting up with my constant chatter and my family for helping me through. Special thanks also to my friends, classmates and most importantly, the wonderful participants who so willingly provided their time and effort from the very beginning.

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Abstract

The aim of the study was to discover if playing a popular video game (Portal 2) would result in short-term cognitive and psychological improvements, namely problem solving, spatial skills, and persistence. It partially replicated previous research by Shute, Ventura and Ke (2015), which found that playing Portal 2 was associated with cognitive and non-cognitive gains in comparison to the control condition. In this study, 40 participants with a male to female ratio of 18:22, and an age range of 20-64 (*M*= 30.83 years; *SD* = 10.39), were assigned to the gameplay or control condition. Participants completed paper-based tests before and after 0h or 2h of gameplay within a 2-week timeframe. The tests measured cognitive flexibility and mental rotation ability, while self-report surveys computed gaming experience and persistence. Results revealed that participants in the gameplay condition did not significantly differ from participants in the control condition on each of the measures, $F(1,36) = .729$, $p > .399$, 3.263, $p > .065$, 1.177, $p > .285$. The author discusses results in terms of study limitations. Findings may also offer practical applications to video game developers and upcoming researchers within the field of computer gaming. Future research should carefully consider the use of the Remote Associates Test to measure cognitive flexibility and a performance-based measure of persistence is suggested.

Introduction

The tendency to play video games for one's own enjoyment is now regarded as a common pastime for both children and adults alike (Kühn et al., 2011). Its growth in popularity can be attributed to the advancement of computer technology (Errity, Rooney, & Tunney, 2016). A video game can be defined as an interactive activity played by manipulating images on an electronic device (Granic, Lobel, & Engels, 2014). There are many different genres of video games including but not limited to platformer, first-person shooter, role-playing, and puzzle, which can be played single or multiplayer, and collaboratively or combatively across a variety of electronic devices (see Rabin, 2011 for further detail). For the purpose of simplifying its definition, Granic et al. (2014) postulate that a video game differs according to its level of intricacy and its degree of social interaction. Given the increased ubiquity of video gaming in modern society, the psychological impact it may have on its users is important to consider (Errity et al., 2016). The following paragraphs will examine the effects of video gaming in the area of cognition, problem solving, spatial skills and persistence.

Video Gaming and Cognition

It is hypothesised that video games require cognitive skills in order to be played effectively (Bavelier, Green, Pouget, & Schrater, 2012). Thus, the effects of video games on cognition have been examined in studies where performance on cognitive tasks is compared between those who regularly play video games and those who do not, and also in studies where the performance of participants is analysed pre and post video game training (Sobczyk, Dobrowolski, Skorko, Michalak, & Brzezicka, 2015).

Across both types of studies, video games have been linked with improvements in the area of information processing, including the development of auditory processing skills, executive functions such as working memory and attention, motor and spatial skills, and visual processing abilities (Powers, Brooks,

Aldrich, Palladino, & Alfieri, 2013; Mishra, Bavelier, & Gazzaley, 2012). However, only a certain type of video game, known as an "action" game in the research but as a shooter game by players, has been associated with the strongest findings (Green & Bavelier, 2012). More recently, it has been postulated that playing video games may lead to problem solving skill improvements (Prensky, 2012).

Video Gaming and Problem Solving

Problem solving can be simply defined as a series of goal-directed cognitive processes (Anderson, 1980; Mayer & Wittrock, 1996). More specifically, problem-solving skill is an individual's ability to utilise one's own cognitive operations to comprehend and overcome events, in which the strategy to resolve the problem is not initially clear (Shute, Wang, Greiff, Zhao, & Moore, 2016). Shute, Ventura and Ke (2015) argue that problem solving consists of four main components; rule application, cognitive flexibility, problem decomposition, and resource management. Rule application involves the identification and implementation of existing rules in a problem in order to decipher it, whereas cognitive flexibility is the capacity to rearrange prior ways of thinking and investigate other methods of solving a problem, thereby appropriately employing previous knowledge or rules in a new environment (Shute & Wang, 2015). Problem decomposition comprises of breaking the goal of the dilemma down into steps, while resource management encompasses effectively managing resources to help unravel the solution (Shute et al., 2015).

Shute and Wang (2015) maintain that rule application and cognitive flexibility are the two main components of problem solving that are theorised to develop in those who play video games. They contend that "good digital games" (p.13) require the player to constantly formulate new knowledge and novel strategies to fulfil a variety of interesting goals in different scenarios. Moreover, many problems become increasingly difficult as the game progresses and require new thought processes in order to advance to the next level. Furthermore, Prensky (2012) proposes that games in which limited information is provided on how to solve a problem are extremely beneficial as it allows the participant to learn through trial and error.

Nonetheless, there is a limited amount of research that directly examines the relationship between the development of problem solving skills and video games (Shute et al., 2016; Granic et al., 2014). One research study found that the more adolescents played strategic video games, the more they self-reported improved problem solving skills the following year (Adachi & Willoughby, 2013). Moreover, self-report improvements in problem solving skills were indirectly linked with better academic grades. While also not objectively analysing problem solving skills, this finding was not attributed to other types of video games. However, another study, consisting of 228 undergraduate students, discovered that the students who were in the gameplay condition performed better on the Wisconsin Card Sorting Test than those who were in the non-gameplay (control) condition (Buelow, Okdie, & Cooper, 2015). Unfortunately, this study did not take account of the participants' video game play frequency. Therefore, the researchers are unable to determine the degree to which this may have effected their findings. The development of spatial skills have been more promisingly associated with action video games (Green & Bavelier, 2012).

Video Gaming and Spatial Skills

Spatial skills consist of abilities that allow an individual to use different types of information, which can be internal, external, static or dynamic, to find one's own sense of location (Uttal et al., 2012). Ventura, Shute, Wright and Zhao (2013) classify spatial abilities according to three distinct components; figural, vista and environmental. Figural spatial skills involve the ability to use external information relative to one's own body, while vista spatial skills comprise of the capacity to imagine an object or oneself from different locations, and environmental spatial skills include the tendency to apply information from the environment, in order to locate oneself.

It is argued that the nature of action video games allows for the development of different spatial skill abilities (Ventura et al., 2013). Action video games are generally fast-paced with objects that move swiftly or suddenly appear and disappear in the visual field of the game. They also place high cognitive, motor and

sensory loads on their users and require them to divide their attention across various situations within the game in order to play successfully (Green & Bavelier, 2012). Shute et al. (2015) label these features of 3D action video games as visual-spatial requirements, which are postulated to help enhance spatial skills. However, as Wauck, Xiao, Chiu and Fu (2017) point out, there has been little to no research on examining the specific features of action video games that can result in spatial skill gains. Nonetheless, promising findings in relation to action video games and spatial skill development have been noted in studies where inexperienced gamers are randomly allocated to either play an action video game or to play a different type of video game for an equal amount of time (Granic et al., 2014).

In numerous studies, compared with participants in the control condition, gamers in the action video game condition show quicker and improved attention allocation, visual processing skills, and mental rotation ability (see Green & Bavelier, 2012). A meta-analysis by Uttah et al. (2013) that examined the effectiveness of spatial skills training in 206 studies, revealed that 24 of the studies used video games and had an overall moderate effect on improving participants' spatial skills. Moreover, Ventura et al. (2013) found that participants' self-reported appraisals of their video game experience were correlated with their environmental spatial skills as measured by the authors' spatial ability assessment, in that higher video game use was associated with better spatial skill scores. Although the authors developed a covert measure of environmental spatial skills, they did not ask specific enough questions in relation to the participants' video game use. Therefore, it is unknown as to which type of video game leads to the best outcome in terms of environmental spatial skill enhancement. Lastly, it is important to consider that other genres of video games such as puzzle and role-playing games have not been linked with cognitive improvements (Green & Bavelier, 2012). However, this may be due to other methodological factors and confounding variables such as the implementation of inappropriate control conditions (Kristjánsson, 2013). Moreover, psychological factors such as persistence can influence one's experience of a game (Granic et al., 2014).

Video Gaming and Persistence

Persistence is a component of conscientiousness that expresses an individual's inclination to complete challenging tasks with high quality execution no matter how exasperating the encounter (McClelland, 1961; Dudley, Orvis, Lebiecki, & Cortina, 2006). Dweck and Molden (2005) argue that it is important to examine persistence as it ultimately helps human beings to succeed and achieve in life.

According to Ventura, Shute and Zhao (2013), persistence in video games may operate via the principle of challenge, whereby video games will adjust their level of difficulty just slightly beyond the player's current ability, coinciding with Vygotsky's (1978) zone of proximal development theory. Nonetheless, there has been very little evidence to suggest that video games are explicitly associated with persistence in both experimental and real-world settings (Granic et al., 2014). However, the aforementioned study by Ventura et al. (2013) discovered that frequent video game players spend a longer amount of time attempting to solve problems than infrequent video game players. Using anagrams and riddles, the researchers designed a measure of persistence, defining it as the amount of time spent on unanswered puzzles. One strength of the study was its performance-based assessment of persistence but it could not stipulate the direction of its effects. It is possible that individuals who persist for a longer duration in problem solving challenges are more prone to playing video games in the first place (Adachi & Willoughby, 2013). Further research is urgently required in this area in order to discover the relationship between persistence and video gaming. On the other hand, a study by Shute, Ventura and Ke (2015) encompasses a variety of different findings in relation to problem solving, spatial skills, persistence and video gaming. These findings will now be discussed in the following paragraphs.

Video Gaming, Problem Solving, Spatial Skills, and Persistence

In Shute et al. (2015), 77 undergraduate students were randomly assigned to one of two groups, in which participants in one group played a popular game known

as Portal 2 and participants in another group played a popular brain training game called Lumosity over the duration of 8 hours. Participants' problem solving skills, spatial cognition and persistence were measured pre and post gaming. They discovered that the students who were allocated to the Portal 2 condition performed better on the study's measures of problem solving, spatial skills, and persistence than the students who were in the Lumosity group. Moreover, the most notable result from the study was that the participants in the Portal 2 group showed significant gains from pre-test to post-test on spatial cognition assessments, while those in the Lumosity condition did not improve with respect to spatial skills.

The study displayed rigorous methodological design by its implementation of an active control group and also by attempting to ensure that the participants in the active control group had a similar anticipation of improvement as the intervention group (Boot, Simons, Stothart, & Stutts, 2013). For example, in this particular case, Lumosity, the control condition, explicitly states its aim is to improve the consumer's cognition. Boots et al. (2013) argue that it is only by ensuring both experimental and control groups have the same expectations of the intervention that placebo effects can be completely ruled out as an explanation for significant findings in video gaming studies. On the other hand, the researchers were unable to fully explain why the problem solving scores of the participants in the Lumosity group decreased from pre-test to post-test. Replication of the study is warranted in order to explore these findings further. The following section will outline Portal 2, the game utilised in the study.

Portal 2

Portal 2, created and distributed by Valve Corporation, is a widely known first-person 3D puzzle video game. It requires the gamer to solve a succession of challenging problems. The main aim of the game is to escape from the dilapidated headquarters of Aperture Science, a fictional scientific research company, which tests their products on humans. Players are given the first-person role of Chell, a previous testing subject, who must use a variety of tools to flee the facility through a

series of doors, known as portals. The main device is the portal gun, which utilises physics in order to create portals that effectively allow Chell to transport from one area to another. Flinging, shown in Figure 1, is one such ability in the game that entails the application of physics principles; any force such as speed or gravity applied to Chell while entering the portal will occur when leaving it, thus the player can "fling" themselves long distances mid-air (Shute et al., 2015). Other in-game tools, depicted in Figure 2, include Thermal Discouragement Beams (lasers that attack turrets who fire fatal laser beams at Chell), Redirection Cubes (that can divert laser beams from attacking Chell), gels (that can result in differing effects when applied to a surface or object, for example, Repulsion Gel reduces the friction of anything that touches it or makes contact with it), Excursion Funnels (tractor beams), and Hard-Light Bridges (semi-translucent solids made from sunlight that can act as bridges or shields against hazards for the player). The gamer must figure out how to use these devices to their advantage in helping Chell to reach the exit (Shute & Wang, 2015).

Upon initial introduction to the game, players are brought through a series of tutorial levels where the general movement controls and their interaction with the environment are explained. Chell can die after falling into a bottomless pit or toxic pool but not if she lands onto a hard surface (Shute et al., 2015). The subsequent section will discuss how a player might develop their problem solving abilities, spatial skills and persistence as a result of Portal 2 gameplay.

Portal 2, Problem Solving, Spatial Skills and Persistence

Shute and Wang (2015) hypothesise that in the context of problem solving, rule application and cognitive flexibility are two problem solving skills that could be potentially developed by playing Portal 2. Players must identify and implement existing rules in the game in order to solve a problem. For example, a cube is required to act as a weighted item in order to keep any device associated with it activated. Once a gamer discovers this, they can use this rule to help them open a

a portal, thereby solving the immediate problem. Moreover, gamers start to discover how to apply the rules or in-game tools in a novel way depending on the circumstances of the game. For instance, the Repulsion Gel, which is initially used for the purposes of making objects bounce off Shell, can also be applied to turrets in order to extinguish them. This new insight is extremely helpful to the player as it enables him or her to succeed with ease in the game.

Figure 1

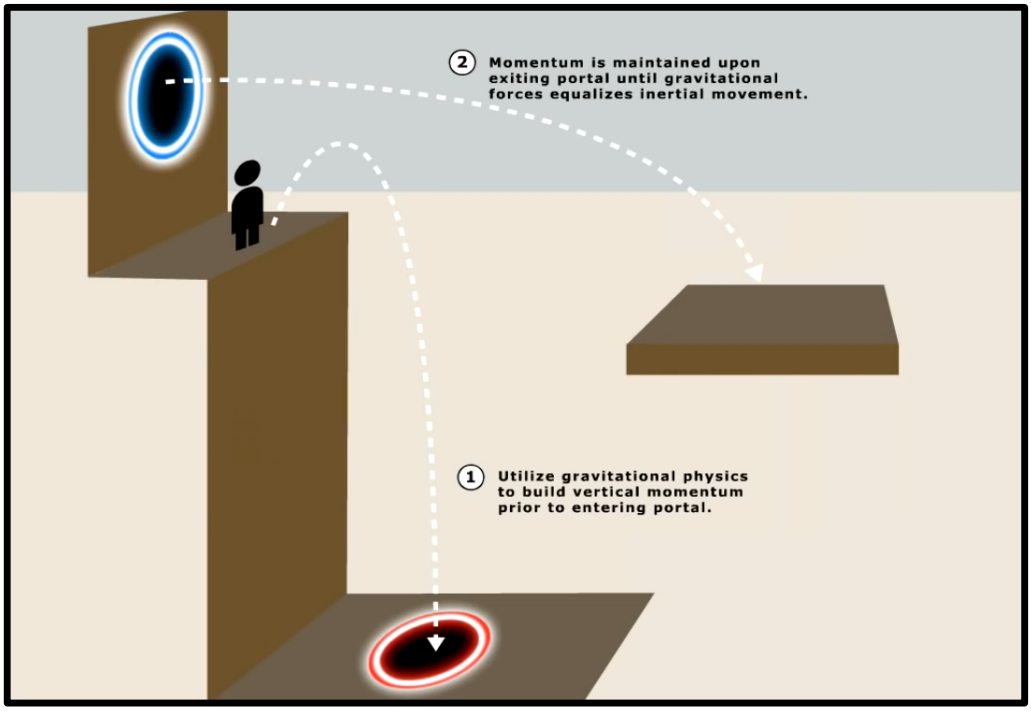
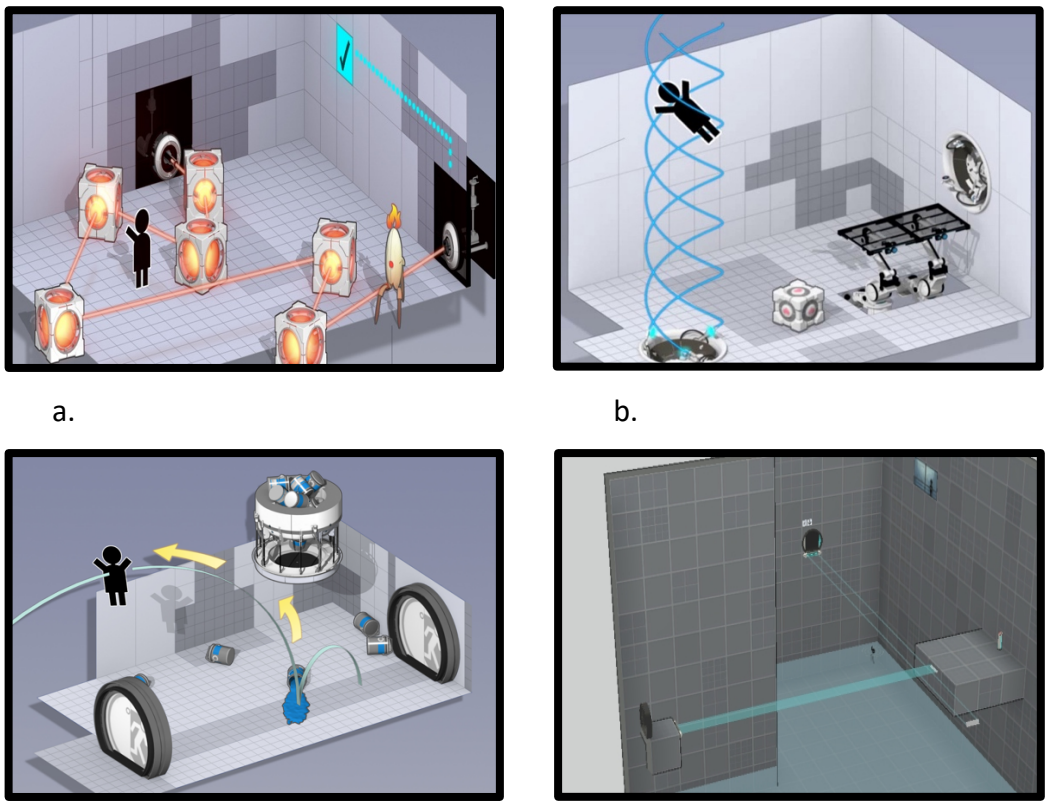


Figure 1. How flinging occurs in Portal 2. Chell builds up momentum and uses gravitational physics prior to entering the portal (1). Gravitational forces equalise movement upon exiting the portal (2) (Valve Corporation, 2016).

In relation to spatial skills, it is argued that because Portal 2 is played from a first-person perspective and requires the player to navigate through a 3D environment by referring to neighbouring or remote features of the immediate gameplay setting, it has the capacity to develop them (Wauck et al., 2017). Chell must navigate her way through Aperture Science's Enrichment Centre by jumping, pulling, pushing, and running, all the while keeping in constant touch with her sense of direction.

Figure 2



a. b.

c. d.

Figure 2. Tools used in Portal 2 (a) Thermal Discouragement Beams alongside Redirection Cubes, depicted attacking a turret, (b) an Excursion Funnel transporting Chell, (c) Repulsion Gel allowing Chell to jump higher than usual, and (d) a Hard-Light Bridge allowing Chell to cross over an area that was previously inaccessible (Valve Corporation, 2010, 2011, 2017).

Finally, Portal 2 provides a large number of opportunities to challenge its players. Gamers must become frustrated and fail in the game in order to eventually succeed. Even at the beginning of the game, some players will find it difficult to understand the concept of the teleporting portals. Persistence is a central tenet of Portal 2 as it gradually becomes more difficult and instils a greater amount of cognitive load on its user. Figure 3 provides an overview of the specific Portal 2 features that may correspond with specific cognitive and non-cognitive skills.

Figure 3

Possible skill developed	Portal 2 features
Rule application and cognitive flexibility	Redirection Cubes Gels (e.g. Repulsion Gel)
Spatial skill	First-person perspective 3D environment
Persistence	Opportunities for challenge Increasingly difficult

Figure 3. An overview of Portal 2 features that may develop specific skills.

The Present Study

While previous research has discovered that Portal 2 has a significant positive effect on problem solving, spatial skills, and persistence (Shute et al., 2015), to the author's knowledge this was the first study of its kind to directly examine the cognitive and non-cognitive effects of a commercially available video game. The present study acknowledges that there is little research in this area and the aforementioned study requires replication to explore these findings further. Research questions and hypotheses are outlined below.

Research Questions

1. Will playing computer games result in problem solving and spatial skill gains?
2. Will playing computer games improve one's persistence?

Hypotheses

1. Hypothesis One: There will be differences between participants who play Portal 2 in terms of problem solving in comparison to those who do not.

2. Hypothesis Two: There will be differences between participants who play Portal 2 in terms of spatial skills in comparison to those who do not.
3. Hypothesis Three: There will be differences between participants who play Portal 2 in terms of persistence in comparison to those who do not.

Methodology

Pilot Study

Before commencing full-scale data collection, the researcher conducted a pilot study in order to examine the feasibility of its approach (see Leon, Davis, & Kraemer, 2011). In particular, the investigator evaluated the practicality of the study's location and study materials, and its exclusion or inclusion criteria. The study was piloted with one female participant, aged 59. The tutorial rooms available in IADT were deemed as an appropriate location for testing and adjustments relating to the management and organisation of study materials were addressed. The baseline and post assessment materials were grouped together to help testing run more smoothly. For example, form A was separated from form B. Information leaflets were given to participants prior to testing so that they would have ample time to read before consenting. It was also decided that being comfortable with using a computer mouse and laptop computer to play a video game would be listed as an additional inclusion criterion. Otherwise it could potentially serve as a barrier to participation and affect the future consent rate of participants (Leon et al., 2011).

Design

The research design of the present study was experimental in nature, implementing a 2x2 mixed-design analysis of variance model (ANOVA), with 1 independent variable and 3 dependent variables. The independent variable was playing Portal 2 versus not playing Portal 2, while the dependent variables were problem solving, spatial skills and persistence. The research design enabled the researcher to examine if differences between the gameplay and control groups were associated with pre and post cognitive and non-cognitive performance.

Participants

18 males and 22 females agreed to take part in the study. 38 participants completed both the pre and post-tests, while 2 participants in the control condition did not complete the post-tests. Participants were aged between 20 and 64 (*M*= 30.83 years; *SD* = 10.39). Participation was requested by posting in Facebook pages, for example the Psychology IADT Facebook group, and via flyer advertisements placed around IADT campus. The researcher also invited participation from IADT's Psychology undergraduates by briefly chatting to them, leaving information about the study with students and lecturers, and providing a sheet to list contact details if interested. Participants could take part in the study if they were; aged between 18 and 65 years, comfortable with using a computer mouse and laptop computer to play a video game, and able to give 1.5 hours of their time over two sessions. Exclusion criteria included susceptibility to motion sickness and playing Portal 2 previously. Due to the time constraints of the study, the first 20 participants that were interested in taking part were assigned to the gaming condition while the remaining participants were assigned to the control condition.

Materials

Within 20-30 minutes, participants in both the control and gaming condition filled in demographic information, current gaming experience (see Appendix A), and completed paper and pen-based cognitive and non-cognitive assessments, which measured problem solving, spatial skills, and persistence (see Appendices B, C and D). Participants completed forms A pre-test and forms B post-test. Details surrounding the tests will be explained below.

Gaming Experience

Current gaming experience was measured using a self-report survey, which was designed under the supervision of Dr. Gráinne Kirwan.

Problem Solving

Cognitive flexibility, one of the four main aspects of problem solving skills previously outlined, was measured by the remote associates test (RAT). Developed by Mednick and Mednick (1967), the RAT was designed to measure creative thought without the necessity of having expertise in any particular field (Chermahini, Hickendorff, & Hommel, 2012). According to Mednick's (1962) associative theory of creativity, creative thought occurs when one realises that the solution is not the obvious choice and he or she must think beyond the information that is given, arriving at more remote associations.

Two college-level versions of the test are available, each consisting of 30 items (Mednick, 1968; Mednick & Mednick, 1967). Every problem comprises of 3 words and participants are requested to discover the fourth word that is associated with all 3, which on the outset initially appear unlinked to one another (Shute & Wang, 2015). The fourth word can be connected with the 3 words in a variety of ways. For example, the 3 words COTTAGE/SWISS/CAKE are associated with the answer CHEESE, involving synonymy (cottage = cheese), forming a compound word (cheesecake), and a semantic association (Swiss cheese) (Chermahini et al., 2012).

In the present study, 5 different items from the RAT were administered pre and post-test, with a time limit of 5 minutes per problem. According to Shute et al. (2015), the reported reliability of the 5 items in the pre-test was .54. The reliability was corrected to .82 when it was calculated using the Spearman-Brown prediction formula on a 20-item test length of the test. The Spearman-Brown coefficient was not reported for the post-test. In the current study, the Cronbach alpha coefficient for the pre-test was .6 and .61 in the post-test (see Appendix E). However, as there were only 5 items in both tests, Briggs and Cheek (1986) recommend reporting the mean inter-item correlation, which in this case was .24 in the pre-test and .27 in the post-test. As the inter-item correlations are between .2 and .4, they are within the optimal range.

Spatial Skills

The mental rotation task (MRT), adapted from Vandenberg and Kuse (1978), was used to measure figural spatial skill. In this task, participants are shown a three-dimensional reference figure and 4 target figures. Test subjects must mentally rotate the target figures to locate the 2 correct items that match the reference figure (Hoyek, Fargier, Collet & Guillot, 2012).

In the present study, 6 different MRT items were administered pre and post-test, with no time limit required. The total score was based on the total number of problems where both accurate figures were selected. Higher scores indicated better figural spatial skill. According to Shute et al. (2015), the reported reliability of the 6 items in the pre-test was .65. The reliability was corrected to .90 when it was calculated using the Spearman-Brown prediction formula on a 30-item test length of the test. The Spearman-Brown coefficient was not reported for the post-test. In the current study, the Cronbach alpha coefficient for the pre-test was .58 and .67 in the post-test (see Appendix F). The mean inter-item correlations were .18 in the pre-test and .26 in the post-test. The reliability of the pre-test was below the optimal range, while the reliability of the post-test was within range.

Persistence

Persistence was measured using a self-report survey, which was administered pre and post-test. 8 questions relating to persistence were adapted from the International Personality Item Pool (IPIP) perseverance/industriousness/persistence scale. The items were rated on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree. For example, “I don’t get side-tracked when I work”, and “I give up easily”, which was reverse scored. According to Shute et al. (2015), the reported reliability of the 8 items in the pre-test was .79. The reliability was corrected to .84 when it was calculated using the Spearman-Brown prediction formula based on a 15-item survey length. The persistence survey was not administered post-test, therefore the Spearman-Brown coefficient was not reported. In the current study, the

Cronbach alpha coefficient for the pre-test was .76 and .78 for the post-test (see Appendix G), suggesting acceptable reliability. The mean inter-item correlations were .31 in the pre-test and .32 in the post-test, which were within the optimal range.

Procedure

Participants in the gaming condition spent a total of 3 hours in the study, while those in the control condition spent a total of 1 hour. Testing in both groups took place over 2 separate sessions in the tutorial rooms of the college campus, across a period of 2 weeks. Each of the sessions lasted 1.5 hours if the participant was in the gaming condition, and 30 minutes if the participant was in the control group.

Participants were emailed or given a copy of the information leaflet prior to Session 1 of the study (see Appendix H). In Session 1, subjects re-read the information leaflet and signed the consent form (see Appendix I). All participants completed the gaming experience survey and were then administered the pre-tests, which were completed in 20-30 minutes. Following on from this, a 2-week post-test was arranged with those in the control condition, while those in the gaming condition were requested to read over the brief instructions provided for Portal 2.

The researcher set up the video game for participants in the gameplay group and ensured the developer console version of the game was enabled in order to create log files, which could track the user's performance during gameplay. The computer mouse was attached to the laptop computer and the sound was set to an appropriate volume. Participants were then requested to start playing the video game. The researcher took a note of the time the subject started playing and only interrupted gameplay once the hour was up. The researcher stayed present throughout gameplay, for the sole purpose of providing technical assistance to the participant if it was requested. The gamer's progress was saved. The follow-up 1-hour gaming session and post-tests were then scheduled for 2 weeks later.

In the final session of the study, Session 2, participants in the control condition were administered the pre-tests, which were completed in 20-30 minutes, and were then debriefed (see Appendix J). Subjects in the gaming condition once again began playing the game for 1 hour, from where the game had been saved in the previous session. Finally, gamers were administered the pre-tests and were debriefed.

Ethical Considerations

In accordance with IADT, PSI and BPS guidelines, participants were ensured that their answers to the cognitive and non-cognitive assessments would be kept confidential and unidentifiable as they would be given a unique study ID. As a result, participants were also informed that the correct answers to the tests could not be given if requested. Furthermore, they were informed that the data collected would be stored in a locked filing cabinet and in a password-protected laptop in a password-protected SPSS file, that only the researcher would have access to. Participants were also informed that they could withdraw their data from the study at any stage.

Another ethical issue that was considered before the researcher commenced data collection was that participants might feel motion sickness from playing the video game. The researcher stressed that motion sickness is an exclusion criterion to interested participants, which helped to prevent any participation problems. It was also re-emphasised that subjects must immediately stop playing the game should they experience even the slightest feelings of motion sickness.

Results

The following section reports the main findings from the analysis. Results were examined within the context of the research questions, which attempted to discover if playing computer games enhance problem solving and spatial skills, and if playing computer games improve persistence. Data were arranged according to the condition participants were assigned to, which included the gameplay condition or the control condition.

Method of Data Management and Analysis

Data were collected and inputted into SPSS version 24 (IBM Corp., 2016). SPSS was used to determine the frequency distribution of participants' age and gender (see Appendix K). A two-way repeated measures ANOVA analysed differences between participants in the test condition and in the control condition by comparing scores on pre and post-tests of problem solving, spatial skills, and persistence.

Descriptive Statistics

The data of 18 male and 22 female participants were analysed, which consisted of responses to the gaming experience survey (see Appendix L), the Remote Associates Test (RAT) (Mednick, 1968), the Mental Rotation Test (MRT) (Vandenberg & Kuse, 1978), and the persistence survey. Figures 4 and 5 summarise the descriptive statistics for the gameplay condition and the control condition separately. Mean pre and post-test responses to the RAT, MRT and persistence survey are shown (see Appendix M).

In relation to the gaming experience survey, 21 participants (12 males and 9 females) admitted to playing video games once per week, with the mean duration of gaming sessions lasting between 1 and 3 hours. Participants mostly played video games on smartphones, Xbox consoles, laptop and desktop computers. The remaining 19 participants did not report playing video games at the time of testing.

Figure 4

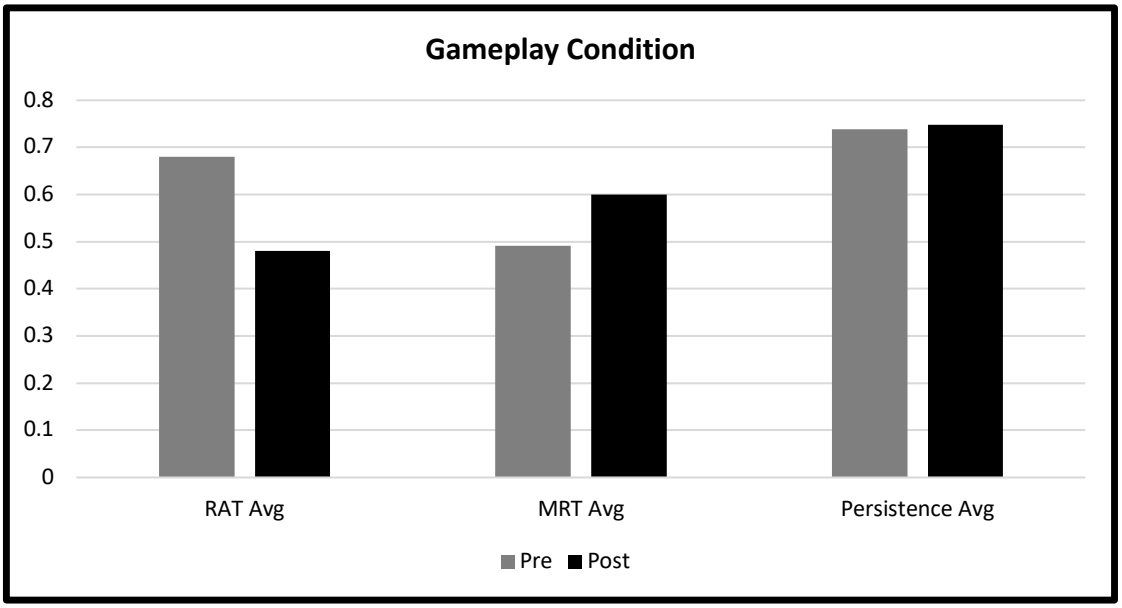


Figure 4. Descriptive statistics for the gameplay condition, displaying pre and post mean scores on the MRT, RAT and persistence survey (n = 40). RAT scores decreased, while MRT and scores increased from pre to post-test. Persistence scores increased very slightly.

Figure 5

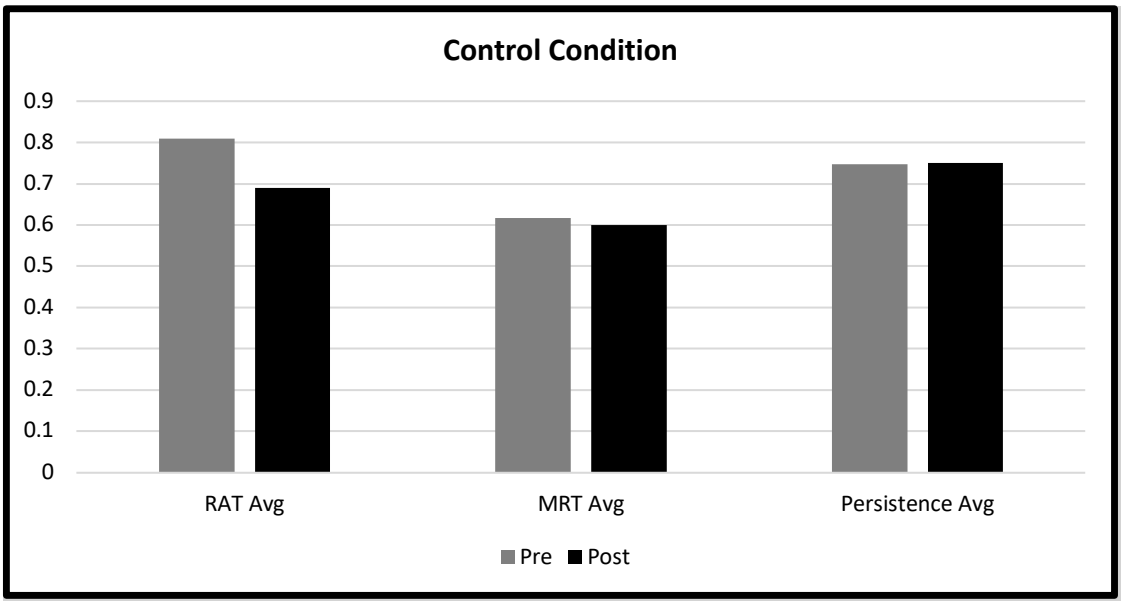


Figure 5. Descriptive statistics for the control condition, displaying pre and post mean scores on the MRT, RAT and persistence survey (n = 40 pre-test, n = 38 post-test). RAT and MRT scores decreased, while persistence scores increased very slightly from pre to post-test.

Inferential Statistics

Hypothesis 1, which stated that there will be differences between participants who play Portal 2 in terms of problem solving in comparison to those who do not, was not supported as an interaction effect between RAT scores and study condition was not observed $F(1,36) = .729$, $p > .399$. However, there was a significant small main effect observed for study condition and RAT scores, $F(1,36) = 5.134$, $p < .03$, where both groups overall showed a statistically significant reduction in RAT scores at the second time point, $F(1,36) = 8.927$, $p < .005$. This effect was most pronounced in the gameplay group, $t(19) = 2.757$, $p < 0.013$, leading to a significant difference in the performance of the two groups at time point two, $F(1,36) = 1.597$, $p < .037$. See Appendix N for further detail.

Hypothesis 2, which stated that there will be differences between participants who play Portal 2 in terms of mental rotation in comparison to those who do not, was not supported as an interaction effect between MRT scores and study condition was not observed, $F(1,36) = 3.263$, $p > .065$. Main effects were also non-significant $F(1,36) = .7$, $p > .408$. See Appendix O for further detail.

Hypothesis 3, which stated that there will be differences between participants who play Portal 2 in terms of persistence in comparison to those who do not, was not supported as an interaction effect between persistence self-report scores and study condition was not observed, $F(1,36) = 1.177$, $p > .285$. Main effects were also non-significant, $F(1,36) = .3$, $p > .587$. However, an interaction effect was incidentally found between participants who self-reported as gamers or non-gamers and persistence scores, $F(1,36) = 7.052$, $p < .012$, such that gamers scored higher on the persistence scale than non-gamers at time point two. Moreover, when participants were analysed by group (Portal 2 gamers, Portal 2 non-gamers, control gamers, and control non-gamers), an interaction effect was observed, $F(1,34) = 3.535$, $p < .025$ (Appendix P). Portal 2 gamers and control gamers performed higher on the persistence scale at time point two than Portal 2 non-gamers and control non-gamers. Figure 6 displays the mean difference in scores.

Figure 6

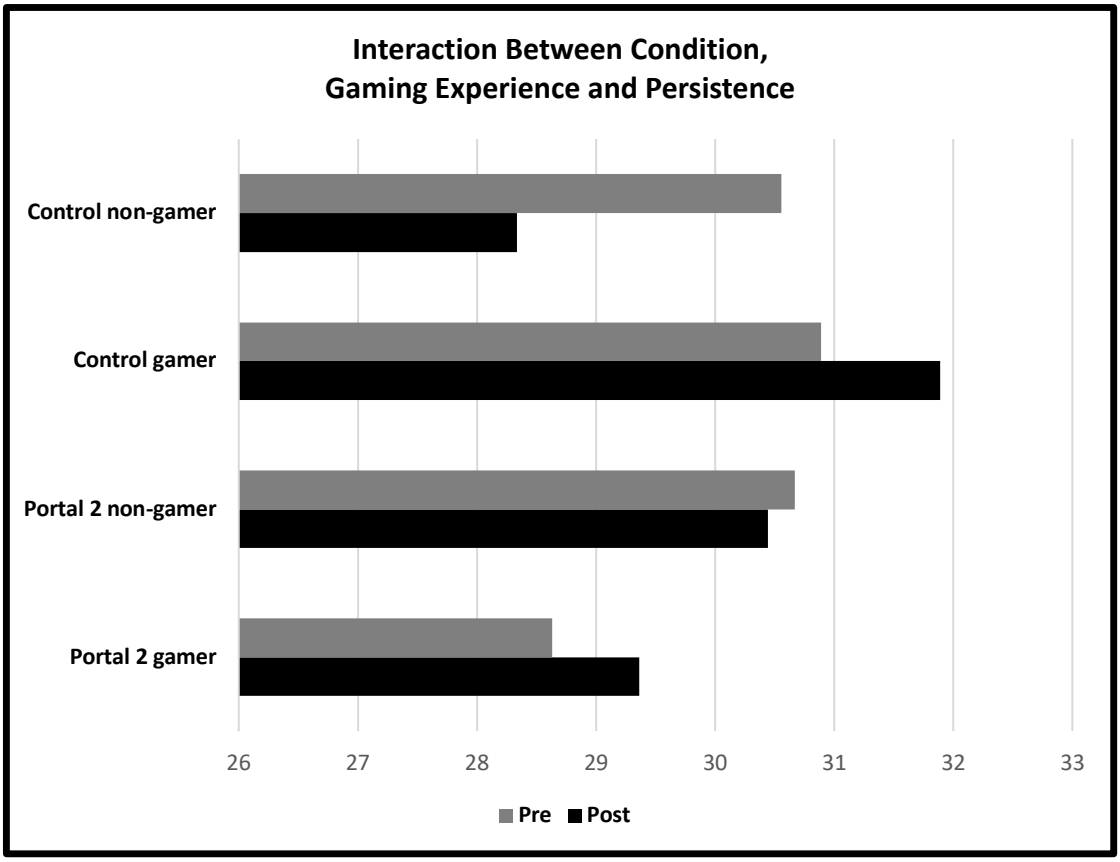


Figure 6. Mean differences in persistence scores pre and post study condition categorised further by responses to the self-report gaming experience questionnaire.

The results of the present study will be discussed in greater detail in the next section. Findings will be briefly summarised and hypotheses will be critiqued, before outlining possible theoretical and practical implications, and suggesting directions for future research.

Discussion

Summary of Findings

The two main aims of the study were to examine if playing computer games result in problem solving and spatial skill gains, and to discover if playing video games improve one's persistence. Results suggest that playing Portal 2, a commercially available video game, does not result in changes in cognitive flexibility, figural spatial skill or persistence. However, regardless of study condition, all participants who self-reported as gamers scored higher on the persistence self-report survey at time point two than those who considered themselves non-gamers.

Partial Replication

The present study attempted to partially replicate Shute, Ventura and Ke (2015), which was the first of its kind to directly examine the cognitive and psychological effects of playing video games. However, it is worth noting that both studies differed with respect to control group, duration of gameplay, mode of testing, testing battery, and sample numbers. The previous study featured an active control group that played Lumosity and participants in both groups completed 8 hours of gameplay. 8 pre and post-tests were administered online to 77 participants. On the other hand, only participants assigned to the test condition in current study played for a total duration of 2 hours and 3 tests were presented in pen-and-paper format to 38 participants. Nonetheless, as replication is important in determining whether effects are true or false, the current study offers a valuable contribution to knowledge (Francis, 2012).

While Shute et al. (2015) found that playing Portal 2 had a positive impact on problem solving, spatial skills, and persistence relative to playing Lumosity, the present study observed contrasting findings. The following paragraphs will discuss results in comparison to Shute and colleagues' study.

Hypotheses

Hypothesis 1, which stated that there will be differences between participants who play Portal 2 in terms of problem solving in comparison to those who do not, was not supported. This suggests that playing Portal 2 does not affect an individual's cognitive flexibility. However, both groups attained statistically significant lower RAT scores at time point two. While Shute et al. (2015) found that RAT scores increased in Portal 2 players post gameplay, RAT scores decreased in Lumosity players. Similar to the present study, the relative standard deviation observed between both groups on pre and post RAT scores was substantial (see Appendix Q), indicating high variability among participant responses. Responses may have varied owing to items utilised. The test items require participants to identify verbal associations, which may be more familiar to English speakers accustomed to US culture (Chermahini, Hickendorff, & Hommel, 2012). Moreover, the RAT is challenging for non-native English speakers (Estrada, Isen, & Young, 1994). To the author's knowledge, Shute and colleagues did not account for non-native English speakers, which may also help to explain the variance. As the current study consisted of 4 non-native speakers of English, RAT items may account for some of the variance in results.

Hypothesis 2, which stated that there will be differences between participants who play Portal 2 in terms of mental rotation in comparison to those who do not, was not supported. This suggests that playing Portal 2 does not affect one's figural spatial skill. Again, the relative standard deviation was high among both groups in pre and post MRT scores, while it was moderate in Shute and colleagues' study (2015) (see Appendix Q). The difference in variance may be explained by the method of MRT implementation. While the present study administered the MRT in pen-and-paper format, the previous study provided the test online. As previous research indicates that MRT modality may influence performance (see Monahan, Harke, & Shelley, 2008) and the MRT utilised was intended to be viewed on a computer, this may help to explain some of the variance encountered.

Finally, Hypothesis 3, which stated that there will be differences between participants who play Portal 2 in terms of persistence in comparison to those who do not, was not supported. This suggests that playing Portal 2 does not affect one's persistence. Nonetheless, participants who self-reported as gamers performed higher on the persistence scale than non-gamers at time point two. Moreover, when participants were analysed by group (Portal 2 gamers, Portal 2 non-gamers, control gamers, and control non-gamers), participants in the gaming condition and self-reported gamers performed significantly higher on the persistence scale at time point two than self-reported gamers in the gaming and control condition. This result should be viewed with caution as the measure used to assess persistence was a self-report survey. Responses to self-report surveys can be influenced by social desirability, which is the tendency to present the best version of oneself in light of existing cultural normalities (Krumpal, 2013).

Theoretical and Practical Implications

Cognitive flexibility may not have developed in Portal 2 players as the specific cognitive processes involved were not directly targeted, including working memory, attention, and knowledge acquisition (Glass, Maddox, & Love, 2013; Cañas, Quesadas, Antolí, & Fajardo, 2003). Furthermore, Glass and colleagues (2013) argue that video games from certain genres may be more inclined to develop cognitive flexibility, with their study showing significant improvements in participants who played real-time strategy games. Moreover, cognitive flexibility varies with age and is associated with fluid intelligence, well-being and age (Colzato, van Wouwe, Lavender, & Hommel, 2006; Moore & Malinowski, 2009; Kray, Li, & Lindenberger, 2002), suggesting that it may be more difficult to measure than anticipated.

Although figural spatial skill did not change in participants who played Portal 2, it is unknown if it affected environmental spatial abilities. To play Portal 2 successfully, the gamer is required to create an internal map of the gaming environment (Montello & Golledge, 1999), which could potentially transfer to real life settings. In addition, the degree to which a gamer experiences spatial presence

and flow may influence the capacity for video games to develop spatial skills (Havranek, Langer, Cheetham, & Jäncke, 2012). According to Weibel & Wissmath (2011), flow and presence rely on motivation, which in turn relate to improved performance and enjoyment. Improved performance may equate with improved spatial skills.

Enjoyment has also been associated with persistence and may help to explain why gamers scored slightly higher than non-gamers on the present study's self-report survey of persistence at time point two (Neys, Jansz, & Tan, 2014). According to self-determination theory, when gamers play video games their needs for autonomy, competence and relatedness are satisfied, resulting in enjoyment and increased intrinsic motivation (Deci & Ryan, 2000, Tamborini, Bowman, Eden, Grizzard, & Organ, 2010). Participants who played Portal 2 and who play video games normally may have enjoyed doing so and increased their persistence scores as a result of this.

Research findings may have practical implications for video game developers who wish to design cognitive programs for recreational use. Results are limited in terms of their generalisability due to small sample numbers and high variability in participants' responses. For the RAT and MRT, shortened versions were administered from Shute, Ventura and Ke (2015), which reduced their reliabilities. The present study recorded gaming experience to examine its effect on results. This represents a methodological strength. Moreover, it was relatively gender balanced and consisted of participants from a variety of different backgrounds including gamers, non-gamers, students and working professionals. Future research should attempt to carefully consider using the RAT amongst non-native English speakers, measure multiple spatial abilities, utilise a performance-based measure of persistence to reduce psychometric effects, analyse participants' enjoyment, add more items to the RAT and MRT tests, incorporate longer periods of gameplay, and include an active control condition.

Conclusion

The present study reported contrasting findings to Shute, Ventura and Ke (2015). While results were conflicting, partial replication was accomplished and this represents a significant contribution to knowledge. Overall, the study was influenced by a number of data collection issues. Due to time and funding constraints, it was not possible to control for all elements involved in the data collection. Ideally when conducting a research study, the researcher will not be acquainted with participants. However, for the purposes of a Master's study, it can be difficult to recruit participants and for this reason, most of the participants that were recruited were known to the researcher. It is unknown the extent to which participants' familiarity of the researcher and demand characteristics may have influenced results (see McCambridge, de Bruin, & Witton, 2012). Moreover, it was difficult to recruit participants who had never played video games before as an overt participant recruitment method was implemented and self-selection bias may have influenced findings (see Khazaal et al., 2014). The decision to host surveys and tests online may serve as a solution to some of the data collection issues encountered in the present study, although self-selection bias can also accompany research conducted online (Khazaal et al., 2014). In conclusion, this study highlights the practical problems that researchers can be confronted with during the data collection phase in gaming studies. It is hoped that these reflections will inform future studies that wish to explore this avenue of research.

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Appendices

Appendix A – Gaming Experience Self-Report Survey

Gaming Experience

In order to gain an understanding of your level of experience with video gaming, some questions are asked below. Please tick the boxes, keeping in mind the researcher's definition of a video game:

A video game is an interactive pastime played by manipulating images on an electronic device.

Do you play video games?

- ☐ Yes
- ☐ No

If you do play video games, how often do you play?

- ☐ Daily
- ☐ Almost every day
- ☐ 2-3 times per week
- ☐ Once per week
- ☐ 2-3 times per month
- ☐ Once per month
- ☐ Every 2-3 months
- ☐ Every 4-6 months
- ☐ Once per year
- ☐ Less than once per year
- ☐ Never

On average, how many hours do you play per gaming session?

- ☐ Less than 1 hour
- ☐ 1-2 hours
- ☐ 2-3 hours
- ☐ 4-5 hours
- ☐ 5-6 hours

What device(s) do you play on? Tick all that apply.

- ☐ Smartphone
- ☐ Tablet
- ☐ Laptop
- ☐ Desktop computer
- ☐ PlayStation
- ☐ Xbox
- ☐ Nintendo Wii/ Switch (when used with a larger screen such as a television)
- ☐ Retro games console (e.g. SNES, Sega Dreamcast)
- ☐ Handheld gaming console (e.g. PS Vita, Nintendo 3DS, Nintendo Switch when used as a separate device)

If your gaming device is not listed here, please list:

_____

Appendix B – Remote Associates Test (RAT) A and B

Test A

Instructions:

Think of a fourth word that is related to each of the first three words shown for each set and write it down in the answer space provided beside it. Example:

sleeping/bean/bin	Answer: bag
night/wrist/stop	Answer:_____
aid/rubber/wagon	Answer: _____
dream/break/light	Answer: _____
piece/mind/dating	Answer: _____
pie/luck/belly	Answer: _____

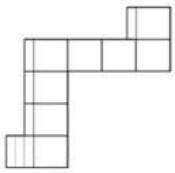
Test B

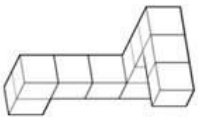
duck/fold/dollar	Answer: _____
stick/maker/point	Answer: _____
dust/cereal/fish	Answer: _____
boot/summer/ground	Answer: _____
fly/clip/wall	Answer: _____

Appendix C – Mental Rotation Test (MRT) A and B

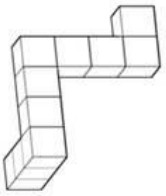
Instructions:

Your task is to observe the target figure at the top and to identify two of the four possible figures shown underneath that are identical to the target figure. There are always two correct answers. In this example the two answers are displayed below. As you can see, these two figures are the same as the target figure but are rotated and shown from different angles. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next. In the following 6 problems, write in the figures that you think are identical to the target figure.

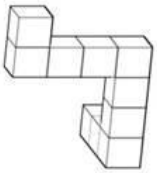




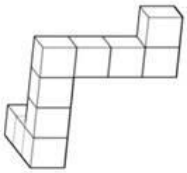
1.



2.



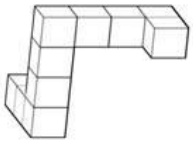
3.

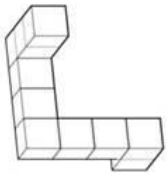


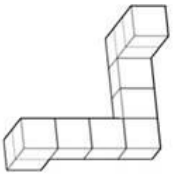
4.

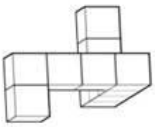
Answer(s): 2 and 4

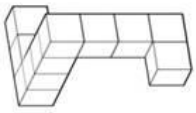
1.











1. 2. 3. 4.

Answer(s):

*Task continues in a similar fashion, presenting six different mental rotations in total, with six different rotations for the post-test.

Appendix D – Persistence Self-Report Survey A and B

For each of the following items, please circle an answer which describes you best.

1. I don't quit a task before it is finished.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

2. I don't finish what I start.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

3. I am a goal-orientated person.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

4. I finish things despite obstacles in the way.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

5. I give up easily.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

6. I am a hard worker.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

7. I do not tend to stick with what I decide to do.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

8. I don’t get side tracked when I work.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

Appendix E – Reliability Analysis for the Remote Associates Test (RAT) A and B

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.604	.617	5

Item Statistics

	Mean	Std. Deviation	N
Remote A1	1.03	.158	40
Remote A2	1.18	.385	40
Remote A3	1.30	.464	40
Remote A4	1.55	.504	40
Remote A5	1.23	.423	40

Inter-Item Correlation Matrix

	Remote A1	Remote A2	Remote A3	Remote A4	Remote A5
Remote A1	1.000	.348	-.105	.145	.297
Remote A2	.348	1.000	.129	.417	.382
Remote A3	-.105	.129	1.000	.154	.300
Remote A4	.145	.417	.154	1.000	.367
Remote A5	.297	.382	.300	.367	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.243	-.105	.417	.521	-3.974	.025	5

Scale: RAT A

Case Processing Summary

		N	%
Cases	Valid	40	100.0
	Excludeda	0	.0
	Total	40	100.0

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Remote A1	5.25	1.474	.234	.197	.613
Remote A2	5.10	1.067	.471	.291	.492
Remote A3	4.98	1.153	.221	.138	.633
Remote A4	4.73	.922	.427	.227	.513
Remote A5	5.05	.972	.526	.297	.452

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
6.28	1.589	1.261	5

Scale: RAT B

Case Processing Summary

		N	%
Cases	Valid	38	95.0
	Excludeda	2	5.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.645	.652	5

Item Statistics

	Mean	Std. Deviation	N
Remote B1	1.24	.431	38
Remote B2	1.50	.507	38
Remote B3	1.37	.489	38
Remote B4	1.39	.495	38

Remote B5	1.61	.495	38

Inter-Item Correlation Matrix

	Remote B1	Remote B2	Remote B3	Remote B4	Remote B5
Remote B1	1.000	.309	.473	.310	.323
Remote B2	.309	1.000	.218	.054	.269
Remote B3	.473	.218	1.000	.276	.282
Remote B4	.310	.054	.276	1.000	.212
Remote B5	.323	.269	.282	.212	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.273	.054	.473	.419	8.781	.011	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Remote B1	5.87	1.631	.549	.320	.527
Remote B2	5.61	1.759	.302	.136	.639
Remote B3	5.74	1.605	.466	.260	.558
Remote B4	5.71	1.779	.300	.133	.639
Remote B5	5.50	1.662	.402	.165	.590

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
7.11	2.421	1.556	5

Appendix F – Reliability Analysis for the Mental Rotation Test (MRT) A and B

Scale: MRT A

Case Processing Summary

		N	%
Cases	Valid	40	100.0
	Excludeda	0	.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.575	.568	6

Item Statistics

	Mean	Std. Deviation	N
Rotation A1	1.25	.439	40
Rotation A2	1.30	.464	40
Rotation A3	1.80	.405	40
Rotation A4	1.30	.464	40
Rotation A5	1.78	.423	40
Rotation A6	1.25	.439	40

Inter-Item Correlation Matrix

	Rotation A1	Rotation A2	Rotation A3	Rotation A4	Rotation A5	Rotation A6
Rotation A1	1.000	.126	.000	.252	-.104	.333
Rotation A2	.126	1.000	.191	.405	.353	.126
Rotation A3	.000	.191	1.000	.191	.030	.289
Rotation A4	.252	.405	.191	1.000	.222	.252
Rotation A5	-.104	.353	.030	.222	1.000	.035
Rotation A6	.333	.126	.289	.252	.035	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.180	-.104	.405	.508	-3.903	.020	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rotation A1	7.42	1.789	.208	.189	.575
Rotation A2	7.37	1.522	.425	.257	.476
Rotation A3	6.87	1.804	.236	.133	.561

Rotation A4	7.37	1.471	.478	.246	.449
Rotation A5	6.90	1.836	.183	.167	.583
Rotation A6	7.42	1.635	.354	.210	.512

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
8.67	2.225	1.492	6

Scale: MRT B

Case Processing Summary

		N	%
Cases	Valid	38	95.0
	Excludeda	2	5.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.672	.674	6

Item Statistics

	Mean	Std. Deviation	N
Rotation B1	1.16	.370	38
Rotation B2	1.39	.495	38
Rotation B3	1.26	.446	38
Rotation B4	1.42	.500	38
Rotation B5	1.71	.460	38
Rotation B6	1.45	.504	38

Inter-Item Correlation Matrix

	Rotation B1	Rotation B2	Rotation B3	Rotation B4	Rotation B5	Rotation B6
Rotation B1	1.000	.241	.397	-.077	.276	.191
Rotation B2	.241	1.000	.129	.075	.397	.356
Rotation B3	.397	.129	1.000	.217	.381	.544
Rotation B4	-.077	.075	.217	1.000	.074	.305
Rotation B5	.276	.397	.381	.074	1.000	.341
Rotation B6	.191	.356	.544	.305	.341	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.256	-.077	.544	.621	-7.071	.025	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rotation B1	7.24	2.456	.307	.234	.660
Rotation B2	7.00	2.162	.371	.266	.642
Rotation B3	7.13	2.063	.535	.446	.585
Rotation B4	6.97	2.405	.189	.126	.706
Rotation B5	6.68	2.114	.466	.275	.608
Rotation B6	6.95	1.889	.581	.416	.560

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
8.39	2.948	1.717	6

Appendix G – Reliability Analysis for the Persistence Self-Report Survey A and B

Scale: Persistence Survey A

Case Processing Summary

		N	%
Cases	Valid	40	100.0
	Excludeda	0	.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.757	.782	8

Item Statistics

	Mean	Std. Deviation	N
Persistence A1	3.55	1.085	40
Persistence A2	3.83	.813	40
Persistence A3	4.15	.736	40
Persistence A4	4.05	.714	40
Persistence A5	4.05	.749	40
Persistence A6	3.98	.698	40

Inter-Item Correlation Matrix

	Persistence A1	Persistence A2	Persistence A3	Persistence A4	Persistence A5	Persistence A6
Persistence A1	1.000	.432	.472	.361	.344	.357
Persistence A2	.432	1.000	.345	.501	.604	.309
Persistence A3	.472	.345	1.000	.522	.312	.257
Persistence A4	.361	.501	.522	1.000	.618	.311
Persistence A5	.344	.604	.312	.618	1.000	.199
Persistence A6	.357	.309	.257	.311	.199	1.000
Persistence A7	.130	.274	.112	.095	.285	.160
Persistence A8	.135	.242	.180	.252	.271	.309

Persistence A7	3.60	1.057	40
Persistence A8	2.53	1.132	40

Inter-Item Correlation Matrix

	Persistence A7	Persistence A8
Persistence A1	.130	.135
Persistence A2	.274	.242
Persistence A3	.112	.180
Persistence A4	.095	.252
Persistence A5	.285	.271

Persistence A6	.160	.309
Persistence A7	1.000	.266
Persistence A8	.266	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.309	.095	.618	.523	6.501	.019	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Persistence A1	26.18	13.789	.472	.346	.730
Persistence A2	25.90	14.349	.610	.457	.705
Persistence A3	25.58	15.430	.484	.374	.728
Persistence A4	25.68	15.046	.580	.537	.715
Persistence A5	25.68	14.789	.593	.533	.711
Persistence A6	25.75	15.885	.431	.237	.737
Persistence A7	26.13	15.240	.292	.160	.767
Persistence A8	27.20	14.421	.357	.179	.758

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
29.73	18.769	4.332	8

Scale: Persistence Survey B

Case Processing Summary

		N	%
Cases	Valid	38	95.0
	Excludeda	2	5.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.778	.789	8

Item Statistics

	Mean	Std. Deviation	N
Persistence B1	3.74	.978	38
Persistence B2	3.74	.760	38
Persistence B3	4.00	.870	38
Persistence B4	4.03	.592	38

Persistence B5	3.89	.894	38
Persistence B6	4.18	.652	38
Persistence B7	3.76	.852	38
Persistence B8	2.66	.966	38

Inter-Item Correlation Matrix

	Persistence B1	Persistence B2	Persistence B3	Persistence B4	Persistence B5	Persistence B6
Persistence B1	1.000	.304	.413	.246	.802	.163
Persistence B2	.304	1.000	.409	.737	.396	.210
Persistence B3	.413	.409	1.000	.472	.417	.429
Persistence B4	.246	.737	.472	1.000	.312	.267
Persistence B5	.802	.396	.417	.312	1.000	.127
Persistence B6	.163	.210	.429	.267	.127	1.000
Persistence B7	.248	.569	.219	.495	.321	.275
Persistence B8	.160	.316	.193	.252	.207	-.026

Inter-Item Correlation Matrix

	Persistence B7	Persistence B8
Persistence B1	.248	.160
Persistence B2	.569	.316
Persistence B3	.219	.193
Persistence B4	.495	.252
Persistence B5	.321	.207
Persistence B6	.275	-.026
Persistence B7	1.000	-.003
Persistence B8	-.003	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.319	-.026	.802	.828	-30.881	.034	8

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Persistence B1	26.26	12.578	.543	.654	.743
Persistence B2	26.26	13.118	.654	.640	.727
Persistence B3	26.00	13.027	.560	.425	.740
Persistence B4	25.97	14.188	.618	.592	.741
Persistence B5	26.11	12.583	.617	.680	.729
Persistence B6	25.82	15.344	.300	.242	.779
Persistence B7	26.24	13.807	.436	.418	.761
Persistence B8	27.34	14.664	.230	.172	.801

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
30.00	17.297	4.159	8

Appendix H – Information Leaflet

Information Sheet

Study Title: An exploration of computer gaming, problem solving and persistence.

Purpose of the Research

The aim of the current study is to examine if there are any cognitive and psychological benefits associated with playing a computer game. The researcher is aiming to recruit 40 participants to take part in the study.

Invitation

You are being invited to consider taking part in the research study: An exploration of computer gaming, problem solving and persistence. This project is being undertaken by Niamh Daly Ryan, a Masters student of Cyberpsychology in the Institute of Art, Design, and Technology (IADT), Dún Laoghaire, who is under the guidance of Liam Challenor.

Before you decide whether or not you wish to take part, it is important for you to understand why this research is being done and what it will involve. Please take time to read this information carefully and discuss it with friends and relatives if you wish. Feel free to ask the researcher if there is anything that is unclear or if you would like more information.

Do I have to take part?

You are free to decide whether you wish to take part or not. If you do decide to take part you will be asked to sign two consent forms, one is for you to keep and the other is for the researcher's records. You are free to withdraw from this study at any

time and without giving reasons. By choosing to take part or not to take part, this will have no impact on your participation in future or recent studies. If you are a student of IADT, your decision to take part or not take part in the study will have no impact on your marks, assessments or future studies related to the college.

If I take part, what do I have to do?

Participants who agree to take part will be randomly assigned to one of two groups; Group A and Group B. Group A will play the computer game while Group B will not.

Group A:

- Participants in Group A will be required to come into IADT at a time that suits them and complete a form used for demographic information, two cognitive tests and a survey. This part will take approximately 30 minutes.
- Following this, participants will be asked to play a computer game for one hour.
- Two weeks after this, the same participants from Group A will be asked to come back to IADT and play the game for another hour. After the hour, two cognitive tests and a survey will be administered, which will take 30 minutes.

Group B:

- Participants in Group B will be required to come into IADT at a time that suits them and complete a form used for demographic information, two cognitive tests and a survey. This part will take 30 minutes.
- Two weeks after this, the same participants from Group B will be asked to come back to IADT and complete two cognitive tests and a survey, which will take 30 minutes.

What are the benefits (if any) of taking part?

Some studies have found that playing computer games can lead to cognitive and psychological improvements. However, the current study cannot guarantee this as the research is exploratory in nature. Therefore, there are no known benefits of taking part.

What are the disadvantages and risks (if any) of taking part?

There are no known disadvantages and risks associated with playing the computer game. However, some participants may experience feelings of motion sickness from playing the game. Should this lead to feelings of discomfort, the participant will be requested to discontinue playing and to withdraw from the study.

How will information about me be used?

The data will be used solely for the purposes of completing a research project, as part of the researcher's requirements for a Masters in Cyberpsychology, granted by IADT.

Who will have access to information about me?

Your data will be kept confidential in a password protected computer. Your identity will be anonymised with a unique participant ID. Data will be kept in a confidential folder in a locked filing cabinet. Only the researcher will have access to the data. The data will be retained by the researcher for at least one year. However, if the research is published, most scientific journals require original data to be kept for 5 years. After this period, the data will be shredded and be disposed of.

What will happen to the results of the study?

The results of the study will be written up by the researcher, presented at research conferences and possibly published in peer-reviewed journals. Should you require a copy of the research project, presentation or of any subsequent publications, you can contact the researcher who will be happy to provide you with one.

Who has reviewed the study?

This study has been approved by the Department of Technology and Psychology Ethics Committee (DTPEC).

What if there is a problem?

If you have a concern about any aspect of this study, you may wish to speak to the researcher who will do their best to answer your questions. You should contact Niamh Daly Ryan or her supervisor Liam Challenor.

Contact for further information

Niamh Daly Ryan

Tel: 0852061372/ Email: niamhdalyryan@gmail.com

Liam Challenor

Email: liam.challenor@dcu.ie

Thank you for taking the time to read the information sheet.

Date: 24/01/2018

Appendix I – Consent Form

Consent Form

Title of Project: An exploration of computer gaming, problem solving and persistence.

Name of Researcher: Niamh Daly Ryan

If you are happy to consent, please tick the box:

1	I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.	□
2	I understand that my participation is voluntary and that I am free to withdraw at any time.	□
3	I agree to take part in this study.	□
4	I understand that data collected about me during this study will be anonymised before it is submitted for publication.	□

_____	_____	_____
Name of participant	Date	Signature
_____	_____	_____
Name of researcher	Date	Signature

Appendix J – Debriefing Information

Debrief

Thank you very much for taking part in this research study.

The study in which you just participated in was designed to investigate the effects of a computer game, known as Portal 2, on problem solving and persistence. You were randomly assigned to either the computer gaming group (Group A) or the control group (Group B). This was to determine if there was a difference between those who played Portal 2 versus those who did not in terms of problem solving and persistence. The results of the study will now be analysed.

If you have questions about this study or you wish to have your data removed, please contact me at the following e-mail address: niamhdalyryan@gmail.com or via phone on 085 206 1372. Alternatively, you may contact my supervisor, Liam Challenor at liam.challenor@dcu.ie.

We thank you sincerely for contributing and assure you that your data is confidential and anonymous, and if published the data will not be in any way identifiable as yours.

Niamh Daly Ryan

Appendix K – Frequency Distribution for Age and Gender

Statistics

		Pps Age	Pps Gender
N	Valid	40	40
	Missing	0	0
Mean		30.83	1.55
Std. Error of Mean		1.642	.080
Median		27.00	2.00
Mode		24a	2
Std. Deviation		10.387	.504
Variance		107.892	.254
Skewness		1.685	-.209
Std. Error of Skewness		.374	.374
Kurtosis		2.530	-2.062
Std. Error of Kurtosis		.733	.733
Range		44	1
Minimum		20	1
Maximum		64	2

a. Multiple modes exist. The smallest value is shown

Frequency Table

Pps Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20	2	5.0	5.0	5.0
	21	1	2.5	2.5	7.5
	22	1	2.5	2.5	10.0
	23	2	5.0	5.0	15.0
	24	5	12.5	12.5	27.5
	25	5	12.5	12.5	40.0
	26	3	7.5	7.5	47.5
	27	3	7.5	7.5	55.0
	28	2	5.0	5.0	60.0
	29	2	5.0	5.0	65.0
	30	2	5.0	5.0	70.0
	31	1	2.5	2.5	72.5
	36	2	5.0	5.0	77.5
	37	1	2.5	2.5	80.0
	38	1	2.5	2.5	82.5
	41	2	5.0	5.0	87.5
	43	1	2.5	2.5	90.0
	48	1	2.5	2.5	92.5
	52	1	2.5	2.5	95.0
	59	1	2.5	2.5	97.5

	64	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Pps Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	18	45.0	45.0	45.0
	Female	22	55.0	55.0	100.0
	Total	40	100.0	100.0	

Appendix L – Descriptive Statistics for the Self-Report Gaming Survey

Statistics

		Play VGs?	How frequent?	Hours per session?	What device for play?
N	Valid	40	40	40	40
	Missing	0	0	0	0
Mean		1.48	2.18	1.33	5.10
Std. Error of Mean		.080	.399	.236	.987
Median		1.00	1.00	1.00	1.00
Mode		1	0	0	0
Std. Deviation		.506	2.521	1.492	6.242
Skewness		.104	.834	.626	.746
Std. Error of Skewness		.374	.374	.374	.374
Kurtosis		-2.097	-.266	-1.098	-1.121
Std. Error of Kurtosis		.733	.733	.733	.733
Range		1	9	4	17
Minimum		1	0	0	0
Maximum		2	9	4	17

Frequency Table

Play VGs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	21	52.5	52.5	52.5
	No	19	47.5	47.5	100.0
	Total	40	100.0	100.0	

How frequent?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	19	47.5	47.5	47.5
	Daily	2	5.0	5.0	52.5
	Almost every day	1	2.5	2.5	55.0
	2-3 times per week	6	15.0	15.0	70.0
	Once per week	4	10.0	10.0	80.0
	2-3 times per month	3	7.5	7.5	87.5
	Once per month	3	7.5	7.5	95.0
	Every 2-3 months	1	2.5	2.5	97.5
	Once per year	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Hours per session?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	19	47.5	47.5	47.5
	Less than 1 hour	4	10.0	10.0	57.5
	1-2 hours	7	17.5	17.5	75.0

Appendix M – Descriptive Statistics for the RAT, MRT and Persistence Survey

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Skewness
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Remote A Tot	40	4	1	5	3.72	.199	1.261	-.742
Remote B Tot	38	5	0	5	2.89	.252	1.556	-.361
Rotation A Tot	40	6	0	6	3.33	.236	1.492	-.252
Rotation B Tot	38	6	0	6	3.63	.276	1.699	-.465
Persistence A Tot	40	19	20	39	29.92	.701	4.434	-.371
Persistence B Tot	38	20	19	39	29.97	.677	4.175	-.444
Valid N (listwise)	38							

	2-3 hours	5	12.5	12.5	87.5
	4-5 hours	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

What device for play?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	19	47.5	47.5	47.5
	Smartphone	2	5.0	5.0	52.5
	Laptop	2	5.0	5.0	57.5
	Desktop computer	1	2.5	2.5	60.0
	PlayStation	1	2.5	2.5	62.5
	Xbox	2	5.0	5.0	67.5
	Desktop computer and PlayStation	2	5.0	5.0	72.5
	Smartphone, desktop computer and PlayStation	1	2.5	2.5	75.0
	PlayStation and Xbox	2	5.0	5.0	80.0
	Laptop and desktop	2	5.0	5.0	85.0
	Smartphone and Xbox	1	2.5	2.5	87.5
	Smartphone and laptop	2	5.0	5.0	92.5
	Smartphone, desktop computer, PlayStation and handheld	1	2.5	2.5	95.0
	Smartphone, laptop and tablet	2	5.0	5.0	100.0
	Total	40	100.0	100.0	

Descriptive Statistics

	Skewness	Kurtosis	
	Std. Error	Statistic	Std. Error
Remote A Tot	.374	-.686	.733
Remote B Tot	.383	-.960	.750
Rotation A Tot	.374	-.685	.733
Rotation B Tot	.383	-.551	.750
Persistence A Tot	.374	.056	.733
Persistence B Tot	.383	.869	.750
Valid N (listwise)			

Appendix N – Hypothesis One

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

pre_post_rat	Dependent Variable
1	RATA_tot
2	RATB_tot

Between-Subjects Factors

		Value Label	N
Condition	1	Gaming condition	20
	2	Control condition	18

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
Remote A Tot	Gaming condition	3.40	1.046	20
	Control condition	4.00	1.455	18
	Total	3.68	1.276	38
Remote B Tot	Gaming condition	2.40	1.603	20
	Control condition	3.44	1.338	18
	Total	2.89	1.556	38

Box's Test of Equality of Covariance Matricesa

Box's M	2.784
F	.872
df1	3
df2	381693.991
Sig.	.455

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_rat

Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.
pre_post_rat	Pillai's Trace	.199	8.927b	1.000	36.000	.005
	Wilks' Lambda	.801	8.927b	1.000	36.000	.005
	Hotelling's Trace	.248	8.927b	1.000	36.000	.005
	Roy's Largest Root	.248	8.927b	1.000	36.000	.005
pre_post_rat * Condition	Pillai's Trace	.020	.729b	1.000	36.000	.399
	Wilks' Lambda	.980	.729b	1.000	36.000	.399
	Hotelling's Trace	.020	.729b	1.000	36.000	.399

	Roy's Largest Root	.020	.729b	1.000	36.000	.399

Multivariate Testsa

Effect		Partial Eta Squared
pre_post_rat	Pillai's Trace	.199
	Wilks' Lambda	.199
	Hotelling's Trace	.199
	Roy's Largest Root	.199
pre_post_rat * Condition	Pillai's Trace	.020
	Wilks' Lambda	.020
	Hotelling's Trace	.020
	Roy's Largest Root	.020

a. Design: Intercept + Condition

Within Subjects Design: pre_post_rat

b. Exact statistic

Mauchly's Test of Sphericitya

Measure: MEASURE_1

					Epsilonb	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
pre_post_rat	1.000	.000	0	.	1.000	1.000

Mauchly's Test of Sphericitya

Measure: MEASURE_1

	Epsilon
Within Subjects Effect	Lower-bound
pre_post_rat	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_rat	Sphericity Assumed	11.462	1	11.462	8.927	.005
	Greenhouse-Geisser	11.462	1.000	11.462	8.927	.005
	Huynh-Feldt	11.462	1.000	11.462	8.927	.005
	Lower-bound	11.462	1.000	11.462	8.927	.005
pre_post_rat * Condition	Sphericity Assumed	.936	1	.936	.729	.399
	Greenhouse-Geisser	.936	1.000	.936	.729	.399
	Huynh-Feldt	.936	1.000	.936	.729	.399
	Lower-bound	.936	1.000	.936	.729	.399
Error(pre_post_rat)	Sphericity Assumed	46.222	36	1.284		
	Greenhouse-Geisser	46.222	36.000	1.284		
	Huynh-Feldt	46.222	36.000	1.284		
	Lower-bound	46.222	36.000	1.284		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared
pre_post_rat	Sphericity Assumed	.199
	Greenhouse-Geisser	.199
	Huynh-Feldt	.199
	Lower-bound	.199
pre_post_rat * Condition	Sphericity Assumed	.020
	Greenhouse-Geisser	.020
	Huynh-Feldt	.020
	Lower-bound	.020
Error(pre_post_rat)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_rat	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pre_post_rat	Linear	11.462	1	11.462	8.927	.005	.199
pre_post_rat * Condition	Linear	.936	1	.936	.729	.399	.020
Error(pre_post_rat)	Linear	46.222	36	1.284			

Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Remote A Tot	.706	1	36	.406
Remote B Tot	1.597	1	36	.214

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_rat

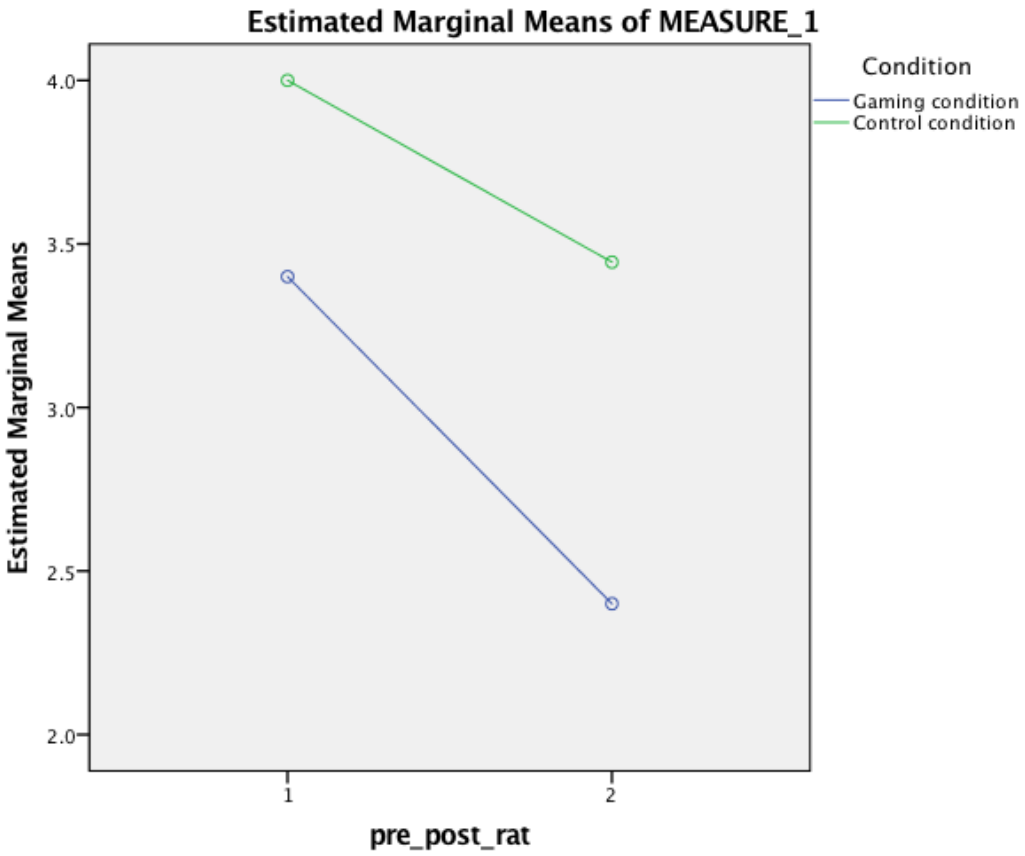
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	830.915	1	830.915	333.024	.000	.902
Condition	12.809	1	12.809	5.134	.030	.125
Error	89.822	36	2.495			

Profile Plots



T-Test

Paired Samples Statistics

Condition			Mean	N	Std. Deviation	Std. Error Mean
Gaming condition	Pair 1	Remote A Tot	3.40	20	1.046	.234
		Remote B Tot	2.40	20	1.603	.358
Control condition	Pair 1	Remote A Tot	4.00	18	1.455	.343
		Remote B Tot	3.44	18	1.338	.315

Paired Samples Correlations

Condition			N	Correlation	Sig.
Gaming condition	Pair 1	Remote A Tot & Remote B Tot	20	.308	.187
Control condition	Pair 1	Remote A Tot & Remote B Tot	18	.362	.139

Paired Samples Test

Condition			Paired Differences			95% Confidence Interval of the Difference
			Mean	Std. Deviation	Std. Error Mean	Lower
Gaming condition	Pair 1	Remote A Tot - Remote B Tot	1.000	1.622	.363	.241
Control condition	Pair 1	Remote A Tot - Remote B Tot	.556	1.580	.372	-.230

Paired Samples Test

Condition			Paired Differences 95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
			Upper			
Gaming condition	Pair 1	Remote A Tot - Remote B Tot	1.759	2.757	19	.013
Control condition	Pair 1	Remote A Tot - Remote B Tot	1.341	1.492	17	.154

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Remote B Tot	Equal variances assumed	1.597	.214	-2.167	36	.037
	Equal variances not assumed			-2.188	35.817	.035

T-Test

Independent Samples Test

		t-test for Equality of Means			
		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Remote B Tot	Equal variances assumed	-1.044	.482	-2.022	-.067
	Equal variances not assumed	-1.044	.477	-2.013	-.076

Appendix O – Hypothesis Two

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

pre_post_MRT	Dependent Variable
1	MRTA_tot
2	MRTB_tot

Between-Subjects Factors

		Value Label	N
Condition	1	Gaming condition	20
	2	Control condition	18

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
Rotation A Tot	Gaming condition	2.95	1.572	20
	Control condition	3.78	1.396	18
	Total	3.34	1.529	38
Rotation B Tot	Gaming condition	3.65	1.899	20
	Control condition	3.61	1.501	18
	Total	3.63	1.699	38

Box's Test of Equality of Covariance Matricesa

Box's M	2.242
F	.702
df1	3
df2	381693.991
Sig.	.551

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_MRT

Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.
pre_post_MRT	Pillai's Trace	.037	1.372b	1.000	36.000	.249
	Wilks' Lambda	.963	1.372b	1.000	36.000	.249
	Hotelling's Trace	.038	1.372b	1.000	36.000	.249
	Roy's Largest Root	.038	1.372b	1.000	36.000	.249
pre_post_MRT * Condition	Pillai's Trace	.091	3.623b	1.000	36.000	.065
	Wilks' Lambda	.909	3.623b	1.000	36.000	.065
	Hotelling's Trace	.101	3.623b	1.000	36.000	.065
	Roy's Largest Root	.101	3.623b	1.000	36.000	.065

Multivariate Testsa

Effect		Partial Eta Squared
pre_post_MRT	Pillai's Trace	.037
	Wilks' Lambda	.037
	Hotelling's Trace	.037
	Roy's Largest Root	.037
pre_post_MRT * Condition	Pillai's Trace	.091
	Wilks' Lambda	.091
	Hotelling's Trace	.091
	Roy's Largest Root	.091

a. Design: Intercept + Condition

Within Subjects Design: pre_post_MRT

b. Exact statistic

Mauchly's Test of Sphericitya

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilonb Greenhouse-Geisser	Huynh-Feldt
pre_post_MRT	1.000	.000	0	.	1.000	1.000

Mauchly's Test of Sphericitya

Measure: MEASURE_1

Within Subjects Effect	Epsilon Lower-bound
pre_post_MRT	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_MRT	Sphericity Assumed	1.347	1	1.347	1.372	.249

	Greenhouse-Geisser	1.347	1.000	1.347	1.372	.249
	Huynh-Feldt	1.347	1.000	1.347	1.372	.249
	Lower-bound	1.347	1.000	1.347	1.372	.249
pre_post_MRT * Condition	Sphericity Assumed	3.558	1	3.558	3.623	.065
	Greenhouse-Geisser	3.558	1.000	3.558	3.623	.065
	Huynh-Feldt	3.558	1.000	3.558	3.623	.065
	Lower-bound	3.558	1.000	3.558	3.623	.065
Error(pre_post_MRT)	Sphericity Assumed	35.350	36	.982		
	Greenhouse-Geisser	35.350	36.000	.982		
	Huynh-Feldt	35.350	36.000	.982		
	Lower-bound	35.350	36.000	.982		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared
pre_post_MRT	Sphericity Assumed	.037
	Greenhouse-Geisser	.037
	Huynh-Feldt	.037
	Lower-bound	.037
pre_post_MRT * Condition	Sphericity Assumed	.091
	Greenhouse-Geisser	.091
	Huynh-Feldt	.091
	Lower-bound	.091
Error(pre_post_MRT)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_MRT	Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_MRT	Linear	1.347	1	1.347	1.372	.249
pre_post_MRT * Condition	Linear	3.558	1	3.558	3.623	.065
Error(pre_post_MRT)	Linear	35.350	36	.982		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_MRT	Partial Eta Squared
pre_post_MRT	Linear	.037

pre_post_MRT * Condition	Linear	.091
Error(pre_post_MRT)	Linear	

Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Rotation A Tot	.334	1	36	.567
Rotation B Tot	1.587	1	36	.216

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_MRT

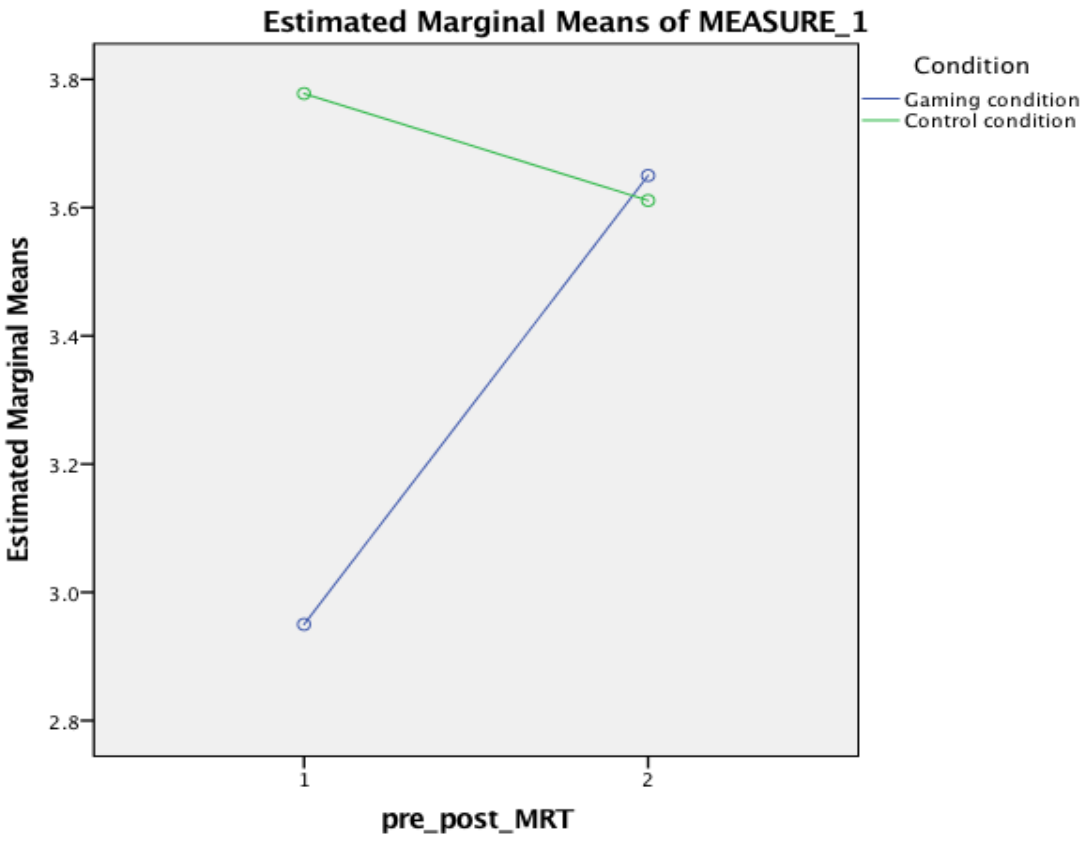
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	926.948	1	926.948	220.208	.000	.859
Condition	2.948	1	2.948	.700	.408	.019
Error	151.539	36	4.209			

Profile Plots



Appendix P – Hypothesis Three

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

pre_post_persistence	Dependent Variable
1	PSA_tot
2	PSB_tot

Between-Subjects Factors

		Value Label	N
Condition	1	Gaming condition	20
	2	Control condition	18

Descriptive Statistics

	Condition	Mean	Std. Deviation	N
Persistence A Tot	Gaming condition	29.55	4.347	20
	Control condition	30.72	4.099	18
	Total	30.11	4.216	38
Persistence B Tot	Gaming condition	29.85	4.295	20
	Control condition	30.11	4.157	18
	Total	29.97	4.175	38

Box's Test of Equality of Covariance Matricesa

Box's M	22.425
F	7.023
df1	3
df2	381693.991
Sig.	.000

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_persistence

Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.
pre_post_persistence	Pillai's Trace	.004	.137b	1.000	36.000	.713
	Wilks' Lambda	.996	.137b	1.000	36.000	.713
	Hotelling's Trace	.004	.137b	1.000	36.000	.713
	Roy's Largest Root	.004	.137b	1.000	36.000	.713
pre_post_persistence * Condition	Pillai's Trace	.032	1.177b	1.000	36.000	.285
	Wilks' Lambda	.968	1.177b	1.000	36.000	.285
	Hotelling's Trace	.033	1.177b	1.000	36.000	.285
	Roy's Largest Root	.033	1.177b	1.000	36.000	.285

Multivariate Testsa

Effect	Partial Eta Squared

pre_post_persistence	Pillai's Trace	.004
	Wilks' Lambda	.004
	Hotelling's Trace	.004
	Roy's Largest Root	.004
pre_post_persistence * Condition	Pillai's Trace	.032
	Wilks' Lambda	.032
	Hotelling's Trace	.032
	Roy's Largest Root	.032

a. Design: Intercept + Condition

Within Subjects Design: pre_post_persistence

b. Exact statistic

Mauchly's Test of Sphericitya

Measure: MEASURE_1

					Epsilonb	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
pre_post_persistence	1.000	.000	0	.	1.000	1.000

Mauchly's Test of Sphericitya

Measure: MEASURE_1

	Epsilon
Within Subjects Effect	Lower-bound
pre_post_persistence	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence	Sphericity Assumed	.458	1	.458	.137	.713
	Greenhouse-Geisser	.458	1.000	.458	.137	.713
	Huynh-Feldt	.458	1.000	.458	.137	.713
	Lower-bound	.458	1.000	.458	.137	.713
pre_post_persistence * Condition	Sphericity Assumed	3.932	1	3.932	1.177	.285
	Greenhouse-Geisser	3.932	1.000	3.932	1.177	.285
	Huynh-Feldt	3.932	1.000	3.932	1.177	.285
	Lower-bound	3.932	1.000	3.932	1.177	.285
Error(pre_post_persistence)	Sphericity Assumed	120.239	36	3.340		
	Greenhouse-Geisser	120.239	36.000	3.340		
	Huynh-Feldt	120.239	36.000	3.340		
	Lower-bound	120.239	36.000	3.340		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared
pre_post_persistence	Sphericity Assumed	.004
	Greenhouse-Geisser	.004
	Huynh-Feldt	.004
	Lower-bound	.004
pre_post_persistence * Condition	Sphericity Assumed	.032
	Greenhouse-Geisser	.032
	Huynh-Feldt	.032
	Lower-bound	.032
Error(pre_post_persistence)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence	Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence	Linear	.458	1	.458	.137	.713
pre_post_persistence * Condition	Linear	3.932	1	3.932	1.177	.285
Error(pre_post_persistence)	Linear	120.239	36	3.340		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence	Partial Eta Squared
pre_post_persistence	Linear	.004
pre_post_persistence * Condition	Linear	.032
Error(pre_post_persistence)	Linear	

Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Persistence A Tot	.069	1	36	.795
Persistence B Tot	.006	1	36	.941

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.a

a. Design: Intercept + Condition

Within Subjects Design: pre_post_persistence

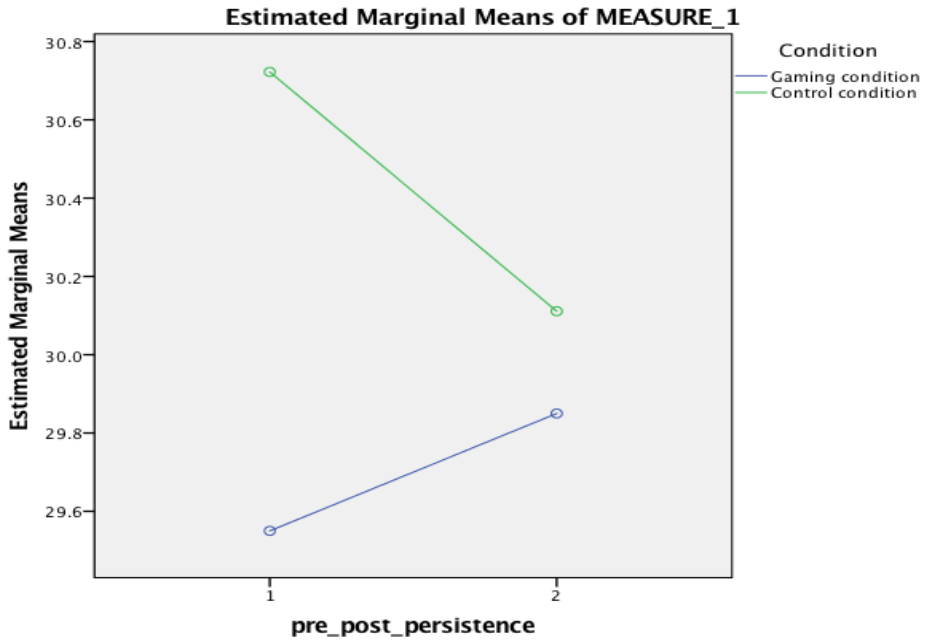
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	68476.047	1	68476.047	2109.389	.000	.983
Condition	9.732	1	9.732	.300	.587	.008
Error	1168.650	36	32.462			

Profile Plots



General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

pre_post_persistence_playVGs	Dependent Variable
1	PSA_tot
2	PSB_tot

Between-Subjects Factors

		Value Label	N
Play VGs?	1	Yes	20
	2	No	18

Descriptive Statistics

	Play VGs?	Mean	Std. Deviation	N
Persistence A Tot	Yes	29.65	4.475	20
	No	30.61	3.973	18
	Total	30.11	4.216	38
Persistence B Tot	Yes	30.50	4.149	20
	No	29.39	4.245	18
	Total	29.97	4.175	38

Box's Test of Equality of Covariance Matricesa

Box's M	3.248
F	1.017
df1	3
df2	381693.991
Sig.	.384

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.a

a. Design: Intercept + Play_VGs

Within Subjects Design: pre_post_persistence_playVGs

Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.
pre_post_persistence_playVGs	Pillai's Trace	.006	.228b	1.000	36.000	.636
	Wilks' Lambda	.994	.228b	1.000	36.000	.636
	Hotelling's Trace	.006	.228b	1.000	36.000	.636
	Roy's Largest Root	.006	.228b	1.000	36.000	.636
pre_post_persistence_playVGs * Play_VGs	Pillai's Trace	.164	7.052b	1.000	36.000	.012
	Wilks' Lambda	.836	7.052b	1.000	36.000	.012
	Hotelling's Trace	.196	7.052b	1.000	36.000	.012
	Roy's Largest Root	.196	7.052b	1.000	36.000	.012

Multivariate Testsa

Effect		Partial Eta Squared
pre_post_persistence_playVGs	Pillai's Trace	.006
	Wilks' Lambda	.006
	Hotelling's Trace	.006
	Roy's Largest Root	.006
pre_post_persistence_playVGs * Play_VGs	Pillai's Trace	.164
	Wilks' Lambda	.164
	Hotelling's Trace	.164
	Roy's Largest Root	.164

a. Design: Intercept + Play_VGs

Within Subjects Design: pre_post_persistence_playVGs

b. Exact statistic

Mauchly's Test of Sphericitya

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilonb	
					Greenhouse-Geisser	Huynh-Feldt
pre_post_persistence_playVGs	1.000	.000	0	.	1.000	1.000

Mauchly's Test of Sphericitya

Measure: MEASURE_1

Within Subjects Effect	Epsilon
	Lower-bound
pre_post_persistence_playVGs	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence_playVGs	Sphericity Assumed	.656	1	.656	.228	.636
	Greenhouse-Geisser	.656	1.000	.656	.228	.636
	Huynh-Feldt	.656	1.000	.656	.228	.636
	Lower-bound	.656	1.000	.656	.228	.636
pre_post_persistence_playVGs * Play_VGs	Sphericity Assumed	20.340	1	20.340	7.052	.012
	Greenhouse-Geisser	20.340	1.000	20.340	7.052	.012
	Huynh-Feldt	20.340	1.000	20.340	7.052	.012
	Lower-bound	20.340	1.000	20.340	7.052	.012
Error(pre_post_persistence_playVGs)	Sphericity Assumed	103.831	36	2.884		
	Greenhouse-Geisser	103.831	36.000	2.884		
	Huynh-Feldt	103.831	36.000	2.884		
	Lower-bound	103.831	36.000	2.884		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared
pre_post_persistence_playVGs	Sphericity Assumed	.006
	Greenhouse-Geisser	.006
	Huynh-Feldt	.006
	Lower-bound	.006
pre_post_persistence_playVGs * Play_VGs	Sphericity Assumed	.164
	Greenhouse-Geisser	.164
	Huynh-Feldt	.164
	Lower-bound	.164
Error(pre_post_persistence_playVGs)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence_playVGs	Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence_playVGs	Linear	.656	1	.656	.228	.636
pre_post_persistence_playVGs * Play_VGs	Linear	20.340	1	20.340	7.052	.012
Error(pre_post_persistence_playVGs)	Linear	103.831	36	2.884		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence_playVGs	Partial Eta Squared
pre_post_persistence_playVGs	Linear	.006
pre_post_persistence_playVGs * Play_VGs	Linear	.164

Error(pre_post_persistence_playVGs)	Linear	

Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Persistence A Tot	1.204	1	36	.280
Persistence B Tot	.001	1	36	.976

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.a

a. Design: Intercept + Play_VGs

Within Subjects Design: pre_post_persistence_playVGs

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	68381.159	1	68381.159	2089.259	.000	.983
Play_VGs	.107	1	.107	.003	.955	.000
Error	1178.275	36	32.730			

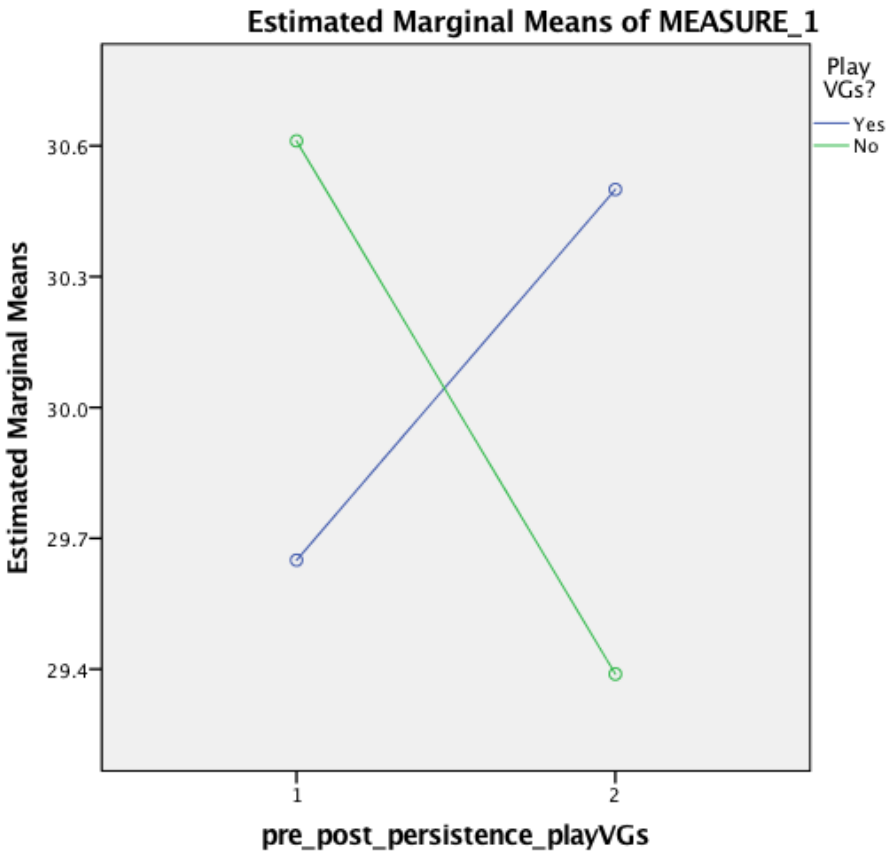
Estimated Marginal Means

Play VGs? * pre_post_persistence_playVGs

Measure: MEASURE_1

				95% Confidence Interval	
Play VGs?	pre_post_persistence_playVGs	Mean	Std. Error	Lower Bound	Upper Bound
Yes	1	29.650	.949	27.725	31.575
	2	30.500	.938	28.598	32.402
No	1	30.611	1.001	28.582	32.641
	2	29.389	.989	27.384	31.394

Profile Plots



T-Test

Paired Samples Statistics

Play VGs?			Mean	N	Std. Deviation	Std. Error Mean
Yes	Pair 1	Persistence A Tot	29.65	20	4.475	1.001
		Persistence B Tot	30.50	20	4.149	.928
No	Pair 1	Persistence A Tot	30.61	18	3.973	.936
		Persistence B Tot	29.39	18	4.245	1.000

Paired Samples Correlations

Play VGs?			N	Correlation	Sig.
Yes	Pair 1	Persistence A Tot & Persistence B Tot	20	.900	.000
No	Pair 1	Persistence A Tot & Persistence B Tot	18	.767	.000

Paired Samples Test

			Paired Differences				
						95% Confidence Interval of the Difference	
Play VGs?			Mean	Std. Deviation	Std. Error Mean	Lower	Upper
Yes	Pair 1	Persistence A Tot - Persistence B Tot	-.850	1.954	.437	-1.765	.065
No	Pair 1	Persistence A Tot - Persistence B Tot	1.222	2.819	.664	-.180	2.624

Paired Samples Test

Play VGs?	t	df	Sig. (2-tailed)

Yes	Pair 1	Persistence A Tot - Persistence B Tot	-1.945	19	.067
No	Pair 1	Persistence A Tot - Persistence B Tot	1.839	17	.083

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

pre_post_persistence_4groups	Dependent Variable
1	PSA_tot
2	PSB_tot

Between-Subjects Factors

		Value Label	N
Condition by group	1	Portal 2 gamer	11
	2	Portal 2 non gamer	9
	3	Control gamer	9
	4	Control non gamer	9

Descriptive Statistics

	Condition by group	Mean	Std. Deviation	N
Persistence A Tot	Portal 2 gamer	28.64	4.589	11
	Portal 2 non gamer	30.67	4.000	9
	Control gamer	30.89	4.256	9
	Control non gamer	30.56	4.187	9
	Total	30.11	4.216	38
Persistence B Tot	Portal 2 gamer	29.36	4.760	11
	Portal 2 non gamer	30.44	3.844	9
	Control gamer	31.89	2.934	9
	Control non gamer	28.33	4.583	9
	Total	29.97	4.175	38

Box's Test of Equality of Covariance Matricesa

Box's M	25.075
F	2.485
df1	9
df2	11707.909
Sig.	.008

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.a

a. Design: Intercept + Condition_group

Within Subjects Design:

pre_post_persistence_4groups

Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.
pre_post_persistence_4groups	Pillai's Trace	.006	.218b	1.000	34.000	.644
	Wilks' Lambda	.994	.218b	1.000	34.000	.644
	Hotelling's Trace	.006	.218b	1.000	34.000	.644
	Roy's Largest Root	.006	.218b	1.000	34.000	.644
pre_post_persistence_4groups * Condition_group	Pillai's Trace	.238	3.535b	3.000	34.000	.025
	Wilks' Lambda	.762	3.535b	3.000	34.000	.025
	Hotelling's Trace	.312	3.535b	3.000	34.000	.025
	Roy's Largest Root	.312	3.535b	3.000	34.000	.025

Multivariate Testsa

Effect		Partial Eta Squared
pre_post_persistence_4groups	Pillai's Trace	.006
	Wilks' Lambda	.006
	Hotelling's Trace	.006
	Roy's Largest Root	.006
pre_post_persistence_4groups * Condition_group	Pillai's Trace	.238
	Wilks' Lambda	.238
	Hotelling's Trace	.238
	Roy's Largest Root	.238

a. Design: Intercept + Condition_group

Within Subjects Design: pre_post_persistence_4groups

b. Exact statistic

Mauchly's Test of Sphericitya

Measure: MEASURE_1

					Epsilonb	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
pre_post_persistence_4groups	1.000	.000	0	.	1.000	1.000

Mauchly's Test of Sphericitya

Measure: MEASURE_1

	Epsilon
Within Subjects Effect	Lower-bound
pre_post_persistence_4groups	1.000

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence_4groups	Sphericity Assumed	.606	1	.606	.218	.644

	Greenhouse-Geisser	.606	1.000	.606	.218	.644
	Huynh-Feldt	.606	1.000	.606	.218	.644
	Lower-bound	.606	1.000	.606	.218	.644
pre_post_persistence_4groups * Condition_group	Sphericity Assumed	29.525	3	9.842	3.535	.025
	Greenhouse-Geisser	29.525	3.000	9.842	3.535	.025
	Huynh-Feldt	29.525	3.000	9.842	3.535	.025
	Lower-bound	29.525	3.000	9.842	3.535	.025
Error(pre_post_persistence_4groups)	Sphericity Assumed	94.646	34	2.784		
	Greenhouse-Geisser	94.646	34.000	2.784		
	Huynh-Feldt	94.646	34.000	2.784		
	Lower-bound	94.646	34.000	2.784		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared
pre_post_persistence_4groups	Sphericity Assumed	.006
	Greenhouse-Geisser	.006
	Huynh-Feldt	.006
	Lower-bound	.006
pre_post_persistence_4groups * Condition_group	Sphericity Assumed	.238
	Greenhouse-Geisser	.238
	Huynh-Feldt	.238
	Lower-bound	.238
Error(pre_post_persistence_4groups)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence_4groups	Type III Sum of Squares	df	Mean Square	F	Sig.
pre_post_persistence_4groups	Linear	.606	1	.606	.218	.644
pre_post_persistence_4groups * Condition_group	Linear	29.525	3	9.842	3.535	.025
Error(pre_post_persistence_4groups)	Linear	94.646	34	2.784		
		Lower-bound				

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	pre_post_persistence_4groups	Partial Eta Squared
pre_post_persistence_4groups	Linear	.006
pre_post_persistence_4groups * Condition_group	Linear	.238
Error(pre_post_persistence_4groups)	Linear	

Levene's Test of Equality of Error Variancesa

	F	df1	df2	Sig.
Persistence A Tot	.254	3	34	.858
Persistence B Tot	.693	3	34	.563

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.a

a. Design: Intercept + Condition_group

Within Subjects Design: pre_post_persistence_4groups

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	68326.427	1	68326.427	2091.625	.000	.984
Condition_group	67.715	3	22.572	.691	.564	.057
Error	1110.667	34	32.667			

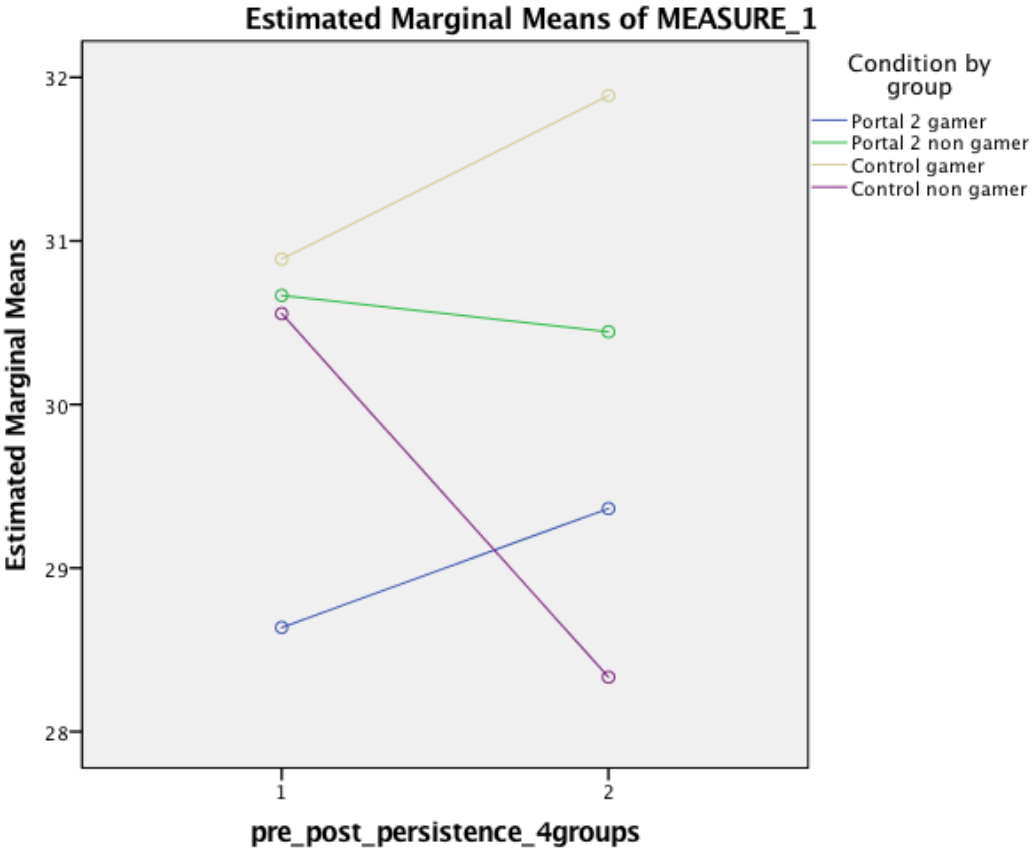
Estimated Marginal Means

Condition by group * pre_post_persistence_4groups

Measure: MEASURE_1

				95% Confidence Interval	
Condition by group	pre_post_persistence_4groups	Mean	Std. Error	Lower Bound	Upper Bound
Portal 2 gamer	1	28.636	1.291	26.012	31.261
	2	29.364	1.247	26.829	31.898
Portal 2 non gamer	1	30.667	1.428	27.765	33.568
	2	30.444	1.379	27.643	33.246
Control gamer	1	30.889	1.428	27.988	33.790
	2	31.889	1.379	29.087	34.691
Control non gamer	1	30.556	1.428	27.654	33.457
	2	28.333	1.379	25.531	31.135

Profile Plots


Estimated Marginal Means of MEASURE_1
Estimated Marginal Means
32
31
30
29
28
1
2
pre_post_persistence_4groups
Condition by group
Portal 2 gamer
Portal 2 non gamer
Control gamer
Control non gamer

Appendix Q – Relative Standard Deviation for the RAT and MRT

Table 1

A Comparison Between the Relative Standard Deviation (RSD) of the RAT and MRT in the Present Study and in Shute et al. (2015).

Present Study	Portal 2 RSD (%)	Control RSD (%)
RAT (pre)	30.76	34.44
RAT (post)	66.79	38.89
MRT (pre)	53.28	36.27
MRT (post)	52.02	41.57
Shute et al. (2015)	**Portal 2 RSD (%)**	**Lumosity RSD (%)**
RAT (pre)	56.01	48.31
RAT (post)	47.35	51.95
MRT (pre)	17.19	26.24
MRT (post)	16.36	25.51