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The Effect of Video Game Experience in Different Genres on Task-Switching Ability

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Abstract

Task-switching is an executive function that refers to an individual's ability to shift attention between different tasks. Previous studies have examined whether video game players perform better on task-switching experiments compared to non-video game players. This study aimed to add to existing research by examining video game experience on a continuous scale. Other factors that may affect the association between video game experience and task-switching ability were also examined, including the specific video game genre(s) played and the age that an individual began actively playing. Sixty participants from the Rochester Institute of Technology completed a questionnaire assessing video game experience and a task-switching experiment with a predictable and random paradigm. Task-switching performance was measured through switch cost, the price paid in response time for switching from one task to another. The results showed that for both the predictable and random task-switching paradigm: 1) Individuals with more video game experience had smaller switch costs than those with less. 2) Individuals who began actively playing earlier in life had no difference in switch cost compared to those who started playing later. 3) Individuals who more frequently play genres higher in complexity had no difference in switch costs compared to those who play less complex genres. 4) Differences in switch cost were robust to a correction that accounts for differences in baseline response times. These results suggest that individuals who play video games frequently may have practice with mechanics that likely transfer to task-switching performance due to them both requiring similar underlying demands.

Keywords: video games, task-switching

Contents

Introduction

Since their creation, video games have been criticized as being a mindless activity with little to no real benefit for those who play them. The majority of research concerning video games has focused on their possible negative impacts, such as violence, depression, and addiction (e.g., Anderson et al., 2010; Gentile et al., 2011; Tortolero et al., 2014). While this research is important, it is critical to take a more balanced perspective on the overall effects of video games by examining their potential benefits.

Researchers first began using video games to examine, measure, and enhance several cognitive, perceptual, and motor abilities in the early 1980s (e.g., Clark, Lanphear, & Riddick, 1987; Gagnon, 1985; Griffith, Voloschin, Gibb, & Bailey, 1983). However, the findings of these studies were somewhat limited by the video games of the era, which were extremely simple in nature and typically only required repetitive responses in order to play successfully (Latham, Patston, & Tippett, 2013b). As part of the *Learning Strategies Program*, cognitive psychologists developed a video game, *Space Fortress*, which has a complex but well-controlled environment (Mané & Donchin, 1989). This game has been used as a standardized task in various studies investigating the development, training, and transfer of skills used in the game (e.g., Blumen, Gopher, Steinerman, & Stern, 2010; Fabiani et al., 1989; Logie, Baddeley, Mané, Donchin, & Sheptak, 1989). Although *Space Fortress* is a sophisticated research tool, it is primitive by today's video game standards (Boot, 2015).

Over the past 15 years, a small subset of research has emerged attempting to study the potential benefits of contemporary video games, which are far more complex, diverse, and social. These studies focus primarily on how video game experience affects cognitive and perceptual abilities (e.g., Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003). One area of interest in this research is task-switching, which refers to an individual's ability to shift his or her attention between different tasks. It is an important executive function that allows an individual to quickly adapt when the situation demands it (Miyake et al., 2000). Since action video games require individuals to adapt to complex situations and switch tasks on the fly, it has been theorized that they are an ideal environment to enhance these skills (Green & Bavelier, 2008). Numerous studies have found enhanced task-switching abilities in action video game players compared to non-video game players (e.g., Andrews & Murphy, 2006; Cain, Landau, & Shimamura, 2012; Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010).

This study sought to expand on previous research examining the differences in task-switching ability between individuals with various levels of video game experience. Rather than defining individuals as either a player or non-player, video game experience was instead measured on a continuous scale. Other factors that might affect the association between video game experience and task-switching ability were also examined, including the specific genre(s) of video games played and the age an individual began actively playing. Previous research has indicated that these factors may account for some of the variability within the video game group's performance on cognitive and perceptual tasks (e.g., Dobrowolski, Hanusz, Sobczyk, Skorko, & Wiatrow, 2015; Hartanto, Toh, & Yang, 2016; Latham, Patston, & Tippett, 2013a). Performance on both a predictable task-switching paradigm and random task-switching paradigm were examined in this study to determine if individuals with video game experience excelled at both anticipated and unexpected task-switching.

Video Games

History and popularity. Video games differ from other forms of media due to the fact that they are interactive and allow players to be actively engaged with them. They were first made available to the public in 1972 with the release of the first arcade machine and household gaming console, the *Magnavox Odyssey* (Latham et al., 2013b). Although video games were previously played by only a small portion of the population, they have become a popular and widespread activity in today's society. Video game players can be found at any age group and socio-economic background (Colzato et al., 2010). Recently, the Entertainment Software Association (2017) reported that there is at least one individual who plays video games for three or more hours per week in 65% of U.S. households. In 2016, the video game industry was worth $99.6 billion (Newzoo, 2016). There are thousands of different video games, which fall into many different genres, or categories based on game mechanics and objectives (Granic, Lobel, & Engels, 2014). They can be played on many different devices (e.g., computer, console, phone, tablet), and in many different ways (e.g., offline or online mode, single or multiplayer format, casually or competitively). According to Bavelier et al. (2011), it is important to note that the term "video games" is far from a single construct and has almost no predictive power on its own. Instead, video games should be classified into some type of taxonomy before being studied.

Taxonomy. The majority of video game studies have categorized video games as either action or non-action (e.g., Cain et al., 2012; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Strobach, Frensch, & Schubert, 2012). Green and Bavelier (2006a) defined action video games as "those that have fast motion, require vigilant monitoring of the visual periphery, and often require the simultaneous tracking of multiple targets" (p. 1466). Later definitions also described action video games as being unpredictable, demanding fast responses to visual and auditory events, and requiring the player to select and switch between a variety of possible actions (e.g., Green & Bavelier, 2012; Green, Li, & Bavelier, 2010; Hubert-Wallander, Green, & Bavelier, 2011). Researchers have theorized that the complex environment and demanding tasks of action video games enhance the cognitive and perceptual abilities of individuals who play them. This definition for action video games is rather broad and includes several different video game genres (e.g., Shooters, Multiplayer Online Battle Arenas or MOBAs, Role-Playing Games or RPGs). Although there may be some overlap, each genre has some distinct gameplay mechanics (e.g., perspective, pace, type of stimuli) that may account for differences in the particular abilities enhanced (Sobczyk, Dobrowolski, Skorko, Michalak, & Brzezicka, 2015). Thus, interpreting and comparing the results of studies that use this definition is challenging, as they do not control for the effects that potentially stem from the different game mechanics present in each video game genre.

A comprehensive taxonomy of video games is difficult to develop because of how diverse they are. Many researchers have argued that the most appropriate way to classify video games is through their genre (e.g., Dobrowolski et al., 2015; Latham et al., 2013a; Sobczyk et al., 2015). While no empirical model currently exists, Granic et al. (2014) developed a conceptual map depicting most video game genres along two dimensions, level of complexity and the extent of social interaction required (Figure 1). Although these dimensions are important and accurately demonstrate how these specific genres can engage players, this taxonomy is still an oversimplification, as some video games can appear at different places along the model depending on the way that an individual chooses to play them. The shooter video game, *Halo 4*,

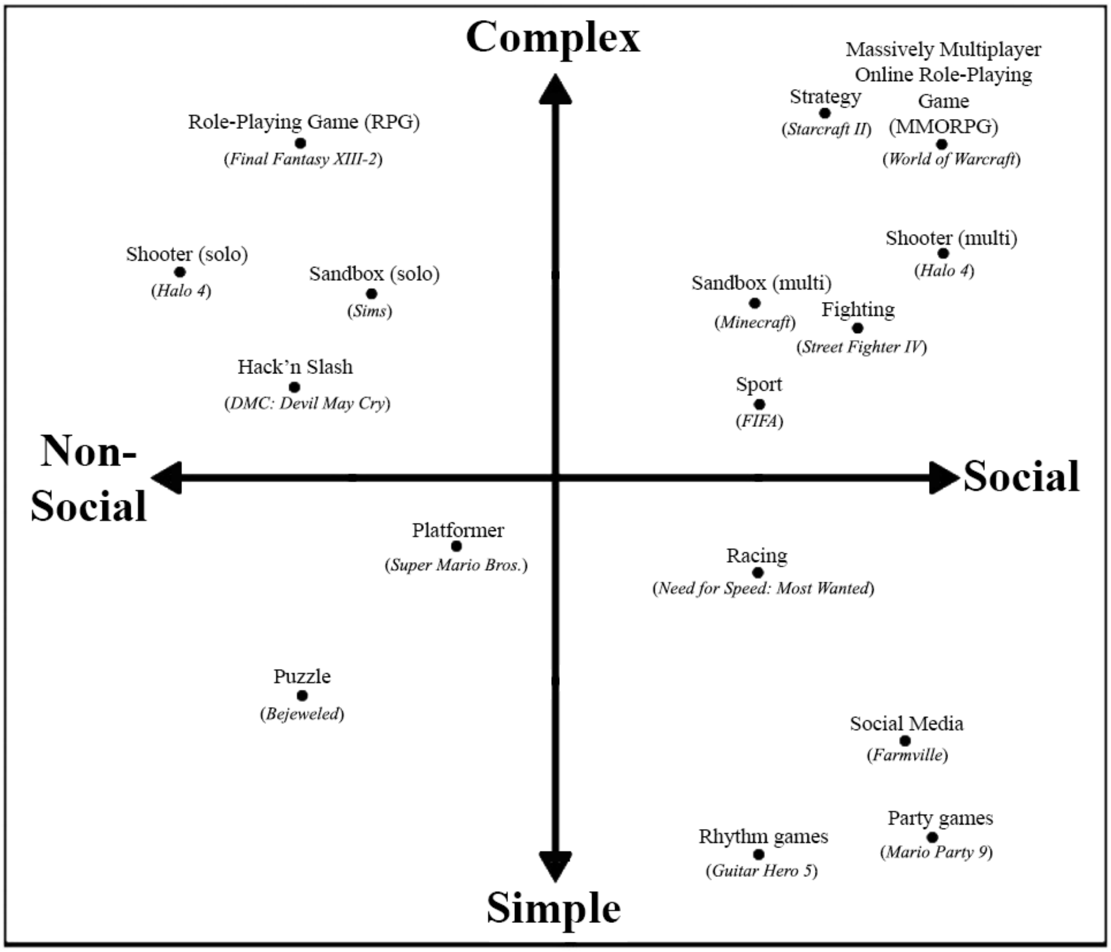

Figure 1. Conceptual map of video game genres (with examples) organized according to two dimensions: level of complexity and extent of social interaction required. Adapted from Granic et al. (2014).

is a perfect example of this. The campaign, or story mode, of *Halo 4* can be played in a social manner (online multiplayer) or a non-social manner (offline single player). Additionally, the difficulty level of the *Halo 4* campaign can be adjusted by the player (i.e., easy, normal, heroic, legendary), making the game more or less complex.

The more complex video game genres depicted in the model (e.g., Massively Multiplayer Online Role-Playing Game or MMORPG, Shooter, Strategy) are typically the ones that require players to have the best task-switching abilities in order to succeed. These video games require players to rapidly attend to numerous tasks in complicated environments, ensuring that they accurately process relevant information and filter out irrelevant information. Failing to appropriately switch from one task to another in a timely manner in these games will result in punishment for the player (e.g., missed opportunities, losing the game, death of the character).

Theories on Video Game Experience and Cognitive/Perceptual Abilities

Learning to learn. Two competing theories seek to explain how video game experience may influence performance on cognitive and perceptual laboratory tasks. The first is the learning to learn theory. This general theory was coined by Harlow (1949), who studied the formation of learning sets in animals, or how animals learn general rules that help them master novel tasks abiding by these previously learned rules. According to this theory, the most important learning for an organism is that which helps it efficiently learn in situations that are frequently encountered. Bavelier, Green, Pouget, and Schrater (2012) refer to this theory to explain how the complex environments of action video games can foster brain plasticity and improve general learning mechanisms. Consistent with the learning to learn theory, Bavelier et al. (2012) argued that action video game experience can teach individuals how to quickly and effectively learn to perform new tasks. While it is reasonable that this experience can lead to improved performance on similar video games, studies have shown that it can also lead to improved performance in other contexts, such as cognitive and perceptual laboratory tasks, which are quite different in nature from video games (e.g., Green & Bavelier, 2003, 2006a, 2006b). This is in sharp contrast to the majority of learning studies, in which training typically only facilitates the trained task and has little benefit to other tasks, including those that are similar to the trained task (e.g., Bachman, 1961; Ball et al., 2002; Fiorentini & Berardi, 1980).

According to Green, Pouget, and Bavelier (2010), action video games are complex and rarely provide repeated situations. To succeed in these games, players must constantly examine and assess sensory evidence on the fly. They must also be able to quickly and accurately determine whether information is important or irrelevant (Green & Bavelier, 2012). Bavelier et al. (2012) theorized that playing action video games leads to a general improvement in probabilistic inference, which refers to the ability to extract patterns from the sensory evidence in an environment and use that information to make predictions. Thus, individuals with action video game experience excel at laboratory tasks because they are more efficient at gathering and interpreting statistical information from repeated exposure to a task. They can then use this information to guide their decision making and allocation of cognitive resources on future trials of a task (Green, Pouget, & Bavelier, 2010). In other words, this action video game training leads to faster and more efficient learning. The learning to learn theory provides a general mechanism that explains how action video game experience enhances performance on a wide range of tasks, rather than proposing distinct mechanisms for each task (Bejjanki et al., 2014).

Common demands. The alternative explanation is the common demands theory, which was coined by Oei and Patterson (2014a). This theory is related to the work of Thorndike and Woodworth (1901), who were among the earliest researchers to demonstrate that transfer of learning depends on similarities between the trained task and the untrained task (theory of identical elements). Drawing from this research, Oei and Patterson (2014a) proposed that training specific abilities in video games improves performance on tasks that have similar underlying demands. Oei and Patterson (2015) note that the common demands theory does not claim that the tasks must be identical in order for transfer to occur, as suggested by Thorndike and Woodworth (1901). Instead, the common demands theory also draws from more recent work on transfer. For instance, Oei and Patterson (2015) also discussed the work of Taatgen (2013), who suggested that the skills necessary to perform tasks can be broken down into primitive information processing elements. These elements can either be specific to the task or general. If the elements from a learned task overlap with the elements of another task, then transfer can occur.

The common demands theory contrasts with the learning to learn theory, as it states that transfer is task-specific and little to no transfer should be expected for cognitive and perceptual tasks requiring skills that were not trained in the video games. In other words, while the learning to learn theory predicts broad transfer, the common demands theory predicts narrow transfer. Although Green and Bavelier (2012) did briefly mention that the general transfer mechanism only applies to new tasks that share structure with the action video game trained, this limitation has not been further explored. Thus, the extent of this generalized transfer is not clear. The common demands theory more specifically explains what skills are likely to transfer and therefore accounts for the studies that have not found action video game experience to improve certain cognitive and perceptual tasks (e.g., Boot et al., 2008; Oei & Patterson, 2014b; Oei & Patterson, 2015). It also accounts for the studies that found improvements in performance on cognitive and perceptual tasks were not limited to action video games (e.g., Oei & Patterson, 2013, 2014b; Okagaki & Frensch, 1994).

Task-Switching

Definition. Task-switching is an important executive function that involves shifting attention between different tasks (Monsell, 2003). It is considered a reliable measure of cognitive flexibility, or how well an individual can control his or her thoughts and behaviors (Miyake et al., 2000). Task-switching is often considered to be a form of multitasking. However, unlike dual-tasking where two tasks are performed simultaneously, task-switching involves performing tasks sequentially (Wickens & McCarley, 2008). People frequently switch between tasks throughout their everyday lives, particularly when interacting with technology. For example, an individual using a computer or smartphone typically switches between a variety of tasks (e.g., checking emails, sending instant messages or texts, browsing the web). Task-switching is also an important part of many jobs. A study completed by González and Mark (2004) revealed that employees at an information-technology company spent an average of only three minutes on a task before switching to another.

Defining what precisely constitutes a task can be difficult (Rogers & Monsell, 1995). This issue is somewhat clarified in controlled studies, as it is up to the researcher to provide clear definitions and instructions for specific tasks (e.g., classify a digit as odd or even). Thus, in terms of experimental design, tasks require the performance of an action in response to the presentation of some stimulus (Kiesel et al., 2010). These actions are typically performed through response mappings set by the researcher. In order to complete a task, an individual must adopt the appropriate task-set. A task-set is defined as a configuration of mental processes and representations that enable an individual to act in accordance with the demands of a specific task (Kiesel et al., 2010). For example, a task-set for an experiment involving a shape (square or circle) or color (red or blue) classification task first involves determining intentions (e.g., the goal is to complete the color task, as indicated by a cue). The next components involve determining the task-relevant dimensions of the stimulus (e.g., red or blue), task-relevant responses (e.g., the relevant keys, b and n), and the corresponding response mappings (e.g., b = red and n = blue). The alternative task-set (e.g. shape classification) must be inhibited.

Measurement. In order to measure task-switching ability empirically, specific task-switching experiments are used. These experiments require participants to complete one of two basic tasks on the same stimulus (e.g., determine whether a number is odd/even or less than 5/greater than 5). These tasks could require classification of an element/feature of the stimulus, or even the computation or retrieval from memory of a different property of the stimulus (Monsell, 2003). The goal in each trial is to select and perform the relevant rather than the irrelevant task. The task that must be completed is determined by some rule set by the researcher (e.g., perform task 1 if the background is blue or task 2 if the background is yellow). In task-switching experiments, a condition is referred to as a non-switch trial when the task that preceded it was the same type. On the other hand, a condition is referred to as a switch-trial when the task that preceded it was a different type, and thus requires the participant to shift his or her attention to complete the alternative task. Performance on switch and non-switch trials is compared.

Previous research on task-switching has revealed that error rates are higher and response times are longer in switch-trials compared to non-switch trials, demonstrating what is referred to as switch cost (Monsell, 2003). Switch cost is calculated by subtracting the response time (RT) for non-switch trials from the RT for switch trials. Thus, smaller switch cost indicates better performance or that less of a price is paid for switching from one task to another. Additionally, the difference in the number of errors in switch and non-switch trials is also compared. Although switch cost can be reduced by practice, it is never completely eliminated (Rogers & Monsell, 1995; Strobach, Liepelt, Schubert, & Kiesel, 2012). Several different paradigms have been developed in an attempt to examine task-switching ability and its underlying mechanics (Kiesel et al., 2010).

Paradigms. Jersild (1927) created the original task-switching paradigm using paper, pencil, and stopwatch. This paradigm involved first presenting participants with a list of non-switch trials (also called pure blocks; e.g., A, A, A, … or B, B, B, …) and then presenting them with a list of alternating trials (e.g., A, B, A, B, …). Later studies also included mixed-task blocks that consisted of both switch and non-switch trials (e.g., A, A, B, B, A, A, …). It was observed that completion times were longer and error rates were higher for mixed-task blocks than for the pure blocks, demonstrating mixing costs (e.g., Los, 1996; Rubin & Meiran, 2005; Steinhauser & Hübner, 2005). According to Rogers and Monsell (1995), an issue with the methodology for this paradigm is that it is based on the comparison of different blocks of trials and therefore does not take into account differences in arousal, effort, or strategy of the participants between blocks. Additionally, the delayed responses in the alternating blocks could reflect higher working memory load rather than the switching process, as they require participants to keep track of a task sequence and maintain two task-sets rather than one.

In an attempt to address the criticisms of the earlier paradigm, Rogers and Monsell (1995) created the alternating-runs paradigm. Rather than presenting non-switch and switch trials in different blocks, this paradigm presented both within the same block. The task alternated every N^{th} trial, where N was constant and predictable (e.g., tasks typically switch every two trials: A, A, B, B, A, A, …), thus the task sequence was known by participants in advance and an external cue (e.g., the position of the stimulus within a 2 x 2 matrix) was provided to help them keep track of the sequence. This paradigm allowed researchers to examine performance on both switch and non-switch trials under identical working memory demands. The major finding with this task-switching paradigm was that performance is worse (i.e., longer RTs and more errors) in switch trials than in non-switch trials, demonstrating switch cost. Additionally, the researchers found that when the run was extended (e.g., switched every four trials: A, A, A, A, B, B, B, B, …), performance was only slower on the first trial of the sequence (the switch trial). This paradigm also allowed researchers to manipulate the time between the participant's response (R) and the presentation of the next stimulus (S), or the available preparation time that participants had. Varying this R-S interval also varied the amount of time available for passive decay of the previous task-set (Monsell, 2003).

The task-cuing paradigm allowed researchers to independently manipulate the active preparation interval (cue-stimulus interval) and the passive decay interval (response-cue interval; e.g., time between the previous response and the cue for the next trial). In this paradigm, the task sequence can be either predictable or unpredictable. A specific task cue is presented either before or with the stimulus to indicate to the participant which task to complete. For example, in a letter (vowel/consonant) or digit (odd/even) classification, a cue (e.g., “Letter” or “Digit”) would be presented. Similar to the alternating-runs paradigm, performance in task-cuing paradigms is determined by comparing performance on switch trials to performance on non-switch trials. Previous studies using the task-cuing paradigm have also demonstrated switch cost (e.g., Dreisbach, Haider, & Kluwe, 2002; Meiran, 1996; Meiran, Chorev, & Sapir, 2000). These studies also provided evidence that increasing the cue-stimulus interval had more of an impact on switch cost than increasing the response-cue interval, suggesting that preparation is more important than passive decay of the previous task-set (Kiesel et al., 2010).

Theories. There is ongoing debate concerning the mechanics underlying task-switching and switch cost. A thorough discussion of task-switching theories is beyond the scope of this paper (for a review see Kiesel et al., 2010). The purpose of this paper is not to add to that research nor clarify those issues. It will instead focus on a hybrid account of task-switching that combines several different theories, as the general consensus is that task-switching involves task-set reconfiguration processes and interference caused by the persisting activation and inhibition of the irrelevant task-set (Monsell, 2003).

In order to change tasks, a process called task-set reconfiguration (TSR) must occur (Rogers & Monsell, 1995). This process involves switching attention to the relevant elements of a stimulus, determining intentions (what to do), and necessary actions (how to do it; Monsell, 2003). According to Rogers and Monsell (1995), some of TSR can be accomplished in advance through endogenous control (e.g., during the anticipatory phase before the stimulus is presented). This is shown by the fact that switch cost can be reduced given an opportunity to prepare (e.g., by using predictable switches), referred to as the preparation effect. The researchers found that increasing the R-S interval from 150 ms to 600 ms led to smaller switch costs. However, after increasing the preparation time from 600 ms onward (e.g., 1200 ms), a large asymptotic switch cost remained. Rogers and Monsell (1995) concluded that this residual switch cost was due to the fact that the other part of TSR cannot be accomplished until exogenously triggered (e.g., when the stimulus is presented).

Allport, Styles, and Hsieh (1994), argued that switch cost arises from proactive interference. This interference occurs because the task-set that is currently relevant (e.g., for task 1) was previously suppressed when it was irrelevant (e.g., when completing task 2), and because the currently irrelevant task-set (e.g., for task 2) received extra activation when it had previously been relevant (e.g., when completing task 2; Allport & Wylie, 1999). Evidence supporting this interference is demonstrated in studies that show responses are slower on the last trial of an A, B, A task sequence than on the last trial of a C, B, A task sequence (e.g., Mayr, 2002; Mayr & Keele, 2000).

Stimulus-based interference and response-based interference also occur (Kiesel et al., 2010). If only one task can be completed with the target stimulus, then it is considered univalent. On the other hand, if both tasks can be completed with the target stimulus, then it is considered bivalent (e.g., a character pair consisting of a letter and a digit, both the letter and digit task can be completed). Bivalent stimuli can either be congruent or incongruent. In congruent conditions, the same response is required for both tasks (e.g., a character pair consisting of a vowel and an odd number would require the left key press for both tasks). Alternatively, the stimuli require different responses for both tasks in incongruent conditions (e.g., a character pair consisting of a vowel and an even number would require the left key press for the letter task, but the right key press for digit task). Switch costs are larger for bivalent stimuli and in incongruent conditions (Rogers & Monsell, 1995). This suggests interference caused by bivalent stimuli activating responses and task-sets that they are associated with (Kiesel et al., 2010). The response mappings can also be univalent (e.g., separate keys to complete each task) or bivalent (e.g., the same keys to complete both tasks). Switch costs are larger for bivalent responses mappings (Meiran, 2000). Overlapping responses cause interference because they are used for both tasks and their meaning must be recoded each time the task switches (Kiesel et al., 2010). A conceptual model of task-switching (using the alternating-runs paradigm) is shown in Figure 2.

Previous Studies on Video Games and Task-Switching

Initial research and theory. Green and Bavelier (2003) were the first researchers to examine the positive effects of contemporary video games. In their study, they compared the visual and attentional skills of action video game players (AVGPs) to those of non-video game players (NVGPs). An individual was considered an AVGP if he or she played action video games at least four hours per week for the past six months, whereas NVGPs played video games very rarely or never. Although Green and Bavelier (2003) found that AVGPs outperformed NVGPs on tests of attentional resources (flanker compatibility and enumeration tasks), attention over space (useful field of view task), and attention over time (attentional blink task), they did not directly measure task-switching ability. However, they did mention the possibility of action-video games enhancing task-switching abilities, since AVGPs were able to detect far more X’s (a second target) presented at shorter intervals (100-500 ms) in the attentional blink task.

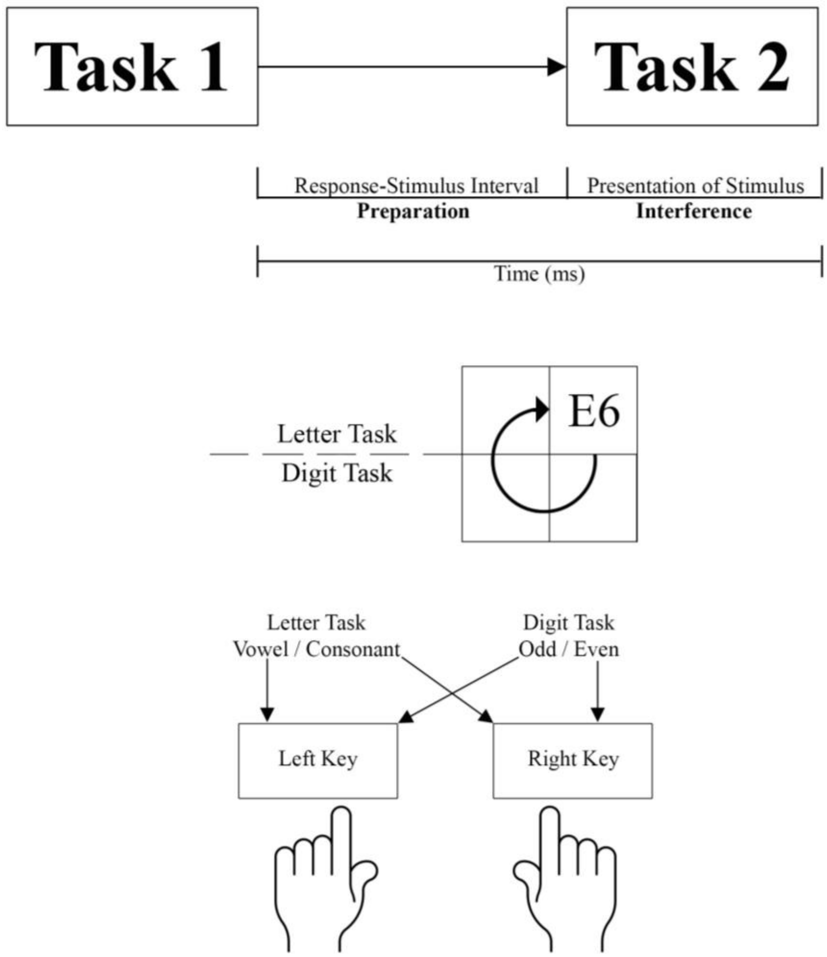

Figure 2. Conceptual model of task-switching in the alternating-runs paradigm. The response-stimulus interval (R-S Interval) allows the individual time to prepare for the upcoming switch from Task 1 to Task 2. However, preparation does not eliminate switch cost completely. Even when given ample time to prepare (e.g., 600 ms), residual switch cost remains (Rogers & Monsell, 1995). This residual switch cost is theorized to result from proactive interference caused by the irrelevant task-set (Allport et al., 1994; Allport & Wylie, 1999), particularly for bivalent stimuli, incongruent conditions, and when the response mappings overlap, as depicted (Rogers & Monsell, 1995).

Given the importance of task-switching in everyday life, many researchers attempted to expand on the Green and Bavelier (2003) results through studies that focused exclusively on how action video games impacted task-switching ability. Action video games might serve as effective tools to enhance this ability, as they constantly require players to re-evaluate their current task-set in the context of a complex and fast-paced environment (Cardoso-Leite, Green, & Bavelier, 2015). Thus, action video games place strong demands on cognitive flexibility and require individuals to quickly re-evaluate goals and tasks in an environment where contingencies are continuously changing. Developing these skills from playing these types of games could lead to enhancement in task-switching ability that can generalize to contexts beyond the game.

Types of studies. Two types of studies have been utilized in the video game and task-switching research, cross-sectional and training. In the cross-sectional studies, AVGPs (or sometimes players of specific genres) and NVGPs are recruited based on self-reported video game experience. Both groups complete a task-switching experiment and then their results are compared. Cross-sectional studies are used to test whether or not there is an association between specific video game experience and task-switching ability. If a difference is found, then training studies are used to establish if this relationship is causal. In training studies NVGPs are recruited and randomly assigned to groups. Those in the experimental group play the video game expected to improve task-switching ability (e.g., FPS), while those in the control group play a different type of game (e.g., Puzzle). Sometimes a control group of participants who play no video games is used to examine practice effects, or how much participants improve just by completing the task more than once. Pre-training and post-training results on the task-switching measure are then compared. Previous studies on video games and task-switching are summarized in Table 1.

Table 1

Summary of Previous Studies on Video Games and Task-Switching

Author(s)	Study Type	Criteria for Video Game Player or Total Training Time	Video Game Category or Genre	Task-Switching Paradigm
Gamer/Non-Gamer Differences Observed				
Basak et al. (2008)	Training	Trained for 23.5 hours.	RTS (*Rise of Nations: Gold Edition*)	Random (No precue)
Boot et al. (2008)	Cross-sectional	Played for at least 7 hours per week for the past 2 years.	Action category	Random (No precue)
Cain et al. (2012)	Cross-sectional	Played for at least 6 hours per week and ranked themselves as a 5 or higher in FPS or action video game expertise.	Action category	Random (No precue)
Colzato et al. (2010)	Cross-sectional	Played at least 4 times a week for a minimum of 6 months.	Action category (sample consisted of mainly FPS players), those who played primarily web-based puzzle games were excluded	Predictable (Task-cuing)
Green et al. (2012)	Cross-sectional	Experiment 1: Played for at least 5 hours per week for the past 6 months. Experiments 2 & 3: Played for at least 5 hours per week for the past year.	Action category	Experiments 1 & 2: Predictable (Alternating-runs variants) Experiment 3: Random (No precue)
Hartanto et al. (2016)	Cross-sectional	Played for at least 5 hours per week for the past 6 months. Early video game players began playing actively before age 12, while late video game players started at age 12 or later.	Action category, those who played primarily web-based puzzle games were excluded	Random (Task-cuing)
Strobach et al. (2012)	Cross-sectional	Played for at least 6 hours of action video game playing per week for the past 6 months.	Action category	Predictable (Alternating-runs)
	Training	Trained for 15 hours.	FPS (*Medal of Honor*) & Puzzle (*Tetris*)	Predictable (Alternating-runs)

Note. FPS = First-Person Shooter; RTS = Real-Time Strategy.

Author(s)	Study Type	Criteria for Video Game Player or Total Training Time	Video Game Category or Genre	Task-Switching Paradigm
		Limited Gamer/Non-Gamer Differences Observed		
Andrews & Murphy (2006)	Cross-sectional	Played for at least 4 hours per week for the past 6 months.	Action category	Predictable (Alternating-runs)
Dobrowolski et al. (2015)	Cross-sectional	Played at least 7 hours of specific genre (FPS or RTS) and less than 5 hours of other genre (FPS or RTS) per week for past 6 months. Experience with other genres did not disqualify the participant as long as he or she played the specific genre more frequently than any other genre.	FPS & RTS	Predictable (Task-cuing)
Green et al. (2012)	Training	Trained for 50 hours.	FPS (*Unreal Tournament 2004* & *Call of Duty 2*) & Life Simulation (*The Sims 2* & *The Sims 2: Open for Business*)	Predictable (Alternating-runs variant)
Karle et al. (2010)	Cross-sectional	Played for at least 4 hours per week for the past 6 months.	Action category (sample consisted of mainly FPS players), those who played primarily web-based puzzle games were excluded	Experiment 1: Random (Task-cuing and no precue) Experiment 2: Random (Task-cuing)
		No Gamer/Non-Gamer Differences Observed		
Boot et al. (2008)	Training	Trained for 21.5 hours.	FPS (*Medal of Honor*), Puzzle (*Tetris*), & RTS (*Rise of Nations*)	Random (No precue)
Boot et al. (2013)	Training	Trained for 60 hours.	Racing (*Mario Kart DS*) & Puzzle (*Brain Age 2™*)	Random (No precue)
Oei & Patterson (2014b)	Training	Trained for 20 hours.	FPS (*Modern Combat*), Puzzle (*Cut the Rope*), RTS (*Starfront Collision*), & Arcade (*Fruit Ninja*)	Random (Alternating-runs variant)

***Cross-sectional studies*.** Numerous studies have examined whether AVGPs have superior task-switching abilities than NVGPs. Andrews and Murphy (2006) used the alternating-runs paradigm to compare the task-switching ability of AVGPs and NVGPs. Participants either performed a letter classification (vowel/consonant) or digit classification (odd/even) task based on the location of a pair of characters within a 2 x 2 matrix. The location of the character pair rotated in a clockwise sequence. The results showed that AVGPs had smaller switch costs than NVGPs for shorter R-S intervals (150 ms) but not for longer ones (600 ms and 1200 ms). The researchers interpreted this to mean that AVGPs are better able to anticipate and prepare for upcoming switches. In other words, the researchers theorized that this type of video game experience enhances the endogenous component of task-set reconfiguration (Rogers & Monsell, 1995). Additionally, at the longer interval (1200 ms), AVGPs had smaller switch costs for the incongruent condition. This led the authors to conclude that this type of video game experience also affects the exogenous component of task-switching by enhancing the ability to switch tasks in the presence of a conflict given enough time to prepare. Strobach et al. (2012, Experiment 1) used a similar design in their study. Their results also showed that AVGPs had lower RTs than NVGPs on switch trials, leading them to conclude that AVGPs have enhanced executive control in situations that require switching tasks.

Several studies in this area have also utilized a task-cuing paradigm. For instance, Colzato et al. (2010) had participants in their study determine the shape (square or rectangle) of either local or global (made up of local) geometric figures. The task order was predictable (alternated every four trials) and a cue was provided before each trial, allowing time for participants to prepare. The results of the study showed that AVGPs had smaller switch costs than NVGPs. Since the time between the cue and the presentation of the stimuli was rather long (400-500 ms), the researchers could not assess the preparatory component of task-switching. Instead, they concluded that video game experience affects the residual switch cost and that this was due to AVGPs being better able to selectively update and activate task-sets. Dobrowolski et al. (2015) used the same design as Colzato et al. (2010) in their study to compare the task-switching abilities of video game players of two specific genres (FPS and RTS), and NVGPs. The results of their study revealed that RTS players had significantly smaller switch costs than NVGPs and slightly smaller switch costs than FPS players. Although FPS players had smaller switch costs than NVGPs, the difference was only a non-significant trend. The researchers concluded that since both video game groups had similar task-switching abilities, it could not be said whether one genre enhanced this ability more than the other.

Hartanto et al. (2016) also used a task-cuing paradigm. In this experiment, participants had to indicate either the color (red or green) or shape (circle or triangle) of stimuli. The task order was random, but cues were given 250 ms before the stimulus was presented to inform participants which task to complete. The results showed that AVGPs had only marginally smaller switch costs than NVGPs. However, when age of onset was controlled for, the results showed that early players (who started before age 12) had significantly smaller switch costs than late players (who started at age 12 or later) than NVGPs. There was no difference in switch cost between late players and NVGPs. Thus, the researchers concluded that age of active video game onset served as a better predictor of task-switching ability than frequency of recent gameplay. Specifically, those who begin actively playing video games before the age of 12 seem to reap greater benefits than those who begin later, most likely due to the fact that these are periods where the brain is highly plastic to environmental influences. According to Blakemore and Choudhury (2006), the brain undergoes widespread development during childhood and preadolescence. Additionally, studies on the development of task-switching ability have shown that there are age-related changes from 7 to 11 years old, but that adult-level performance is attained around age 12 (e.g., Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Cepeda, Kramer, & Gonzalez de Sather, 2001). Thus, it is possible that the brain may be particularly sensitive to video game experience prior to the age of 12.

Some researchers in this area have utilized random task-switching paradigms (e.g., task-cue is not provided until the stimulus is presented). For example, Boot et al. (2008) had participants classify whether a number was odd/even or smaller than 5/larger than 5 based on the color of the background behind the number. Their results were consistent with previous studies in showing that AVGPs had smaller switch costs than NVGPs. Cain et al. (2012) also used a random task-switching paradigm, however, they varied the difficulty of the tasks in their study. In the easy task, participants had to indicate which way the arrow in the center of the screen (located between two other distractor arrows) pointed, while in the more challenging task they had to indicate the opposite way the arrow pointed (the color of the stimuli indicated which task to complete). Previous research on task-switching involving tasks of unequal difficulty has shown that people have larger switch costs when switching from the difficult task to the easier task than vice versa (e.g., Allport et al., 1994; Monsell, Yeung, & Azuma, 2000). This is due to the fact that the easier task carries over more strongly than the difficult one and therefore needs to be inhibited more strongly. Overcoming this inhibition on future trials prolongs RTs. While the NVGPs showed results that were consistent with this finding, AVGPs had less difficulty switching between the two tasks and had overall smaller and more symmetrical switch costs than NVGPs.

One group of researchers attempted to examine what aspect of task-switching and related cognitive control processes were impacted by experience with action video games (Karle et al., 2010). The first experiment in their study involved minimal trial-to-trial interference. Participants were presented with stimuli from non-overlapping sets (letters and digits) and made responses using non-overlapping keys. The tasks were either cued with informative information or no information, and the amount of time between the cue and the presentation of the stimulus was either 100 ms or 1000 ms. AVGPs showed smaller switch costs when the task-cues were presented for longer and when there were informative cues, suggesting that they were better at preparing for upcoming switches. The researchers also determined that this difference in switch cost was not a result of differences in baseline RTs between groups. In the second experiment, participants had to complete one of three tasks on a digit (odd/even, prime/multiple, and less than 5/greater than 5). This experiment was more challenging, as there was substantial overlap between the response keys. The results of this experiment showed no difference in switch cost between AVGPs and NVGPs. Thus, the researchers concluded that action video game experience may provide a benefit in selective attention to activate relevant task-sets in advance. However, this experience does not improve resistance to proactive interference caused by overlapping responses, which involves inhibiting the conflicting task-set.

Green et al. (2012) used a few different task-switching paradigms in their study. In the first experiment, the researchers used different modes where participants either verbally or manually selected the color (red/blue) or shape (circle/square) of an object depending on which side of a horizontal line the object appeared (it moved counterclockwise in a predictable manner). In the second experiment, participants completed the same perceptual tasks that were done in the first experiment, as well as conceptual tasks based on the same pattern (determine whether a number was less than 5/greater than 5 or even/odd). In the third experiment, participants completed the same tasks as the previous experiment, but used the color of the background to indicate which task was to be completed. Additionally, participants also completed only the odd/even task using different hands based on the background color. This was to examine the effect of switching the response mappings rather than the task goals or stimuli. The results of all three studies showed that AVGPs had smaller switch costs than NVGPs, suggesting that this result holds true regardless of whether the task-switching experiment involved vocal or manual responses, conceptual or perceptual tasks, and goal or response mapping switches. Additionally, these results were consistent even after proportional switch cost (the percent increase in RT from non-switch to switch trials) was calculated. This correction was used to account for any difference in baseline RTs, as past research has shown that AVGPs have faster RTs than NVGPs (Dye, Green, & Bavelier, 2009).

A variety of task-switching paradigms (e.g., predictable and random) have been used in cross-sectional video game studies. The results of these studies have consistently shown that AVGP have smaller switch costs than NVGPs. As a result, researchers have theorized that individuals with action video game experience pay less of a price when switching from one task to another. However, the different criteria used to classify AVGPs makes comparing the results of these studies to one another challenging. The action video game category is loosely defined and encompasses several different video game genres. Thus, these studies do not allow researchers to examine the potential effects that different video game genres have on task-switching ability. Only Dobrowolski et al. (2015) controlled for video game genre in their study, making their results far easier to interpret. Although both RTS-players and FPS-players showed smaller switch costs than NVGPs, this difference was only statistically significant for the RTS group. Other factors that could lead to variability within the video game group(s), such as age of onset, have also rarely been examined (with the exception of Hartanto et al., 2016).

***Training studies*.** After studies found an association between action video game experience and task-switching, researchers began to utilize training studies to examine if this association was causal. In the same research that contained a cross-sectional study supporting the association, Boot et al. (2008) also utilized a training study. In this experiment, NVGPs were randomly assigned to play either 21.5 hours of an FPS (*Medal of Honor*), Puzzle (*Tetris*), or RTS game (*Rise of Nations*). A no-training control group was also used to examine practice effects. The task-switching test used in this experiment was identical to the one used in the cross-sectional study. However, the results of the training study were not consistent with the results of the cross-sectional study. Although switch costs diminished with repeated testing, there was no difference between any of the groups. These results also contradicted an earlier study from the same laboratory that used the same task-switching paradigm. Basak, Boot, Voss, and Kramer (2008) found that older adults trained on an RTS game (*Rise of Nations: Gold Edition*) for 23.5 hours showed a significant decrease in switch costs compared to the no-training control group. Another study using the same task-switching paradigm also failed to find a significant reduction in switch costs after older adults were trained for 60 hours on either a Racing (*Mario Kart DS*) or Puzzle game (*Brain Age 2*™; Boot et al., 2013).

Strobach et al. (2012, Experiment 2) also utilized a training study after examining the results of their cross-sectional study. Participants played 15 hours of either an FPS (*Medal of Honor*) or Puzzle game (*Tetris*). A no-practice control group was also included. The task-switching experiment was identical to the one used in their cross-sectional study. The researchers found that those who trained on the FPS game showed a significant decrease in switch cost compared to those trained on the Puzzle game and those in the no-training control group. Oei and Patterson (2014b) used a modified version of this paradigm. Instead of rotating in a predictable pattern, the stimuli appeared in one of the four boxes randomly. Participants in this study were trained for 20 hours on an FPS (*Modern Combat*), RTS (*Starfront Collision*), Puzzle (*Cut the Rope*), or Arcade game (*Fruit Ninja*). Only those trained on the complex Puzzle game showed a significant reduction in switch costs after training.

Green et al. (2012, Experiment 4) also utilized a training study after assessing the results of their cross-sectional studies. In an attempt to train NVGPs to a similar level as AVGPs, the researchers trained participants in the experimental group for 50 hours on FPS games (*Unreal Tournament 2004* and *Call of Duty 2*) and participants in the control group for 50 hours on Life Simulation games (*The Sims 2* and *The Sims 2: Open for Business*). The task-switching experiment was identical to the one used in the first experiment of the study, with the exception that only manual responses were used. Individuals in the experimental group showed significant decreases in switch cost compared to those in the control group. However, this change was only marginally significant when proportional switch cost was calculated and compared, suggesting that a large portion of this benefit was from shorter RTs.

Unlike cross-sectional studies on video game experience, the results of training studies in this area are mixed. There are a few possible explanations for this. Different genres of video games used in these training studies may account for some of the inconsistencies in the results. For instance, a few studies selected an FPS for their action game (e.g., Green et al., 2012; Strobach et al., 2012), while another study used a Racing game (Boot et al., 2013). Another reason for the conflicting results could be the different task-switching paradigms used. For instance, Strobach et al. (2012, Experiment 2) and Green et al. (2012, Experiment 4) utilized a predictable paradigm where the task switched after a predetermined number of trials. Boot et al. (2008), Boot et al. (2013), and Oei and Patterson (2014b) instead utilized a random paradigm. Research has shown that random task-switching paradigms are more demanding than predictable ones and typically yield greater switch costs (e.g., Kiesel et al., 2010; Monsell, 2003). Thus, it is possible that action video game training may improve the ability to prepare for upcoming switches, but does not impact the more demanding mental flexibility necessary for random switches (Oei & Patterson, 2014a). There is also some evidence that these two task-switching paradigms may be supported by different neural mechanisms (Pereg, Shahar, & Meiran, 2013).

Purpose of the Current Study

Gaps in previous research. There are several gaps in the literature on video games and task-switching ability. The most significant issue with previous cross-sectional studies is that they continue to use ambiguous definitions for the action video game category. According to Latham et al. (2013b), although the term action video games in the literature typically refers to FPS games, this category actually encompasses many video game genres (e.g., MOBA, RPG, RTS). Despite this, only the FPS and RTS genres have been independently examined in a cross-sectional study involving task-switching. Separating the video games by genre could greatly increase the homogeneity of samples and make comparing and interpreting these results easier. Training studies rarely use other genres aside from FPS and RTS (as action games) and Puzzle games (as a control), most likely because little research exists on other genres. Since training studies are expensive and time consuming, it is unlikely that other genres will be used in them until cross-sectional research is examined and supports their use.

Other relevant features of video game experience, such as age of active onset or years of experience, are rarely examined in cross-sectional studies. According to Latham et al. (2013a) and Hartanto et al. (2016), these variables should always be considered as they could account for some of the variability in AVGPs' performance on measures. For instance, classifying AVGPs based on recent gameplay does not distinguish between those who just started six months ago and those who have accumulated more than 10 years of experience. Additionally, this classification does not take into account whether or not AVGPs began playing during periods of high cognitive plasticity. This is important, as it has been shown that performance gains from training may be less significant in older adults than younger adults (Baltes & Kliegl, 1992). Therefore, it is possible that the benefits from video game experience are not equivalent across the lifespan.

Despite the amount of research on video game experience and task-switching, no research has examined performance on both a predictable and random task-switching paradigm using the same cross-sectional participants. Examining both task-switching paradigms in a single study is important, as different results may be found, which could explain the conflicting results in previous studies. Many cross-sectional studies (with the exception of Karle et al, 2010 and

Green et al., 2012) also did not perform a correction for switch cost to account for differences in baseline RTs between AVGPs and NVGPs. Since AVGPs typically have lower RTs than NVGPs (Dye et al., 2009), it is important to perform some type of correction (e.g., proportional switch cost) and examine if the findings are robust to this correction (Green et al., 2012).

Theory for the current research. Task-switching and video game playing involve many similar cognitive processes and mechanics (e.g., attention to auditory and visual cues, ignoring interference, requiring fast reaction times). According to the common demands theory, video game experience may lead to improved task-switching performance due to the similar underlying demands in both tasks. Individuals who play video games more frequently have more practice with these mechanics and should therefore outperform individuals with little to no video game experience on a task-switching experiment. However, there are many different video game genres for individuals to play. Complex video game genres (e.g., RTS, RPG, MOBA) often require players to switch tasks frequently in complex and fast-paced environments where mistakes can be punished heavily. Individuals who play these genres undergo more demanding training of these mechanics and should therefore outperform individuals who play less complex genres (e.g., Card, Puzzle, Rhythm) on a task-switching experiment. Individuals who began playing video games when they were younger may have reaped greater benefits from training of these mechanics since they were playing during periods where their brain was highly plastic to environmental change. Thus, individuals who began playing when they were younger should outperform those who began playing later in life on a task-switching experiment.

Significance of the current research. This research is significant because of the impact that it could have on future studies. If players of specific genres show enhanced task-switching ability, as was the case in the Dobrowolski et al. (2015) study, then this will suggest that future cross-sectional studies utilize video game genre to differentiate players rather than ambiguous categories (e.g., action). Examining different video game genres in cross-sectional studies is important, as these studies are prerequisites for training studies. Therefore, this research could influence not only future cross-sectional studies, but training studies as well. The majority of training studies attempt to use FPS games to improve task-switching ability in NVGPs (e.g., Boot et al., 2008; Strobach et al., 2012; Green et al., 2012). The results of this study could provide support for considering other genres of video games. Examining predictable and random task-switching paradigms in one study is important, because it can provide information on whether video game experience improves performance on both anticipated and unexpected task-switching. Determining whether or not differences in switch cost are robust to the proportional switch cost correction is also important, as it provides information as to whether video game experience is associated with enhanced task-switching ability, or just overall reduced RTs.

This research also has practical applications for the ongoing development of video games designed specifically to help train and enhance cognitive abilities, such as task-switching. Controlling for video games genre in these studies could allow researchers to better identify and examine the game components that foster task-switching ability (Bavelier & Davidson, 2013). Game developers could then utilize different genres (rather than just FPS) when designing video games that are intended to enhance this ability, thus appealing to a wider audience once these games are placed on the market. Even commercial video games with these components could be useful for training and rehabilitation purposes (Eichenbaum, Bavelier, & Green, 2014).

Green and Bavelier (2008) argued that video games are a good training regimen because they allow players to adjust the difficulty to best fit their needs, provide instant feedback, and offer high variability that ensures more flexible learning than other interventions. Additionally, it is theorized that video games interventions will have higher rates of compliance because they are inherently enjoyable and motivating compared to other types of cognitive interventions and provide a greater sense of accomplishment (Boot et al., 2013). Video games could be particularly beneficial for those with impairments in task-switching ability as a result of disease, disorder, or aging. However, if age of active video game onset is found to be a more significant predictor of task-switching ability than video game experience, then the practical application of these studies as an intervention for the elderly should be carefully considered.

Hypotheses. Four hypotheses were examined in this study. All of these hypotheses were examined for a predictable task-switching paradigm and a random task-switching paradigm.

H1) Consistent with the results of previous cross-sectional studies that compared the task-switching abilities of video game players to non-players (e.g., Andrews & Murphy, 2006; Green et al., 2012; Strobach et al., 2012), it was hypothesized that individuals with larger amounts of video game experience, measured on a continuous scale by the average number of hours played per week over the last 12 months, would have smaller switch costs compared to those with fewer or no hours.

H2) It was hypothesized that individuals who began actively playing video games earlier in life would have smaller switch costs compared to those who started playing later in life.

H3) It was hypothesized that individuals who more frequently play video game genres higher in complexity (e.g., RTS, RPG, MOBA) would have smaller switch costs compared to those who play less complex genres (e.g., Puzzle, Music/Rhythm, Card) due to the strong task-switching demands present in the former.

H4) It was hypothesized that any differences in switch cost would be robust to the proportional switch cost correction (which accounts for differences in baseline RTs).

Method

Participants

Participants were recruited from the Rochester Institute of Technology, a private four-year technical college. An advertisement for the study was sent out through email to recruit participants. This advertisement contained a link to an online questionnaire on *Qualtrics*, which was used to screen participants. Participants were also recruited from video game groups on campus, including esports teams and the electronic gaming society. The goal of the study was to have participants with varying amounts of video game experience in terms of average hours played and different genres played. Thus, participant eligibility in the experiment was determined by the researcher with the goal of recruiting a diverse sample (e.g., if data were already collected from several participants who played very few hours of video games over the last 12 months then similar individuals would no longer be eligible).

In order to participate in the study, participants were required to be at least 18 years old. Given the importance of the auditory noise that sounded when an error was made in the experiment, participants were required to have at least minimal hearing in order to be eligible for the study. In-tact motor skills were also required to press the appropriate keyboard input quickly and accurately. Since the task-switching experiment utilized visual stimuli presented on a computer monitor, participants also needed to have normal or corrected-to-normal vision in order to be eligible. The age, hearing, motor, and vision requirements were assessed through responses on the screener questionnaire.

Of the 130 individuals who completed the screener questionnaire, 60 eligible participants (75% male, 25% female) were recruited to complete the study (see Appendix A for a flowchart for screening participants). Participants ranged in age from 18 to 28 (*M* = 21.72, *SD* = 2.71). This age range was consistent with previous studies that used college samples (e.g., Andrews & Murphy, 2006; Boot et al., 2008; Green et al., 2012).

Screener Questionnaire

A questionnaire consisting of 28 questions was completed through *Qualtrics* (Appendix B). This questionnaire was used to screen participants to determine whether they were eligible to participate in the study. Demographic information (e.g., gender and age) was collected in the first section of the questionnaire. The next section assessed video game experience over the last 12 months (e.g., average number of hours played per week and specific genres played over the last 12 months). The researcher examined the list of video games provided by each participant on the questionnaire to ensure that participants had accurately labeled the genre. There was also a section on video game experience before the last 12 months (e.g., average number of hours played per week and genres played before the last 12 months). Lastly, there was a section on specific experiences with video games (e.g., video game experience rating) and a section on age of active video game onset (e.g., age participants began playing video games for 5 or more hours per week on average, if applicable). The entire screener questionnaire took between 1-30 minutes to complete depending on the amount of video game experience each individual reported.

Responses to the questionnaire were used to measure participants on the independent variables in this study.

Independent Variables

The first independent variable in this study was video game experience. This was measured on a continuous scale based on the average number of hours an individual reported that he or she spent playing video games each week over the last 12 months. The second independent variable in this study was age of active video game onset. This was measured on a continuous scale. The third independent variable in this study was an individual's score on the Complexity Experience Index (CEI; discussed further on p. 45 of the results section), which was created to assess the complexity of the video game genre(s) an individual played as well as how many hours per week he or she spent playing these genres. CEI was measured on a continuous scale.

Task-Switching Experiment

The task-switching experiment in this study was based on the digit/letter classification task used in previous studies (Andrews & Murphy 2006; Oei & Patterson, 2014b; Strobach et al., 2012), which was adapted from Rogers and Monsell (1995). The task-switching experiment was completed on a desktop computer through a *Java* program which recorded data on RTs and errors.

Stimuli and response keys. Character pairs consisting of an uppercase letter and a digit were presented in size 100 Segoe UI font. This font was selected because it is a default font for *Windows* and is a font that can easily be read on screens. Each uppercase letter and digit character pair was presented in the center of one of four equally-sized boxes in a 2 x 2 matrix.

The uppercase letter was either a vowel (from the set: A, E, I, or U) or a consonant (from the set: G, K, M, or R). The digit was either odd (from the set: 3, 5, 7, or 9) or even (from the set: 2, 4, 6, or 8). The letter and digit were randomly selected, with the exception that the same character would not appear on two successive trials. Participants had to classify the letter as a vowel/consonant (task 1) or classify the digit as odd/even (task 2) based on the location of the character pair relative to the horizontal line. Participants were instructed to complete the letter task if the character pair appeared above the horizontal line and the digit task if it appeared below the horizontal line. In the letter task, participants were instructed to press the “Z” key if the letter was a vowel or the “/” key if the letter was a consonant. In the digit task, participants were instructed to press the “Z” key if the digit was odd or the “/” key if the digit was even. Since the letter and digit in the character pair were randomly selected, there were no restrictions on the number of trials in a row that the same key press response could be correct.

Procedure. Participants were provided with general instructions on how to complete the task-switching experiment through the *Java* program and a paper printout of the instructions was also available (Appendix C). In each trial, the character pair appeared and remained on the screen until the participant pressed one of the response keys or 5000 ms had elapsed. Participants were told to respond as quickly and as accurately as possible to each task. If the participant selected the correct option, a short blank 150 ms interval followed before the next stimulus pair appeared. If the participant selected the incorrect option or failed to press one of the keys for 5000 ms, a brief incorrect noise lasting approximately 400 ms was played. The blank interval before the next stimulus pair was then extended to 1500 ms. According to Rogers and Monsell (1995), this design helps control for more errors being made, as participants often lose track of which task is appropriate after they make an error. Every block of trials consisted of an equal number of non-switch and switch trials, as well as an equal number of congruent and incongruent conditions (see p. 18 of introduction).

Two different task-switching paradigms were examined in this study. In the predictable task-switching paradigm, the location of the character pair was predictable, starting in the top left box and rotating in a clockwise pattern. Thus, participants were able to anticipate the upcoming trial, and therefore anticipate task-switches. Conversely, in the random task-switching paradigm the location of the character pair was pseudorandomized, appearing to participants randomly in one of the four boxes. Thus, participants were not able to anticipate or prepare for upcoming trials, and therefore could not anticipate task-switches. These paradigms were presented to participants in a counterbalanced order with a mandatory two-minute break in between.

Validity and reliability of the experiment. According to Colzato et al. (2010), task-switching experiments investigate cognitive flexibility through task-set reconfiguration, or how a person selects and carries out the actions necessary to complete a specific task. These experiments are well controlled and have consistently provided the same basic result in hundreds of studies (Monsell, 2003).

Dependent Variables

The dependent variable in this study was task-switching ability, which was measured through switch cost. Switch cost was calculated by subtracting the RT for non-switch trials from the RT for switch trials. To account for differences in baseline RTs between the groups, proportional switch cost was also examined. Proportional switch cost was calculated as the percent increase in RT from non-switch to switch trials (Green et al., 2012). Differences in accuracy were analyzed by examining the percentage of errors made.

Design

A correlational research method was used in this study to assess the association between video game experience and task-switching ability. It was not possible to establish a causal relationship in this study.

Procedure

Participants completed the screener questionnaire through *Qualtrics*. This questionnaire was used to assess whether an individual was eligible to participate in the experiment. The entire questionnaire took between 1-30 minutes to complete depending on the amount of video game experience each individual reported. Eligible participants were contacted through the email address that they had provided on the questionnaire and invited to participate in the task-switching experiment at the lab. Before beginning the experiment, participants reviewed and signed the informed consent paperwork. They were then seated in front of a desktop computer approximately 60 centimeters from the screen. They were also given noise canceling headphones and instructed to wear them throughout the experiment to minimize distractions.

The entire task-switching experiment was completed through a program written in *Java*. Participants were given general instructions on how to perform the letter and digit tasks. After participants read over the general instructions, they were provided with a brief set of instructions explaining the task-switching paradigm. Half of the participants were given the predictable task-switching paradigm first, while the other half began with the random task-switching paradigm.

Participants completed a block of 60 practice trials, followed by a block of 240 experimental trials for either the predictable or random task-switching paradigm. After these two blocks of trials, participants were given a mandatory two-minute break, during which they were asked to refrain from other activities. After the break, participants completed a block of 60 practice trials, followed by a block of 240 experimental trials for whichever task-switching paradigm they had not yet completed (predictable or random). The entire task-switching experiment took approximately 20 minutes to complete. The researcher monitored participants from a distance in case there were any questions or technical issues.

After completing the task-switching experiment participants were given a $10.00 Amazon gift card as compensated for their time. Participants were required to complete the compensation receipt form to receive the gift card. After collecting data from 60 participants the results of the study were analyzed and a $25.00 Amazon gift card was raffled off to one of the individuals who completed the screener questionnaire. Table 2 depicts a summary of the procedure for the task-switching experiment in this study (the order in which the task-switching paradigms were presented was reversed for half of participants). Informed consent and compensation receipt documents are shown in Appendices D, E, and F.

Table 2

Summary of Procedure for the Task-Switching Experiment (Predictable Paradigm First)

Block #	# of Trials	Type of Task-Switching Experiment	Location of Character Pair
		Informed Consent Paperwork	
1	60	Practice (Predictable)	Rotate in Clockwise Pattern
2	240	Experimental (Predictable)	Rotate in Clockwise Pattern
		Mandatory Break (Two-Minutes)	
3	60	Practice (Random)	Random (No Pattern)
4	240	Experimental (Random)	Random (No Pattern)
		Compensation Receipt Form	

Results

Questionnaire Results

All 60 participants reported that they had played video games over the last 12 months. Additionally, they all reported playing before the last 12 months. Most participants (66.10%) reported that they did not ever take a significant break from video games after they had actively started playing them. Two-thirds of participants reported that they had been involved in a group where video games were played on a regular basis. The majority of participants (83.33%) also reported that they deliberately engage in activities to improve their video gaming skills. Summarized results of additional questions from the questionnaire are shown in Table 3 (continuous questions) and Table 4 (categorical questions).

Table 3

Summarized Results of Continuous Questions in the Screener Questionnaire

Question	Minimum	Maximum	Median	Mean	Standard Deviation
Days / Week (Last 12 Months)	1	7	6	5.33	1.98
Hours / Week (Last 12 Months)	0.50	90	21	24.23	19.10
Days / Week (Before Last 12 Months)	2	7	7	5.87	1.59
Hours / Week (Before Last 12 Months)	2	70	22.50	27.05	17.91
Age of Active Video Game Onset [1]	3	18	8	8.61	3.15
Age of Deliberate Practice Onset [2]	9	26	14	14.39	3.15

Note. [1] Data from 59 participants (1 participant never played more than 5 hours a week);

[2] Data from 49 participants (11 participants never deliberately practiced video games).

Table 4

Summarized Results of Categorical Questions in the Screener Questionnaire

Question	Count (%)				
Device (Last 12 Months)	Computer		Console		Phone
	46 (76.67%)		10 (16.67%)		4 (6.67%)
Device (Before Last 12 Months)	Computer		Console		Phone
	38 (63.33%)		20 (33.33%)		2 (3.33%)
Experience	Novice	Apprentice	Intermediate	Advanced	Expert
	1 (1.67%)	3 (5.00%)	7 (11.67%)	27 (45.00%)	22 (36.67%)
Type of Player	Casual		Somewhere in between		Competitive
	12 (20.00%)		32 (53.33%)		16 (26.67%)
Play Style	Only story mode / against computers	Mostly story mode / against computers but some online multiplayer	About the same amount of story mode / against computers and online multiplayer	Mostly online multiplayer but some story mode / against computers	Only online multiplayer
	5 (8.33%)	13 (21.67%)	17 (28.33%)	23 (38.33%)	2 (3.33%)

Note. n = 60.

Task-Switching Data Cleaning

Before analyzing the results, the data were examined and cleaned. No data were missing from the questionnaire or task-switching experiment. Error data and RTs were collapsed over the letter and digit tasks, consistent with previous studies utilizing this task-switching paradigm (Andrews & Murphy 2006; Oei & Patterson, 2014b; Strobach et al., 2012). A frequency distribution of percent error was created for both the predictable and random task-switching paradigms (Appendix G). From examining these distributions, 20% error was selected as the cut-off at which to exclude participants for making excessive errors. This cut-off number was consistent with the cut-off number used in the Karle et al. (2010) study. In total, 7 participants had their results excluded from analyses due to errors.

One outlier was found in the data and excluded from further analyses. This participant reported playing video games for 20 hours more than any other participant. Given that there are only 168 hours in a week, 90 hours of video games seems both improbable and unsustainable. Additionally, this participant performed poorly and was an outlier in both task-switching paradigms. After examining this participant’s response times, it was determined that this poor performance was due to average response times on non-switch trials, but irregularly long response times on switch trials, ultimately leading to a much higher switch cost for both the predictable and random task-switching paradigms (Appendix H). While this result is suggestive of poor task-switching ability, in this participant it deviated dramatically from the pattern of predictable and random switch-costs obtained by participants who had also played a large amount of video games each week (40-70 hours).

Participants who were excluded ranged in genre(s) played and average hours played per week over the last 12 months. Aside from the high error rates and the one individual who reported an abnormally high number of hours played, there were no differences in relevant variables (genres and average hours played) between individuals who were included and excluded in the study. Data for the remaining 52 participants were examined in further analyses. Consistent with Rogers & Monsell (1995), trials with RTs less than 100 ms (most likely mistakes) and trials following an error trial were excluded from analyses. In the predictable task-switching paradigm, 3.92% of total trials were removed. In the random task-switching paradigm, 4.19% of total trials were removed. All response time analyses were conducted on correct trials only and were conducted individually for the predictable task-switching paradigm and the random task-switching paradigm. Consistent with previous studies, a criterion (α) of 0.05 was adopted for all tests in this study (Andrews & Murphy, 2006; Colzato et al., 2010).

Complexity Experience Index (CEI)

Equation. Participants in this study reported playing around four different video game genres each week (M = 4.12, SD = 2.24). For that reason, it was not possible to group participants neatly into categories based on genre played as had been done previously in the Dobrowolski et al. (2015) study. An equation was created (Equation 1) to examine whether individuals who more frequently play video game genres higher in complexity had smaller switch costs compared to those who play less complex genres, as hypothesized.

This equation combined video game experience (based on average number of hours played per week of each genre over the last 12 months) and complexity ranking of genre(s) played (based on how complex a genre is compared to other genres) to calculate a Complexity

Experience Index (CEI) score. In the equation, e_i represents hours played per week over the last 12 months for the i th genre, while c_i represents complexity ranking for i th genre. CEI score was used to compare participants to one another based on the genre(s) of video games they play and how much they play them each week. Table 5 displays the complexity rankings for each genre. Table 6 provides descriptions of each genre and justifications for the complexity rankings. The complexity rankings provided in this study were consistent with the complexity dimension of the conceptual map of video game genres created by Granic et al. (2014).

$$\text{(1)} \qquad Complexity\ Experience\ Index\ (CEI) = \sum_{i=1}^{n} (e \ \times c)$$

Table 5

Complexity Rankings for Video Game Genres

Complexity Ranking	Video Game Genre	Example Video Games
15	Real-Time Strategy (RTS)	*Age of Empires, Halo Wars, StarCraft II*
14	Role-Playing Games (RPG; Single Player or Multiplayer)	*Pokémon, The Elder Scrolls V: Skyrim, World of Warcraft*
13	Multiplayer Online Battle Arena (MOBA)	*Dota 2, League of Legends, Smite*
12	Shooter	*Call of Duty, Gears of War, Halo*
11	Fighting	*Mortal Kombat, Super Smash Bros., Tekken*
10	Action / Adventure	*Assassin's Creed, Minecraft, The Legend of Zelda*
9	Turn-Based Strategy	*Civilization, Fire Emblem, XCOM: Enemy Unknown*
8	Sport	*FIFA, Madden, Mario & Sonic at the Olympic Games*
7	Platform	*Donkey Kong, Rayman, Super Mario Bros.*
6	Arcade	*Frogger, Pac-Man, Pong*
5	Simulation	*Farming Simulator, The Sims, Tropico*
4	Racing	*Dirt, Forza, Mario Kart*
3	Puzzle	*Candy Crush, Monument Valley, Portal*
2	Music / Rhythm	*Dance Dance Revolution, Guitar Hero, Rock Band*
1	Card	*Hearthstone, Solitaire, The Elder Scrolls Legends*

Note. 15 = Complex; 1 = Simple.

Table 6

Descriptions for Each Video Game Genre and Justification for Complexity Ranking

Complexity Ranking	Video Game Genre	Description	Number of Controls	Number of Possible Tasks	Number of Targets to Monitor	Reaction Time Needed / Time Limit	Punishment Severity for Mistakes
15	Real-Time Strategy (RTS)	Players create and control units and structures around a map to gather additional resources, overcome their opponent's assets, and ultimately destroy the opponent's base to win. Progress is restarted at the beginning of each game. Real-time actions.	Many; Numerous controls to move around the map, and create, select, and control assets	Many; Numerous options to create assets or engage in combat with opponent's assets	Many; Must monitor everything around map, including own assets as well as opponent's	Extreme; Must complete all actions as quickly as possible to avoid falling behind	Extreme; Extremely difficult to recover from mistakes and make a comeback after falling behind
14	Role-Playing Games (RPG; Single Player and Multiplayer)	Players control a character and defeat opponents to level up, improve abilities and equipment, and complete multiple objectives (typically in a non-linear open setting). Real-time actions.	Many; Numerous controls to navigate the environment, use weapons, abilities, and items	Many; Numerous combat options and simultaneous objectives to complete	Many; Numerous allies and opponents to monitor in surrounding area	High; Fast-paced and often requires executing combat quickly	Extreme; Character death can lead to mission failure and loss or damaging of items
13	Multiplayer Online Battle Arena (MOBA)	Players control a character on a team and eliminate opponents to level up, upgrade abilities, and purchase items with a goal of destroying the enemy team's objectives and base. Progress is restarted at the beginning of each game. Real-time actions.	Several; Controls to navigate the map and use different abilities and items	Many; Numerous combat options and simultaneous objectives to complete	Several; Must monitor location of allies and opponents around the map	Extreme; Must complete all actions as quickly as possible and rotate around map at specific times	Extreme; Extremely difficult to recover from mistakes and make a comeback after falling behind

Note. Each genre was evaluated by the researcher based on five criteria using 5-point Likert scales. Likert scale ratings for number of controls, number of possible tasks, and number of targets to monitor: 1 = Singular; 2 = Few; 3 = Some; 4 = Several; 5 = Many. Likert scale ratings for reaction time needed/time limit and punishment severity for mistakes: 1 = None; 2 = Low; 3 = Moderate; 4 = High; 5 = Extreme.

Complexity Ranking	Video Game Genre	Description	Number of Controls	Number of Possible Tasks	Number of Targets to Monitor	Reaction Time Needed / Time Limit	Punishment Severity for Mistakes
12	Shooter (First-Person and Third-Person)	Players control a character and engage in combat (primarily using ranged weapons) to defeat opponents and complete objectives. Real-time actions.	Several; Controls to navigate the environment, and use weapons and items	Several; Variety of weapons and items to use, as well as opponents to engage in combat	Several; Must monitor location of allies and opponents in surrounding area	High; Fast-paced and often requires executing combat quickly	Extreme; Character death can lead to mission failure and can put allies at a disadvantage
11	Fighting	Players control a character and engage in close quarters combat against an opponent with a goal of depleting their health points and winning the majority of rounds in a match to win. Real-time actions.	Many; Numerous controls that are used in different combinations to execute fighting moves	Several; Variety of fighting moves that can be executed or block opponent's fighting moves	Few; Must monitor opponent and the environment	High; Fast-paced combat and each round of a match has a time limit to defeat opponent	High; Difficult to recover from mistakes and make a comeback after falling behind
10	Action/Adventure	Players control a character and navigate through levels avoiding obstacles, defeating opponents, and progressing through objectives (typically linear setting with limited customization). Real-time actions.	Several; Controls to navigate the environment, and use weapons and items	Several; Variety of weapons and items to use, as well as opponents to attack	Several; Must monitor opponents and obstacles in the surrounding area	Moderate; Somewhat fast-paced combat, but typically no time limit to complete objectives	Moderate; Character death leads to having to restart at last checkpoint
9	Turn-Based Strategy	Players strategize and complete tasks using controlled assets over multiple turns to overcome opponent's assets. Turn-based actions.	Few; Controls to select and carry out actions with assets	Several; Variety of tasks to utilize in order to overcome opponent	Several; Must monitor own assets and opponent's assets	Low; Long time limit (if any) given to make decisions and complete each turn	High; Difficult to recover from mistakes and to make a comeback after falling behind

Complexity Ranking	Video Game Genre	Description	Number of Controls	Number of Possible Tasks	Number of Targets to Monitor	Reaction Time Needed / Time Limit	Punishment Severity for Mistakes
8	Sport	Players control a team or individual to complete tasks that closely imitate real-world sports activities to compete against opponents. Real-time actions.	Some; Fair amount of controls to perform a variety of tasks specific to the sport	Some; Fair amount of tasks specific to the sport for a more authentic experience	Some; Must monitor positioning of own team and opponent's team	Low; Time limit based on the sport	High; Difficult to recover from mistakes and to make a comeback after falling behind
7	Platform	Players control a character and navigate around both stationary and moving obstacles (often platforms) and defeat enemies to advance in the level. Real-time actions.	Some; Fair amount of controls to move, jump, defeat enemies, and use items	Few; Tasks include defeating enemies, collecting items, and navigating the level	Some; Must monitor objects, items, and enemies in the environment	Low; Time limit to complete levels	High; Limited number of lives that are easy to lose and must start level over if they deplete
6	Arcade	Players complete simple tasks that typically increase in difficulty over levels with a goal of increasing their score (e.g., destroy objects, make it to a specific location while avoiding obstacles, collect objects). Progress is restarted at the beginning of each game. Real-time actions.	Few; Controls to navigate environment and perform basic tasks	Singular; Only task is to improve score	Several; Must monitor and navigate around several moving obstacles and enemies	Low; Increase score as much as possible before time runs out	High; Limited number of lives that are easy to lose and must start over if they deplete
5	Simulation	Players complete tasks that closely imitate real-world activities (e.g., controlling a type of vehicle, running a business, life activities). Real-time actions.	Some; Fair amount of controls to complete relevant tasks	Some; Fair amount of relevant tasks specific to the simulation for a more authentic experience	Some; Must monitor the status of multiple things	None; No time limit to complete tasks	Low; Easy to recover from mistakes, but may be an inconvenience

Complexity Ranking	Video Game Genre	Description	Number of Controls	Number of Possible Tasks	Number of Targets to Monitor	Reaction Time Needed / Time Limit	Punishment Severity for Mistakes
4	Racing	Players control a type of vehicle to race across a course, often racing against opponents or the clock. Real-time actions.	Few; Controls to steer and sometimes use items	Few; Tasks include navigating the course and using items	Few; Must monitor the course and opponents	Moderate; Race against opponents or the clock	Low; Easy to recover from mistakes, but may fall behind or lose time
3	Puzzle	Players solve puzzles using a specific set of game rules to increase their score. Real-time actions.	Singular; One control to interact with puzzle	Singular; Only task is to interact with the puzzle to solve it	Few; Must monitor all components of the puzzle	Moderate; Must complete the puzzle as quickly as possible (or within time limit) to improve score	Low; Easy to recover from mistakes, but score may be lost
2	Music/Rhythm	Players perform specific music/dance sequences displayed to increase their score. Real-time actions.	Singular; Controls only used to perform musical/dance sequences	Singular; Only task is to perform specific sequences displayed	Singular; Only monitor specific sequences displayed	Moderate; Must press controls at correct time	Low; Easy to recover from mistakes, but score may be lost
1	Card	Players use cards (often drawn from customized decks) and follow a specific set of game rules to defeat their opponent(s). Turn-based actions.	Singular; One control used to switch between and play cards	Singular; Only task is to play cards	Singular; Only monitor cards in hand and in play	Low; Long time limit (if any) given to complete each turn	Low; Easy to recover from mistakes, but opponent may get ahead

While calculating CEI scores, it was discovered that some participants had inaccurately reported their hours per week played of each genre over the last 12 months. For instance, one participant stated that he or she played an average of 28 hours of video games each week over the last 12 months, but that he or she played multiple genres for 28 hours each. To account for this discrepancy, a proportional calculation was done on every participant's hours for each genre (Equation 2).

This calculation was used to convert the number of hours participants stated that they played each genre to calculated hours, based on the proportion. In the equation, Hours of Genre Per Week represents hours of each genre the participant stated that he or she played per week over the last 12 months. Average Hours Per Week Last 12 Months represents the average hours of video games the participant stated that he or she played per week over the last 12 months. Calculated Total Hours Per Week represents the sum of all hours for every genre the participant stated that he or she played per week over the last 12 months. *X* represents the Calculated Genre Hours for each genre played per week, based on the proportion. The value obtained for *X* was used as the video game experience variable in the CEI equation.

$$\frac{\text{Hours of Genre Per Week}}{\text{Calculated Total Hours Per Week}} = \frac{X}{\text{Average Hours Per Week Last 12 Months}} \tag{2}$$

Exploratory Analyses

Kline’s (2011) skew and kurtosis threshold criteria were used to assess the normality of the data. Since the skew and kurtosis of all the variables fell within this threshold (skewness below 3 and kurtosis below 10), it was determined that the data did not deviate severely from normality. The associations between all the major variables in the study were also examined (Table 7). Video game experience and CEI were found to be highly correlated (R = .981, p < .001). This was likely due to the fact that hours played per week over the last 12 months was part of the equation used to calculate CEI. Because of this collinearity, simple linear regressions were used and compared in further analyses. A Fisher r-to-z transformation was then used to more formally assess the significance of the difference between the two regression models.

Table 7

Correlations

Measure	*1*	2	3	4	5	6	7
1. Video Game Experience	–	-.057	.981***	-.325*	-.311*	-.490***	-.464***
2. Age of Active Video Game Onset	-.057	–	-.097	-.141	-.174	-.055	-.019
3. Complexity Experience Index	.981***	-.097	–	-.338*	-.317*	-.502***	-.468***
4. Predictable Switch Cost	-.325*	-.141	-.338*	–	.930***	.663***	.558***
5. Predictable Proportional Switch Cost	-.311*	-.174	-.317*	.930***	–	.686***	.648***
6. Random Switch Cost	-.490***	-.055	-.502***	.663***	.686***	–	.944***
7. Random Proportional Switch Cost	-.464***	-.019	-.468***	.558***	.648***	.944***	–

Note. Associations between all variables in the study. $n = 52$; * = significant at the .05 level; ** = significant at the .01 level; *** = significant at the .001 level.

Video Game Experience and Task-Switching Ability

Predictable switch cost. Linear regression was used to examine whether individuals with more video game experience (defined as average hours played per week within the last 12 months) had smaller switch costs compared to individuals with less video game experience. This hypothesis was first examined for the predictable task-switching paradigm. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Since video game experience and switch cost are both continuous variables, the first assumption was met. Visual examination of a scatterplot of the two variables revealed that there did not appear to be a linear relationship between them (Figure 3). To correct for this assumption, video game experience was transformed using a logarithmic base 10 data transformation, which showed a better linear fit (Figure 4). Visual inspection of this scatterplot revealed that there were no significant outliers. The Durbin-Watson statistic was between 1.5 and 2.5, indicating that the assumption of independence of observations was met (Appendix I). A plot of variance along the line of best fit was also examined and the data were found to show homoscedasticity (Appendix J). Finally, examination of a Normal P-P plot revealed that the residuals of the regression line were approximately normally distributed (Appendix K).

Linear regression was calculated to predict predictable switch cost based on log (video game experience). Regression of predictable switch cost against the average number of hours per week of video games over the last 12 months was statistically significant. Participants' predicted predictable switch cost is equal to 874.897 - 289.984 [log (video game experience)], with an R^2 of .189, $F(1, 50) = 11.627$, $p = .001$. This result supported the hypothesis that individuals who played video games for more hours each week had smaller predictable switch costs compared to individuals who played for fewer hours.

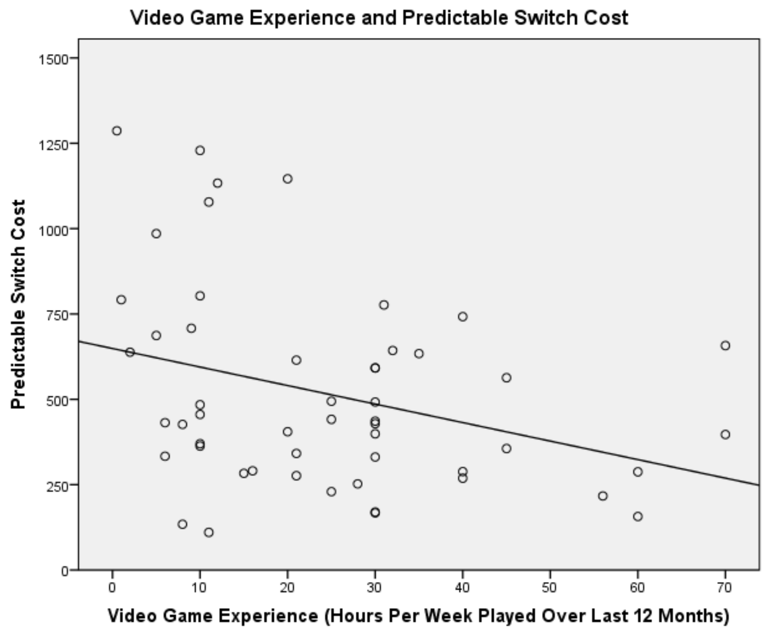

Figure 3. Scatterplot of video game experience plotted against predictable switch cost. The relationship between the two variables is not linear. R^2 = .106, p = .019

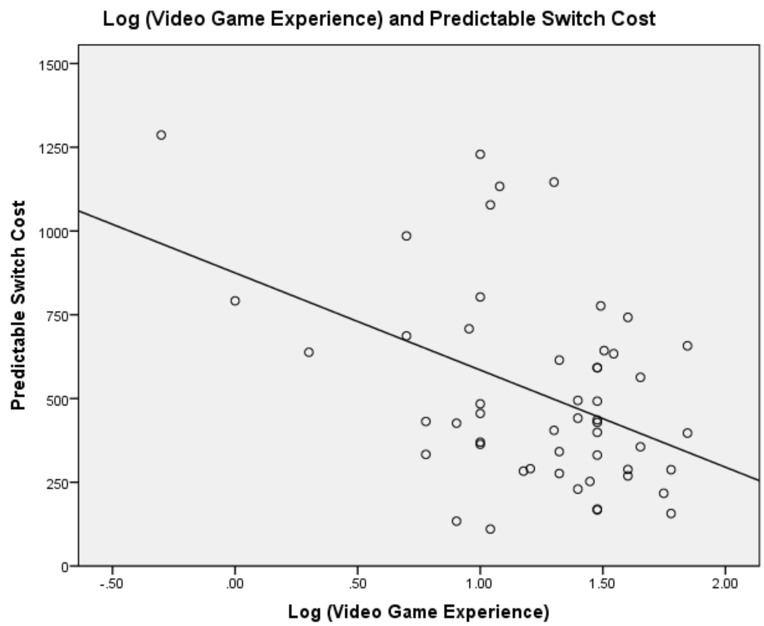

Figure 4. Scatterplot of log (video game experience) plotted against predictable switch cost. The relationship between the two variables is linear. R^2 = .189, p = .001

Predictable proportional switch cost. Since a significant result was found for log (video game experience) and predictable switch cost, additional analyses were completed to determine whether this finding was robust to the proportional switch cost correction (see p. 28 of introduction), as hypothesized. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Proofs for the assumptions are shown in Figure 5 and Appendices I, J, and K.

Linear regression was calculated to predict predictable proportional switch cost based on log (video game experience). Regression of predictable proportional switch cost against the average number of hours per week of video games over the last 12 months was statistically significant. Participants' predicted predictable proportional switch cost is equal to 122.031 -

40.622 [log (video game experience)], with an R^2 of .200, $F(1, 50) = 12.509$, $p = .001$. Thus, the significant result found for predictable switch cost was determined to be robust to the proportional switch cost correction, supporting the hypothesis.

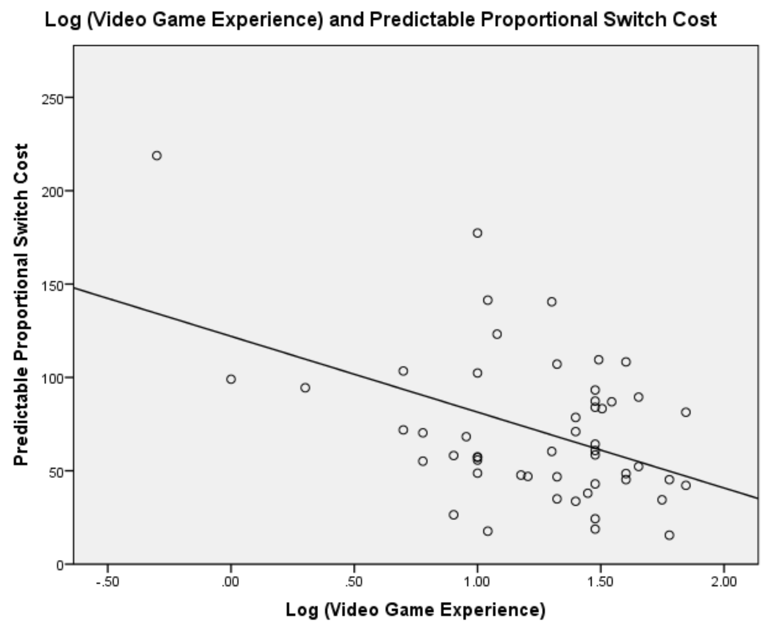

Figure 5. Scatterplot of log (video game experience) plotted against predictable proportional switch cost. The relationship between the two variables is linear. $R^2 = .200$, $p = .001$

Random switch cost. The same hypothesis concerning video game experience and switch cost was examined for the random task-switching paradigm. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Similar to the predictable paradigm, the relationship between video game experience and random switch cost was non-linear (Figure 6). To correct for this assumption, log (video game experience) was used, as it showed a better linear fit. Proofs for the assumptions are shown in Figure 7 and Appendices I, J, and K.

Linear regression was calculated to predict random switch cost based on log (video game experience). Regression of random switch cost against the average number of hours per week of video games over the last 12 months was statistically significant. Participants' predicted random switch cost is equal to 924.158 - 326.600 [log (video game experience)], with an R^2 of .277, $F(1, 50) = 19.135$, $p < .001$. This result showed that individuals who played video games for more hours each week had smaller random switch costs compared to individuals who played for fewer hours, demonstrating that the hypothesis was supported for both predictable and random task-switching paradigms.

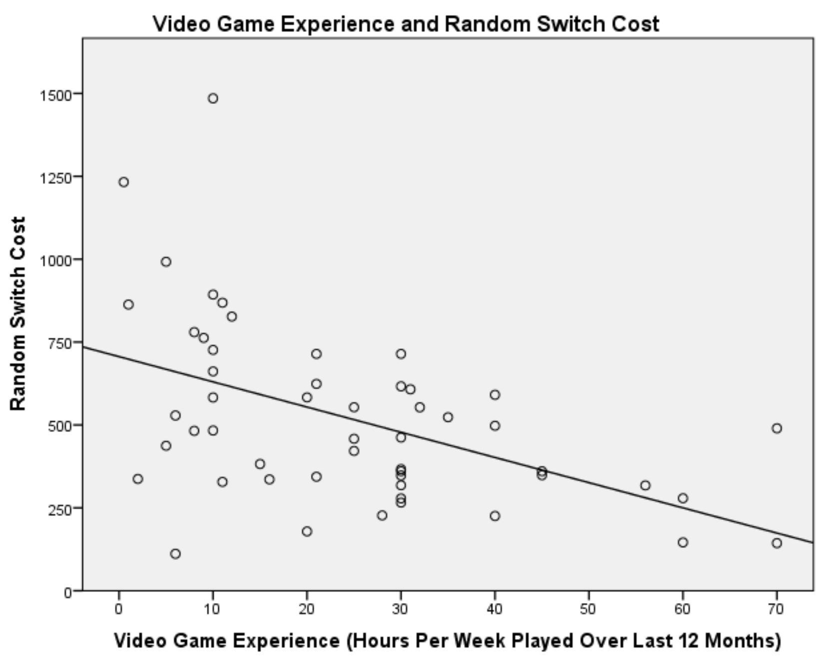

Figure 6. Scatterplot of video game experience plotted against random switch cost. The relationship between the two variables is not linear. $R^2 = .240$, $p < .001$

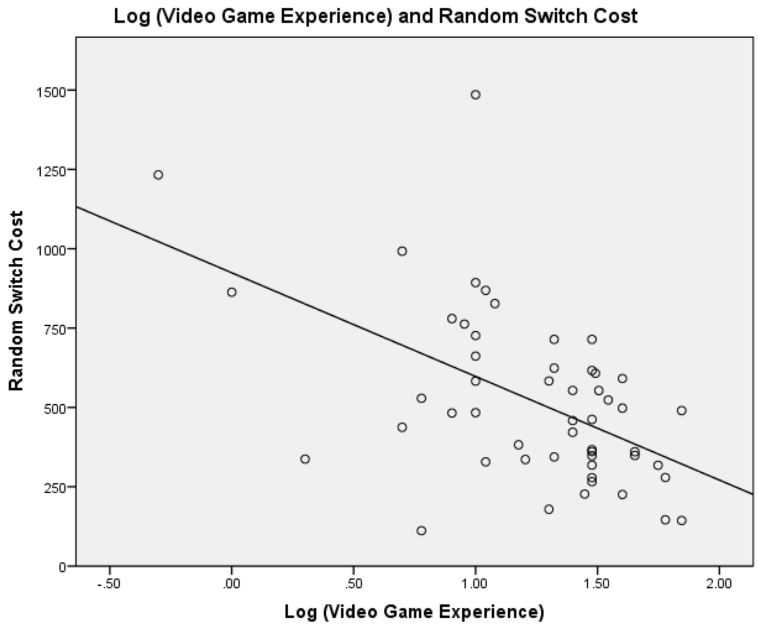

Figure 7. Scatterplot of log (video game experience) plotted against random switch cost. The relationship between the two variables is linear. R^2 = .277, p < .001

Random proportional switch cost. Since a significant result was found for log (video game experience) and random switch cost, additional analyses were completed to determine whether this finding was robust to the proportional switch cost correction, as hypothesized. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Proofs for the assumptions are shown in Figure 8 and Appendices I, J, and K.

Linear regression was calculated to predict random proportional switch cost based on log (video game experience). Regression of random proportional switch cost against the average number of hours per week of video games over the last 12 months was statistically significant. Participants' predicted random proportional switch cost is equal to 101.095 - 34.596 [log (video game experience)], with an R^2 of .270, $F(1, 50) = 18.512$, $p < .001$. Thus, the significant result found for random switch cost was determined to be robust to the proportional switch cost correction, supporting the hypothesis.

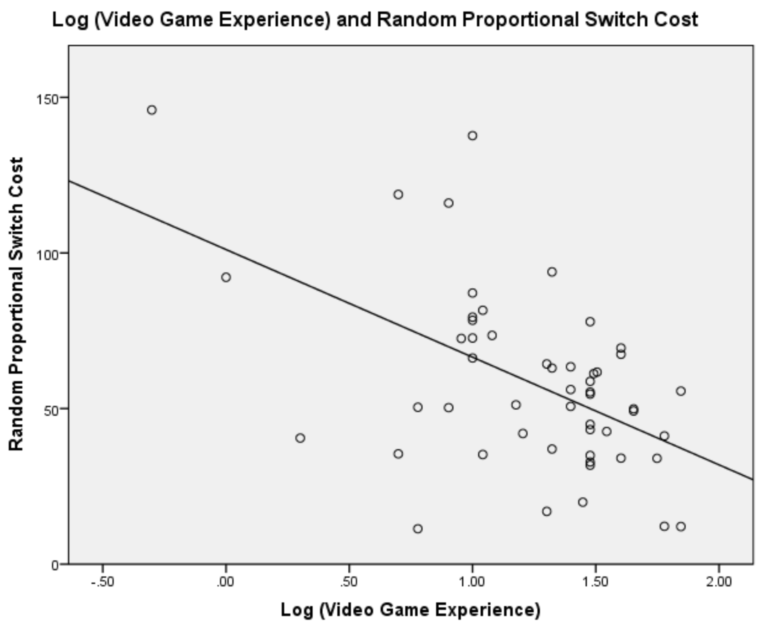

Figure 8. Scatterplot of log (video game experience) plotted against random proportional switch cost. The relationship between the two variables is linear. $R^2 = .270$, $p < .001$

Age of Active Video Game Onset and Task-Switching Ability

Visual inspection of the scatterplots for age of active video game onset against predictable switch cost (Figure 9), as well as age of active video game onset against random switch cost (Figure 10), revealed that there was no relationship between the variables. Therefore, no support was shown for the hypothesis that individuals who started actively playing video games earlier in life had smaller switch costs compared to those who started playing later in life. No further analyses were completed using the age of active video game onset variable.

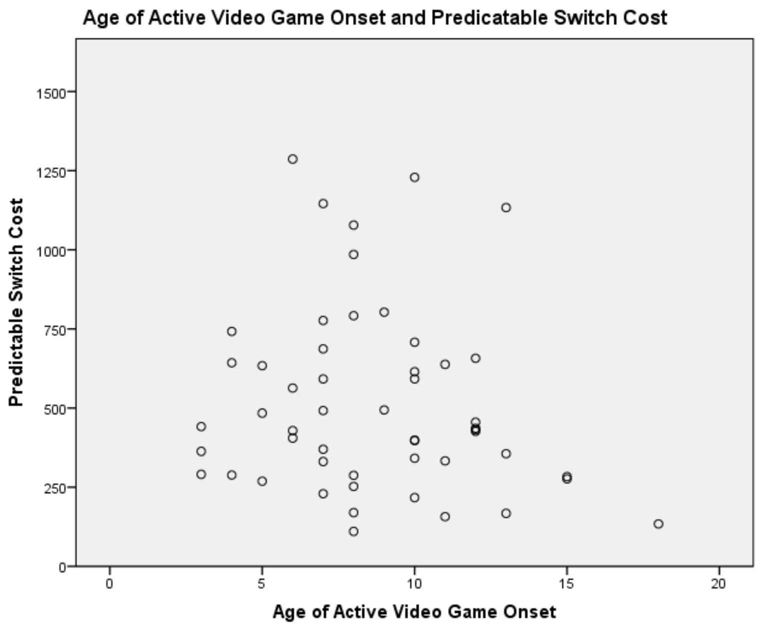

Figure 9. Scatterplot of age of active video game onset plotted against predictable switch cost; no relationship shown between the two variables.

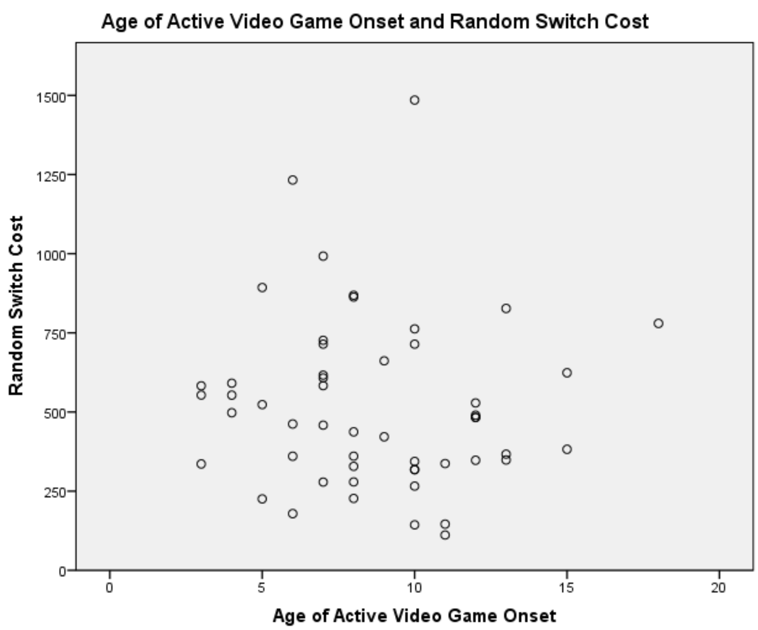

Figure 10. Scatterplot of age of active video game onset plotted against random switch cost; no relationship shown between the two variables.

Complexity Experience Index (CEI) and Task-Switching Ability

Predictable switch cost. The hypothesis concerning CEI and switch cost was first examined for the predictable task-switching paradigm. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Since CEI and switch cost are both continuous variables, the first assumption was met. Visual examination of a scatterplot of the two variables revealed that there did not appear to be a linear relationship between them (Figure 11). To correct for this assumption, CEI was transformed using a logarithmic base 10 data transformation. Proofs for the assumptions are shown in Figure 12 and Appendices I, L, and M.

Linear regression was calculated to predict predictable switch cost based on log (CEI). Regression of predictable switch cost against the Complexity Experience Index score was statistically significant. Participants' predicted predictable switch cost is equal to 1098.696 - 258.315 [log (CEI)], with an R^2 of .226, $F(1, 50) = 14.564$, $p < .001$. Comparison of the R^2 revealed that the CEI regression model was a better fit than the video game experience regression model (.226 compared to .189). To more formally compare the predictive power of the video game experience and CEI regression models, a Fisher r-to-z transformation was calculated ($z = .50$, $p = .31$). This result revealed that the models did not differ significantly in the amount of variance accounted for in predictable switch cost. Thus, the hypothesis that individuals who more frequently play video game genres higher in complexity had smaller predictable switch costs compared to those who play less complex genres was not supported.

Predictable proportional switch cost. Since a significant result was found for log (CEI) and predictable switch cost, additional analyses were completed to determine whether this finding was robust to the proportional switch cost correction, as hypothesized. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Proofs for the assumptions are shown in Figure 13 and Appendices I, L, and M.

Linear regression was calculated to predict predictable proportional switch cost based on log (CEI). Regression of predictable proportional switch cost against the Complexity Experience Index score was statistically significant. Participants' predicted predictable proportional switch cost is equal to 152.409 - 35.755 [log (CEI)], with an R^2 of .234, $F(1, 50) = 15.240$, $p < .001$. The significant result found for predictable switch cost was determined to be robust to the proportional switch cost correction, as hypothesized. Comparison of the R^2 revealed that the CEI regression model was a better fit than the video game experience regression model (.234 compared to .200). To more formally compare the predictive power of the video game experience and CEI regression models, a Fisher r-to-z transformation was calculated ($z = .23$, $p = .41$). This result revealed that the models did not differ significantly in the amount of variance accounted for in predictable proportional switch cost.

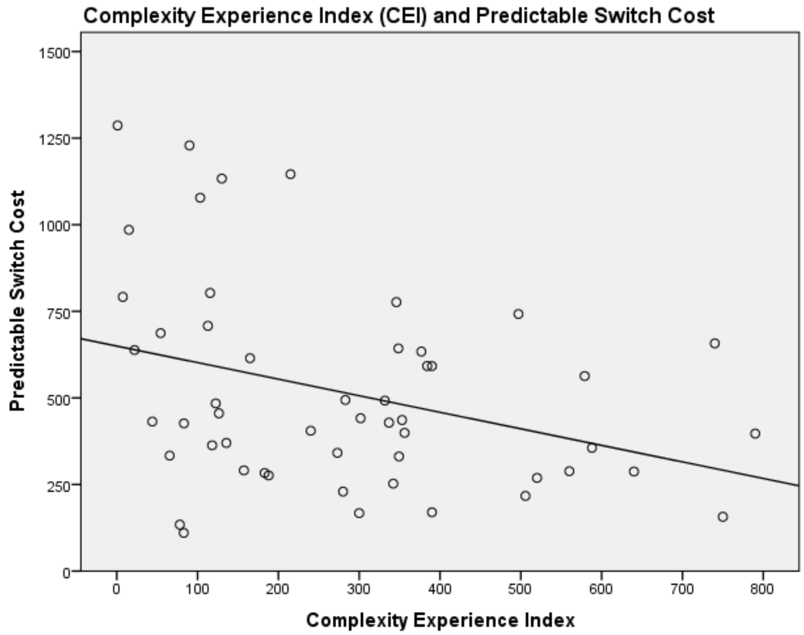

Figure 11. Scatterplot of CEI plotted against predictable switch cost. The relationship between the two variables is not linear. R^2 = .114, *p* = .014

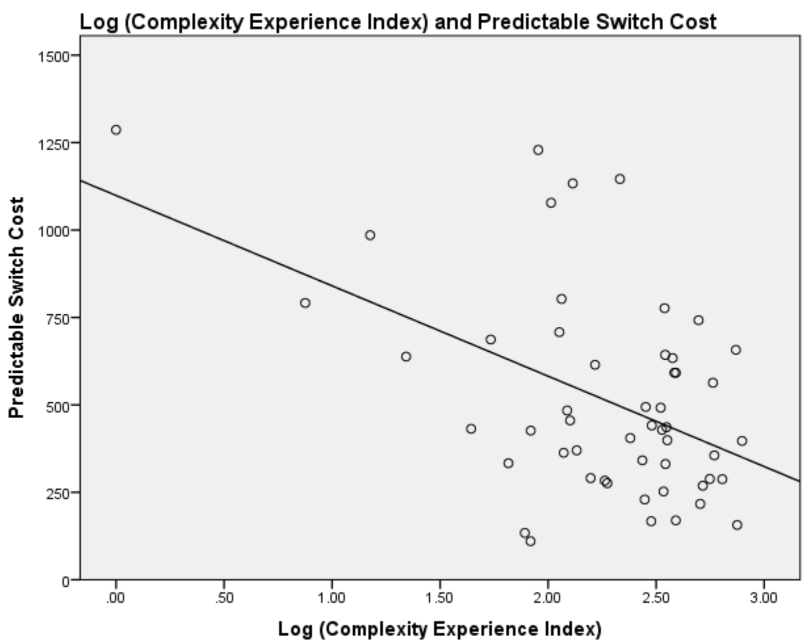

Figure 12. Scatterplot of log (CEI) plotted against predictable switch cost. The relationship between the two variables is linear. R^2 = .226, *p* < .001

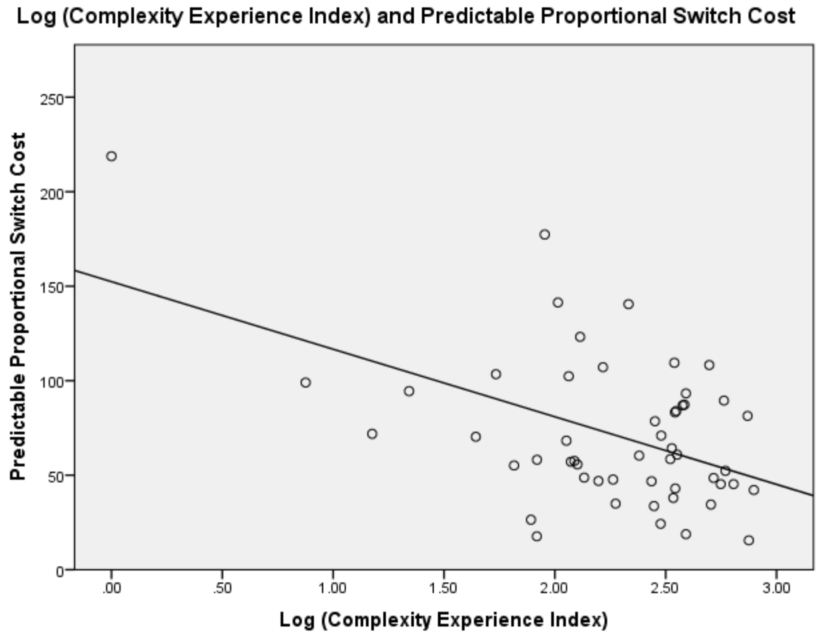

Figure 13. Scatterplot of log (CEI) plotted against predictable proportional switch cost. The relationship between the two variables is linear. R^2 = .234, p < .001

Random switch cost. The same hypothesis concerning CEI and switch cost was examined for the random task-switching paradigm. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Similar to the predictable paradigm, the relationship between CEI and random switch cost was non-linear (Figure 14). To correct for this assumption, log (CEI) was used. Proofs for the assumptions are shown in Figure 15 and Appendices I, L, and M.

Linear regression was calculated to predict random switch cost based on log (CEI). Regression of random switch cost against the Complexity Experience Index score was statistically significant. Participants' predicted random switch cost is equal to 1119.887 - 265.973 [log (CEI)], with an R^2 of .277, $F(1, 50) = 19.115$, p < .001. The R^2 of the CEI regression model and video game experience regression model were identical (.277). To more formally compare the predictive power of the video game experience and CEI regression models, a Fisher r-to-z transformation was calculated (z = .50, p = .31). This result revealed that the models did not differ significantly in the amount of variance accounted for in random switch cost. Thus, the hypothesis that individuals who more frequently play video game genres higher in complexity had smaller switch costs compared to those who play less complex genres was not supported for either the predictable or random task-switching paradigms.

Random proportional switch cost. Since a significant result was found for log (CEI) and random switch cost, additional analyses were completed to determine whether this finding was robust to the proportional switch cost correction, as hypothesized. The data were checked to ensure that they met all six of the assumptions necessary to be analyzed using linear regression. Proofs for the assumptions are shown in Figure 16 and Appendices I, L, and M.

Linear regression was calculated to predict random proportional switch cost based on log (CEI). Regression of random proportional switch cost against the Complexity Experience Index score was statistically significant. Participants' predicted random proportional switch cost is equal to 121.363 - 27.968 [log (CEI)], with an R^2 of .266, $F(1, 50) = 18.126$, $p < .001$. The significant result found for random switch cost was determined to be robust to the proportional switch cost correction, as hypothesized. Comparison of the R^2 revealed that the CEI regression model was a worse fit than the video game experience regression model (.266 compared to .270). To more formally compare the predictive power of the video game experience and CEI regression models, a Fisher r-to-z transformation was calculated (z = .16, p = .44). This result revealed that the models did not differ significantly in the amount of variance accounted for in random proportional switch cost.

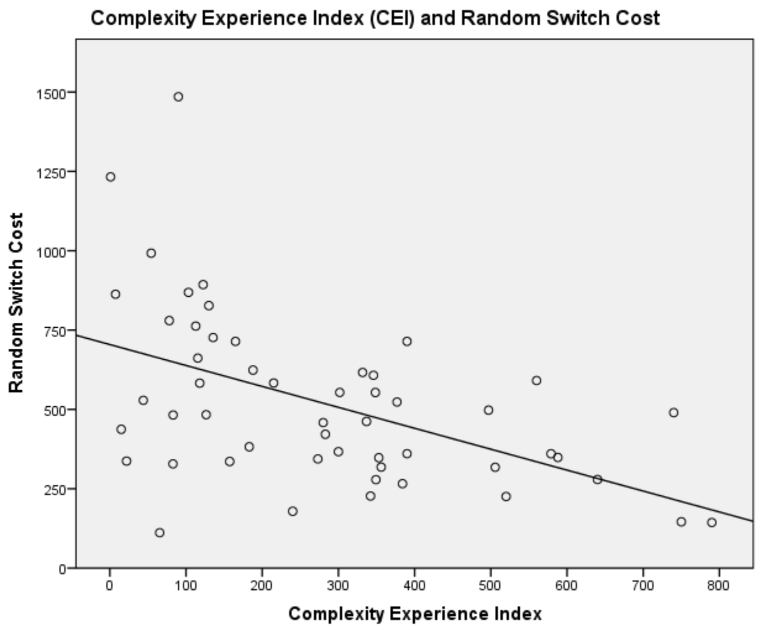

Figure 14. Scatterplot of CEI plotted against random switch cost. The relationship between the two variables is not linear. $R^2 = .252$, $p < .001$

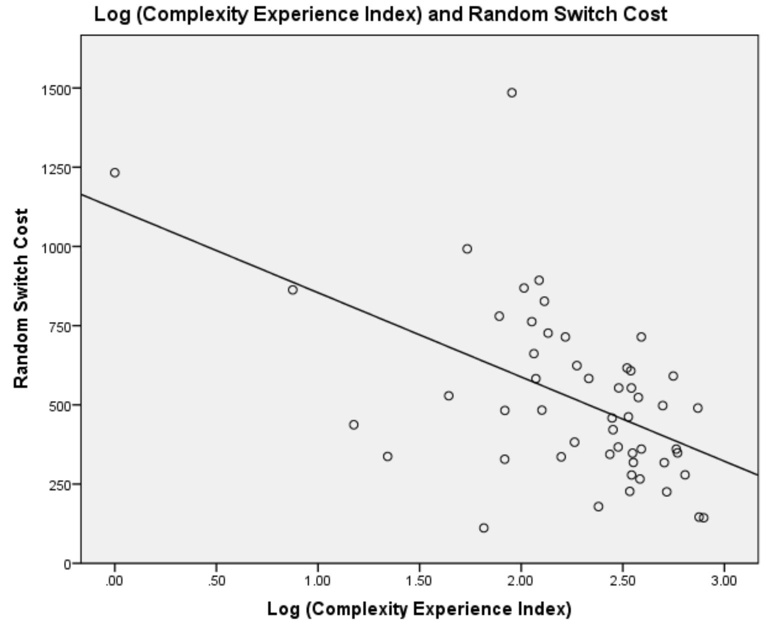

Figure 15. Scatterplot of log (CEI) plotted against random switch cost. The relationship between the two variables is linear. $R^2 = .277$, $p < .001$

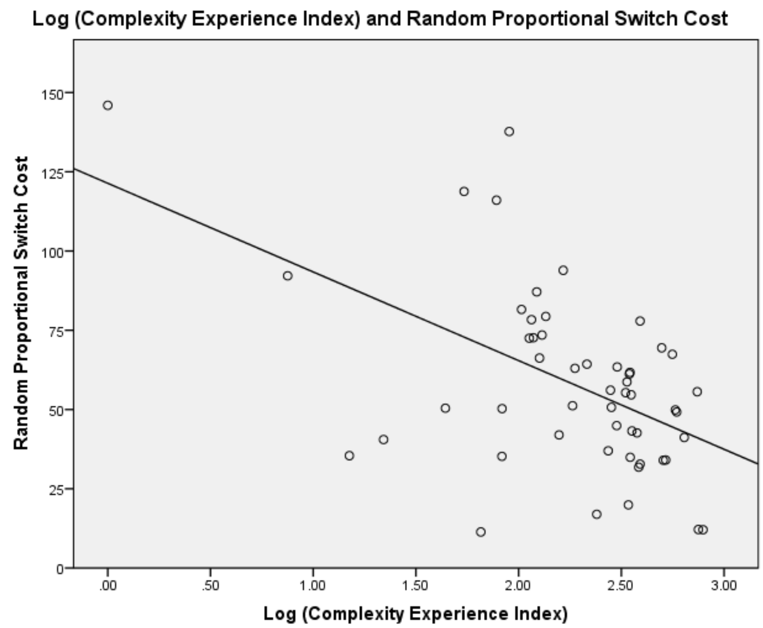

Figure 16. Scatterplot of log (CEI) plotted against random proportional switch cost. The relationship between the two variables is linear. $R^2 = .266$, $p < .001$

Discussion

This study examined video game experience and task-switching ability, an executive function that involves shifting attention between different tasks. Sixty participants from RIT completed a questionnaire assessing video game experience and a task-switching experiment with a predictable and random paradigm. Video game experience was measured as the average number of hours an individual played per week over the last 12 months. Other factors that could affect the association between video game experience and task-switching ability were also examined, including the specific video game genre(s) played and the age that an individual began actively playing (more than 5 hours per week). Since participants could not be neatly categorized based on genre, an equation was used to examine the complexity of the genre(s) they played. This equation combined video game experience (based on average number of hours played per week of each genre over the last 12 months) and complexity ranking (based on how complex a genre is compared to other genres) to calculate a CEI score (see equation on p. 45 of results for more details). Task-switching performance was measured through switch cost, the price paid in response time for switching from one task to another.

The hypothesis that individuals with more video game experience would have smaller switch costs than those with less was supported for both the predictable and random task-switching paradigm. This was consistent with results obtained in previous studies that examined task-switching ability between players and non-players (e.g., Cain et al., 2012; Colzato et al., 2010; Strobach et al., 2012). The hypothesis that this finding would be robust to the proportional switch cost correction (see p. 28 of introduction) was also supported. This indicated that the difference found in switch costs was not simply due to a difference in baseline response times.

The hypothesis that individuals who began actively playing video games earlier in life would have smaller switch costs compared to those who started playing later in life was not supported for either the predictable or random task-switching paradigm. This was not consistent with the result obtained by Hartanto et al. (2016). The difference in results may be due to how the age of active video game onset was measured. In this study, it was measured on a continuous scale, while in the Hartanto et al. (2016) study it was measured as a categorical variable (either before age 12/age 12 or later). It is also possible that the age an individual begins actively playing video games does not significantly impact the benefits they reap from them.

The hypothesis that individuals who more frequently play genres higher in complexity would have smaller switch costs compared to those who play less complex genres was not supported for either the predictable or random task-switching paradigm. Comparisons of the video game experience and CEI regression models revealed that there was not a significant difference in their predictive power. Although the CEI model was a better fit than the video game experience model for predictable task-switching ability, the difference was not significant. The CEI model was an identical fit or slightly worse fit than the video game experience model for random task-switching ability. Since CEI is comprised of video game experience and the complexity of the genre(s) played, it was determined that the complexity of the genre(s) played did not add anything of value compared to the video game experience model. This finding may have been influenced by the fact that in this sample, individuals who played more frequently primarily played complex genres. Although this may be a limitation of this sample, it might also be the case that individuals who play more frequently find complex games more interesting than simple games and choose to play them for longer periods of time since they have more mechanics, are more challenging, and have more to do overall.

The results of this study are consistent with the common demands theory (see p. 12 of introduction). Video games and task-switching involve many similar cognitive processes and mechanics. In complex video game genres (e.g., RTS, RPG, MOBA), players are often required to maintain and frequently switch between multiple control mappings and task sets, monitor multiple targets, and shift attention to relevant information while ignoring interference from irrelevant information. Players must do all of these things in fast-paced environments, under strict time limits, and are heavily punished for mistakes. Simpler video game genres (e.g., Puzzle, Music/Rhythm, Card) can require similar mechanics, however, the magnitude of these mechanics is typically less compared to the complex genres (see Table 6 on p. 48 of results for details on each genre). While playing video games, individuals practice these mechanics in both anticipated and unexpected situations. Individuals who play video games more frequently may have spent additional time developing these skills. This experience likely transferred to performance on the predictable and random paradigms of the task-switching experiment in this study, which require similar underlying demands.

Implications

The findings from this research could have a significant impact on future studies examining video games and task-switching ability. The results of this study suggest that video game experience should be measured on a continuous scale in future cross-sectional studies rather than categorizing individuals as a player or non-player. This arbitrary categorization used in previous studies (e.g., Andrews & Murphy, 2006; Green et al., 2012; Karle et al., 2010) can cause important insights to be overlooked. For instance, whether there are differences in task-switching performance between a video game player who plays for 5 hours per week and another who plays for 40 hours per week. Since the results of this study revealed that there was no difference in task-switching ability based on when an individual began actively playing video games, future studies should also move away from primarily using samples consisting of college students and begin using individuals of all ages to determine if the impact is the same for all of them.

This study also demonstrates a clear need for a better method of measuring the types of video games that an individual plays. Previous studies have either grouped video game players into an ambiguous action category or split them into individual genres, but these categories are not realistic since individuals often play multiple genres. An improved classification system could help researchers better determine exactly what it is about playing video games that impacts task-switching performance. Since the results showed that the complexity of the genre(s) played was not a significant predictor of task-switching ability, this study also provides support for utilizing other genres of video games in training studies aside from FPS and RTS.

This research also has practical implications. Task-switching is an essential ability and the results of this study suggest that it may be possible to improve both anticipated task-switching and unexpected task-switching skills by playing video games. Identifying and examining the components in commercial video games that foster task-switching ability could be very beneficial, as game designers could utilize them to create game environments specifically intended to help train and enhance these skills. The complexity ranking system of genres utilized in this study may be a good starting point in identifying those components as it provides a breakdown of different game mechanics that are similar to the underlying demands of task-switching (e.g., maintaining multiple control mappings and task-sets, ignoring interference, requiring fast reaction times). Since the results of this study suggest that genres aside from FPS and RTS could impact task-switching ability, designers could utilize other genres as well. This could lead to a bigger variety of games that appeal to a wider audience, as some individuals may have different preferences on which genres they like to play. Video games may be an especially effective method to improve skills, such as task-switching, since they provide instant feedback and are inherently enjoyable and motivating compared to other cognitive interventions (Boot et al., 2013; Green & Bavelier, 2008).

Limitations

This study had limitations in methodology as well as limitations in how generalizable the results are to real-world settings. The sample used in this study was a convenience sample consisting of students from a technical college. It is likely that this population plays video games more frequently than other populations due to the abundance of video game programs and clubs on the college campus. Since all of the participants in this study were young college students, the age of active video game onset of the sample did not vary much. Additionally, since covert recruitment was not utilized and the purpose of the study was not hidden, it is possible that participants who play video games frequently had greater motivation to perform better on the task-switching experiment compared to individuals who play video games less often.

Another limitation of this study is that it relied on self-report data, which can often be slightly inaccurate. This was evident from how some individuals reported genre hours that, when added together, totaled a higher number of hours than they had reported playing per week. It is also possible that an individual's average time spent playing video games and the genre that they play could change each week, especially since many new games are released over the course of a year. This information would be difficult to determine from just examining the self-report data collected from the questionnaire.

The complexity rankings system used in this study also has limitations. The five criteria used to rank the complexity of each genre were treated equally, but it is possible that some factors should be weighed higher than others. For example, number of controls might be weighed higher than punishment severity for mistakes when judging a genre's complexity. Additionally, the complexity rankings themselves use an ordinal scale rather than interval scale. Thus, the difference in complexity between each genre is not the same. Although Action / Adventure was ranked as a 10 and Simulation was ranked as a 5, this does not imply that Action / Adventure games are twice as complicated as Simulation games. Video games within each genre can also be dramatically different from one another, and some games can be classified as multiple genres. The complexity ranking system was developed by the researcher and although it was somewhat validated through comparison with a previous conceptual model (Granic et al., 2014), additional research should be done on the topic with input from game designers and video game players, including those who play for fun and those who play professionally. Video games can also be played at different difficulty levels and skill levels determined by matchmaking systems, which may increase or decrease their complexity. Lastly, just because an individual plays a complex genre does not mean he or she excels at it. Neither the complexity ranking of the genre(s) played nor the reported hours played per week fully capture an individual's video game skills or how well he or she handles the complexities of each genre.

Since the study was conducted in a laboratory setting using a controlled task-switching experiment, it is difficult to determine how well the results apply to a real-world setting. Tasks are typically not so clearly defined in the real world and switching between them usually occurs at a slower rate than the task-switching completed in this study's experiment. Additionally, it is not possible to establish a causal relationship from this study. While it is possible that video games experience influences task-switching ability, it is also possible that individuals with greater task-switching skills play video games more frequently since they excel in them. Other factors aside from video game experience may have also influenced an individual's task-switching performance, such as sports involvement or specific work experiences.

Future Research

While this study added additional insights to existing research on video game experience and task-switching ability, further research efforts on the topic are necessary. An unintentional discovery of this research was how ubiquitous video games are becoming, at least among college students. While screening 130 participants, it was observed that there were no individuals who stated they had not played any video games over the last 12 months. It may be beneficial for future cross-sectional studies to move away from the dichotomous categorization of player or non-player in favor of using a continuous scale of hours, as well as a definition that takes video game genre into account. The questionnaire results of this study demonstrated that many individuals play a variety of genres over the course of a year. For that reason, it will likely be challenging to neatly categorize players based on genre in cross-sectional studies and the results may not be generalizable. Using some calculation like CEI score is necessary to analyze the full scope of variability in experience among video game players. Future cross-sectional studies should also attempt to include more individuals who play simple games frequently to help better compare to those who play complex games frequently. Additionally, other metrics such as the difficulty level an individual plays video games on or an individual's ranking in a game should also be investigated in future research to see if they are predictive of task-switching performance.

Accuracy of self-reported hours of video games player per week in cross-sectional studies is critical. The questionnaire results of this study revealed that these self-reports can often be inaccurate either due to confusion with questions or difficulties in recalling an accurate number. Utilizing a different method such as a diary log of video game hours in future studies could greatly improve the accuracy of this data. Accurate reporting of hours is also critical, as it could help give researchers a better idea of a realistic number of hours to have participants play in training studies. The results of this study showed that individuals who play for more hours each week had better task-switching ability compared to those who played less frequently. However, the number of hours played each week by some participants in this study is not feasible for most people. It may be valuable for future training studies to train participants for varying number of hours in order to find an optimal and reasonable number of hours to play each week before results begin to level off. A training study would also make it possible to establish a causal relationship between video game experience and task-switching ability.

Rather than comparing different genres of video games like previous researchers have (e.g., Boot et al., 2008; Green et al., 2012; Oei & Patterson, 2014b), future training studies should create and test a game that allows them to manipulate the mechanics and quantify a player's performance. Some of the mechanics that could be manipulated in the game are the different criteria used in the complexity ranking system (see p. 48 of results). Training individuals on a video game with mechanics that are possible to manipulate could help researchers better discern the underlying demands shared between the game and task-switching, as well as determine which mechanics impact task-switching ability the most. Additionally, having some way to quantify a player's performance could help researchers more accurately measure video game skill, which may be a better predictor of task-switching ability than video game experience (measured through average hours played per week over some period of time).

Exploring additional task-switching methodologies in further research may also be beneficial to see if different results are found. For example, a task-switching experiment where vocal responses are used instead of manual responses, similar to Green et al.'s study (2012). Allowing participants to set their own response key bindings rather than having pre-set keys could also be important to examine, since controls in video games can be customized. Finally, a well-controlled task-switching experiment with real-world tasks should be examined to verify that the enhanced task-switching performance found in video game players on laboratory tasks applies to task-switching ability in a real-world setting as well.

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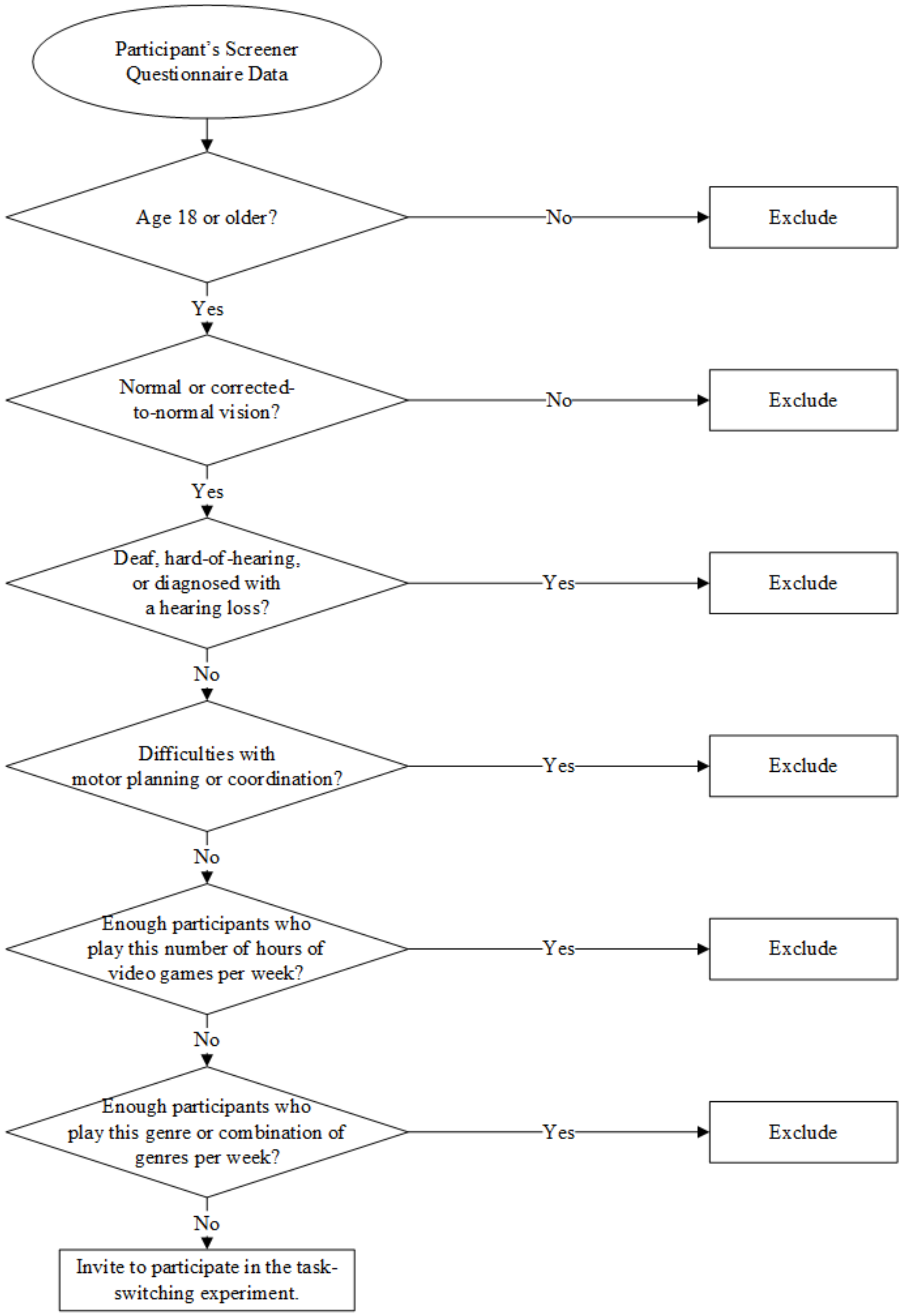
Appendix A

Flowchart for Screening Participants



Method by which individuals were screened to participate in the task-switching experiment. Participants were excluded if they did not meet the age, hearing, motor, and vision requirements, or if there were already 5 individuals included with similar video game experience (e.g., hours and genres played). Of the 130 participants who completed the questionnaire, 60 were eligible.

Appendix B

Screener Questionnaire (Online through *Qualtrics*)

Section A: Demographics

1. Please indicate your gender.

- Male
- Female

2. Please indicate your age.

____

Note: If the participant answers an age less than 18 for Question 2 then he or she skips to the end of the questionnaire.

3. The experiment in this study will require viewing information on a computer monitor. Do you have normal or corrected-to-normal vision?

- Yes
- No

Note: If the participant answers "No" to Question 3 then he or she skips to the end of the questionnaire.

4. The experiment in this study will require listening to an audio cue. Are you deaf, hard-of-hearing, or have you been diagnosed with a hearing loss?

- Yes
- No

Note: If the participant answers "Yes" to Question 4 then he or she skips to the end of the questionnaire.

5. The experiment in this study will require quick responses using keyboard input. Do you experience any difficulties with motor planning or coordination?

- o Yes
- o No

Note: If the participant answers "Yes" to Question 5 then he or she skips to the end of the questionnaire.

6. Please provide your email address.

*This will only be used to contact you if you are eligible for the next part of the study.

____

Section B: Video Game Experience Over the Last 12 Months

1. Have you played any type of video games (including mobile games) <u>over the last 12 months</u>?

- o Yes
- o No

Note: If the participant answers "No" to Question 1 then he or she skips to Section C.

2. On average, how many <u>days per week</u> did you spend playing any type of video games <u>over the last 12 months</u>?

__________ (1-7)

3. On average, how many <u>hours per week</u> did you spend playing any type of video games <u>over the last 12 months</u>?

____

4. Which device have you played video games on most frequently over the last 12 months?

- o Computer
- o Console
- o Phone/Tablet
- o Other (please specify): ______________________________

5. Please indicate all of the video game genres you have played regularly (at least 1 hour a week) over the last 12 months.

- ☐ Action/Adventure (e.g., *Assassin's Creed*, *Minecraft*, *The Legend of Zelda*)
- ☐ Arcade (e.g., *Frogger*, *Pac-Man*, *Pong*)
- ☐ Card (e.g., *Hearthstone*, *Solitaire*, *The Elder Scrolls Legends*)
- ☐ Fighting (e.g., *Mortal Kombat*, *Super Smash Bros.*, *Tekken*)
- ☐ Multiplayer Online Battle Arena (MOBA; e.g., *Dota 2*, *League of Legends*, *Smite*)
- ☐ Music / Rhythm Games (e.g., *Dance Dance Revolution*, *Guitar Hero*, *Rock Band*)
- ☐ Platform (e.g., *Donkey Kong*, *Rayman*, *Super Mario Bros.*)
- ☐ Puzzle (e.g., *Candy Crush*, *Monument Valley*, *Portal*)
- ☐ Racing (e.g., *Dirt*, *Forza*, *Mario Kart*)
- ☐ Real-Time Strategy (e.g., *Age of Empires*, *Halo Wars*, *StarCraft II*)
- ☐ Role-Playing Games (Single Player or Massively Multiplayer Online; e.g., *Pokémon*, *The Elder Scrolls V: Skyrim*, *World of Warcraft*)
- ☐ Shooters (First or Third Person; e.g., *Call of Duty*, *Gears of War*, *Halo*)
- ☐ Simulation (e.g., *Farming Simulator*, *The Sims*, *Tropico*)
- ☐ Sports Games (e.g., *FIFA*, *Madden*, *Mario & Sonic at the Olympic Games*)
- ☐ Turn-Based Strategy (e.g., *Civilization*, *Fire Emblem*, *XCOM: Enemy Unknown*)
- ☐ Other (please specify): ______________________________

Note: The participant answers Questions 5.1 and 5.2 for each genre that he or she selected in Question 5.

5.1. Please indicate your average hours per week played for each genre over the last 12 months.

5.2. Please list up to three video game titles you have played the most for each genre over the last 12 months.

Section C: Video Game Experience Before the Last 12 Months

1. Have you played any type of video games (including mobile games) **BEFORE** the last 12 months?

- Yes
- No

Note: If the participant answers "No" to Question 1 of Section B and Section C then he or she skips to the end of the questionnaire. If the participant answers "Yes" to Question 1 of Section B and "No" to Question 1 of Section C then he or she skips to Section D.

2. On average, how many days per week did you spend playing any type of video games before the last 12 months?

__________ (1-7)

3. On average, how many hours per week did you spend playing any type of video games before the last 12 months?

____

4. Which device have you played video games on most frequently before the last 12 months?

- Computer
- Console
- Phone/Tablet
- Other (please specify): ____

5. Please indicate all of the video game genres that you have played regularly (at least 1 hour a week) before the last 12 months.

- ☐ Action/Adventure (e.g., *Assassin's Creed*, *Minecraft*, *The Legend of Zelda*)
- ☐ Arcade (e.g., *Frogger*, *Pac-Man*, *Pong*)
- ☐ Card (e.g., *Hearthstone*, *Solitaire*, *The Elder Scrolls Legends*)
- ☐ Fighting (e.g., *Mortal Kombat*, *Super Smash Bros.*, *Tekken*)
- ☐ Multiplayer Online Battle Arena (MOBA; e.g., *Dota 2*, *League of Legends*, *Smite*)
- ☐ Music / Rhythm Games (e.g., *Dance Dance Revolution*, *Guitar Hero*, *Rock Band*)
- ☐ Platform (e.g., *Donkey Kong*, *Rayman*, *Super Mario Bros.*)
- ☐ Puzzle (e.g., *Candy Crush*, *Monument Valley*, *Portal*)
- ☐ Racing (e.g., *Dirt*, *Forza*, *Mario Kart*)
- ☐ Real-Time Strategy (e.g., *Age of Empires*, *Halo Wars*, *StarCraft II*)
- ☐ Role-Playing Games (Single Player or Massively Multiplayer Online; e.g., *Pokémon*, *The Elder Scrolls V: Skyrim*, *World of Warcraft*)
- ☐ Shooters (First or Third Person; e.g., *Call of Duty*, *Gears of War*, *Halo*)
- ☐ Simulation (e.g., *Farming Simulator*, *The Sims*, *Tropico*)
- ☐ Sports Games (e.g., *FIFA*, *Madden*, *Mario & Sonic at the Olympic Games*)
- ☐ Turn-Based Strategy (e.g., *Civilization*, *Fire Emblem*, *XCOM: Enemy Unknown*)
- ☐ Other (please specify): ____

Note: The participant answers Question 5.1 for each genre that he or she selected in Question 5.

5.1. Please indicate your average hours per week played for each genre before the last 12 months.

6. Please list up to three video game titles you have played the most (in the order of most played to least played, please specify the genre too if you know it).

____

____

Section D: Specific Experiences with Video Games

1. Please rate your overall experience level with video games.

- o Novice
- o Apprentice
- o Intermediate
- o Advanced
- o Expert

2. Would you define yourself as a casual (play for fun) or competitive (play to win) player?

- o Casual
- o Competitive
- o Somewhere in between

3. Do you primarily play video games in story mode/against computers or online multiplayer?

- o Only story mode/against computers
- o Mostly story mode/against computers but some online multiplayer
- o About the same amount of story mode/against computers and online multiplayer
- o Mostly online multiplayer but some story mode/against computers
- o Only online multiplayer

4. When you play video games do you deliberately engage in activities to improve your gaming skill and performance as opposed to playing strictly for entertainment (e.g., practice, read guides, watch streams/videos)?

- o Yes
- o No

Note: If the participant answers "Yes" to Question 4 then he or she answers Question 4.1.

4.1. Please specify what you do to improve your gaming skill or performance.

____

Section E: Age of Active Video Game Onset

Note: Section E is only completed by participants who indicated that they played at least 5 hours of video games per week in Question 3 of Section B and/or Section C. Additionally, Question 3 of Section E is only completed by participants who answered "Yes" to Question 4 of Section D.

1. At what age did you begin actively playing video games (more than 5 hours a week)?

____

2. After you began actively playing video games, did you ever take a significant break from them (stop playing completely for more than 3 months)?

- o Yes
- o No

3. At what age did you begin deliberately attempting to improve your video game skills or performance?

____

Appendix C

General Instructions for the Task-Switching Experiment

Instructions

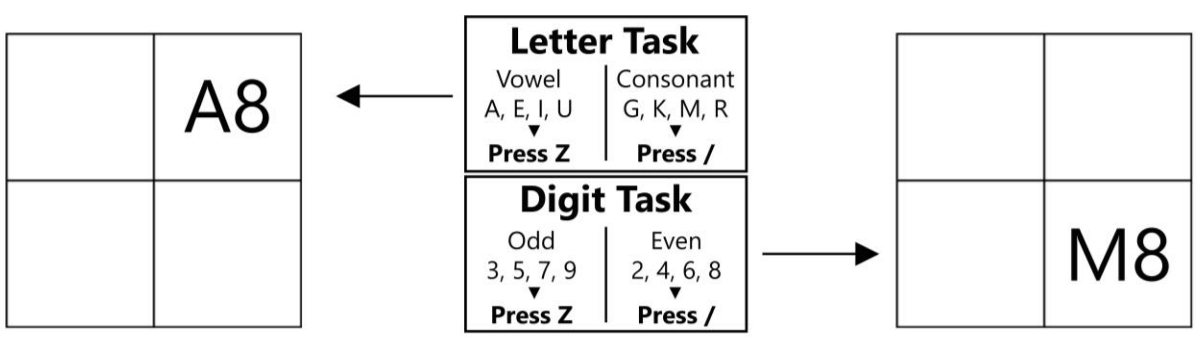
In this experiment you will be presented with a pair of characters consisting of a letter and a digit, for example G5. The location of the character pair inside of a 2 x 2 matrix will determine whether you complete the letter or digit classification task. If the character pair appears above the horizontal line (in one of the top two boxes), complete the letter task. If the character pair appears below the horizontal line (in one of the bottom two boxes), complete the digit task.

For the letter task, press the Z key if the letter is a vowel or the / key if the letter is a consonant. For the digit task, press the Z key if the digit is odd or the / key if the digit is even. The letter and digit will be randomly selected from the set below.

Letters		**Digits**	
Vowels	**Consonants**	**Odd**	**Even**
A, E, I, U	G, K, M, R	3, 5, 7, 9	2, 4, 6, 8

Please respond as quickly as possible while making as few errors as possible. A short beep will sound when an error is made. Examples of the task are provided below.

Examples



Since the character pair is above the horizontal line in this case, you would respond to the A and ignore the 8. Since A is a vowel, you would press the Z key.

Since the character pair is below the horizontal line in this case, you would respond to the 8 and ignore the M. Since 8 is even you would press the / key.

Please ask the researcher if you have any questions about the task. You may press the Enter key when you are ready to continue.

Appendix D

Informed Consent Form (Screener Questionnaire on *Qualtrics*)

Title of Study
The Effect of Video Game Experience in Different Genres on Task-Switching Ability

Introduction
You are invited to take part in a research study investigating the impact of video games on certain cognitive abilities. The purpose of this study is to examine whether people who have various amounts of experience playing video games perform better on a task-switching experiment compared to people without any video game experience. In this part of the study you will complete a screener questionnaire. Your responses will be used to assess your previous experience playing video games to determine whether you are eligible to participate in the follow-up study. This questionnaire will take approximately 15 minutes to complete.

Risks
Participation in this study will not involve any risks beyond the minimal risk that you would encounter throughout your everyday life. The email address you provide will only be used to contact you if you are eligible for the follow-up study. No identifiable information will be used in the published findings of this study.

Your Rights as a Research Participant
Participation in this study is voluntary. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with the researcher or the Rochester Institute of Technology.

Incentives
A $25.00 Amazon gift card will be raffled off to one of the participants who completes this questionnaire. If you are eligible and choose to participate in the follow-up experiment, you will be given a $10.00 Amazon gift card as compensation for your participation.

Consent of Subject
By clicking Agree and Continue, you are stating that you understand what will happen in this study and your rights as a participant. You are also giving permission to have your data anonymously used for analyses in this research study, for which the findings will be published.

Appendix E

Informed Consent Form (Task-Switching Experiment)

Title of Study
The Effect of Video Game Experience in Different Genres on Task-Switching Ability

Introduction
You are invited to take part in a research study investigating the impact of video games on certain cognitive abilities. Please take whatever time you need to read about the study, ask questions, and decide whether or not you would like to participate. The purpose of this study is to examine whether people who have various amounts of experience playing video games perform better on a task-switching experiment compared to people without any video game experience.

Study Details
This study will take approximately 20 minutes to complete, including the required two-minute break in the middle of the experiment. The questionnaire that you completed previously will be used to assess your previous experience playing video games. In this part of the study you will complete a task-switching experiment on a computer using a keyboard to enter input.

During the experiment, you will be asked to perform a series of judgements for a digit task (whether a digit is odd of even) or letter task (whether a letter is a vowel or consonant). The type of task you must perform (digit or letter) will be specified in the instructions. For example, you may be asked to complete the letter task if the stimuli appear above the horizontal line and the digit task if the stimuli appear below the horizontal line. Detailed instructions will be presented on the computer monitor prior to the start of the experiment, and you will be given a short set of practice trials to ensure you understand the instructions. Data on your response time and number of errors will be collected as you perform these tasks.

Risks
Participation in this study will not involve any risks beyond the minimal risk that you would encounter throughout your everyday life. This experiment will require extended concentration throughout its duration. Therefore, it could be mentally taxing and may cause fatigue and boredom.

To ensure anonymity and confidentiality, no identifiable information will be attached to the data. Your name and signature will appear only on the informed consent form. This form will contain a code linking you to your data. The informed consent forms will be stored in a locked filing cabinet separate from the data. All data will be stored on one device and will be password protected. Only the researcher will have access to the forms and the data. The data from this study will be aggregated before being published.

Your Rights as a Research Participant
Participation in this study is voluntary. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with the researcher or the Rochester Institute of Technology. Please let the researcher know if you would like to withdraw from the study. The researcher may stop the study at any time or remove you from the study if it is judged to be in your best interest. The researcher may also remove you from the study for various other reasons and this can be done without your consent. Services are available (e.g., public safety, student health center, student psychological center) should any issue arise during the study.

Benefits
Aside from compensation, there are no anticipated direct benefits to you for participating in this study. Others may benefit in the future from the information that is found in this study.

Incentives
You will be given a $10.00 Amazon gift card as compensation for your participation. You will be required to sign a compensation receipt form to receive the monetary incentive at the end of the study.

Contact for Questions or Issues
If you have any questions about the study or procedures, please feel free to ask the researcher. If any questions arise later, you may contact the researcher, Caitlin Brostek, via e-mail at cab5197@g.rit.edu. Contact Heather Foti, Associate Director of the HSRO at (585) 475-7673 or hmfsrs@rit.edu if you have any questions or concerns about your rights as a research participant.

Consent of Subject
By signing this form, you are stating that you understand what will happen in this experiment and your rights as a participant. You are also giving permission to have your data anonymously used for analyses in this research study, for which the findings will be published.

Print Full Name:

____

Signature: Date:

________________________________ __________________

Upon signing, the participant will receive a copy of this form, and the original will be held for the researcher's record.

Appendix F

Compensation Receipt Form

Title of Study
The Effect of Video Game Experience in Different Genres on Task-Switching Ability

Compensation
By signing below you acknowledge that you have participated in the study specified above and have received a $10.00 Amazon gift card as compensation for your time.

Print Full Name:

____

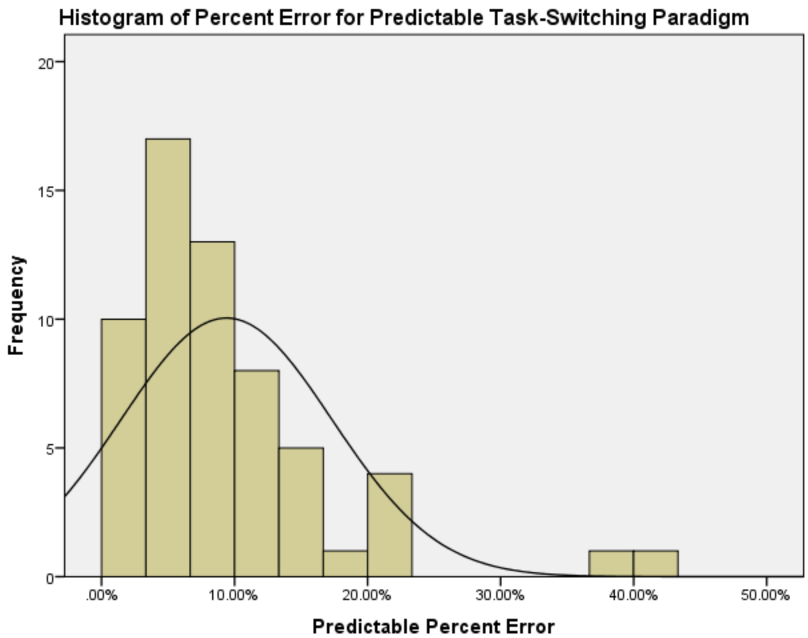
Signature: Date:

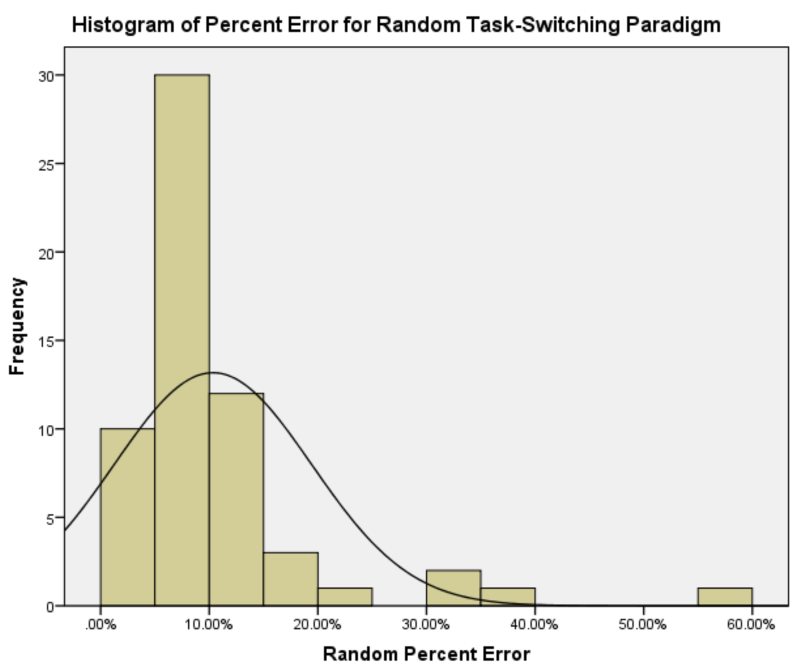
________________________________ __________________

This form will be held for the researcher's record.

Appendix G

Histograms of Percent Error for Predictable and Random Task-Switching Paradigms

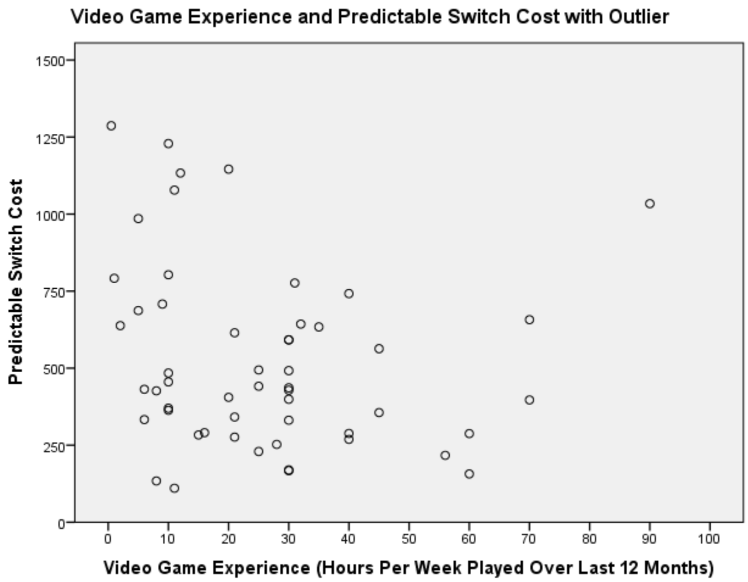


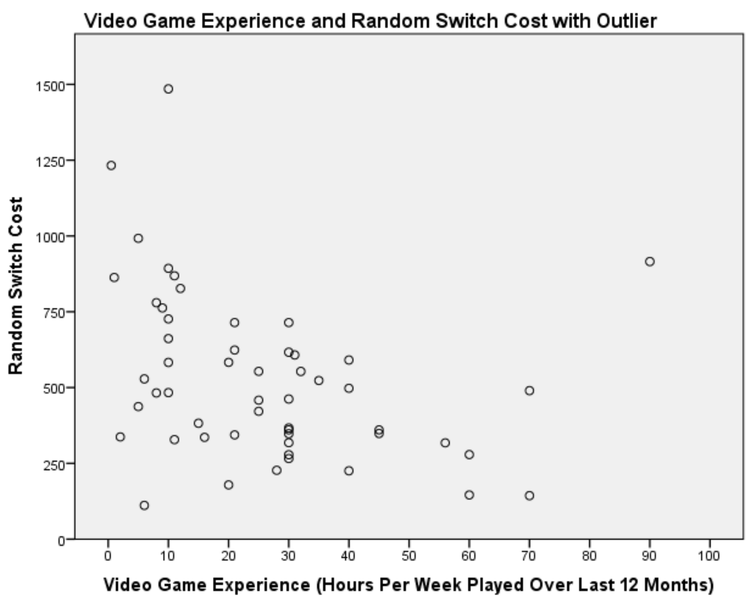


Two individuals had greater than 20% error in the predictable task-switching paradigm and one individual had greater than 20% error in the random paradigm. Four individuals had greater than 20% error in both paradigms. In total, 7 participants had their results excluded due to error.

Appendix H

Video Game Experience and Predictable and Random Switch Cost with Outlier





One participant's data were found to be an outlier and excluded. This participant reported playing video games for 20 hours more than any other participant. Additionally, this participant's results deviated dramatically from the pattern of predictable and random switch-costs obtained by participants who had also played a large amount of video games each week (40-70 hours).

Appendix I

Linear Regression Results for All Predictors and Criterion

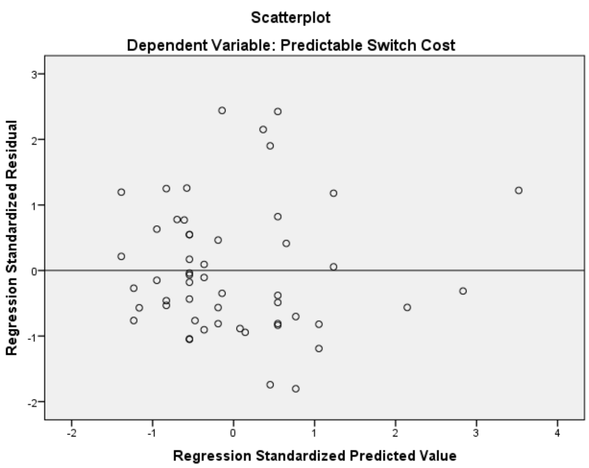
Predictor	Criterion	R	R^2	Standard Error	β	F	Durbin-Watson
Log (Video Game Experience)	Predictable Switch Cost	0.434	0.189	265.577	-.434**	11.627**	2.308
	Predictable Proportional Switch Cost	0.447	0.200	35.867	-.447***	12.509***	2.172
	Random Switch Cost	0.526	0.277	233.163	-.526***	19.135***	2.080
	Random Proportional Switch Cost	0.520	0.270	25.111	-.520***	18.512***	2.122
Log (Complexity Experience Index)	Predictable Switch Cost	0.475	0.226	259.466	-.475***	14.564***	2.270
	Predictable Proportional Switch Cost	0.483	0.234	35.109	-.483***	15.240***	2.150
	Random Switch Cost	0.526	0.277	233.196	-.526***	19.115***	2.058
	Random Proportional Switch Cost	0.516	0.266	25.182	-.516***	18.126***	2.120

Note. Video Game Experience = Average hours of video games played per week over the last 12 months; n = 52; * = significant at the .05 level; ** = significant at the .01 level; *** = significant at the .001 level.

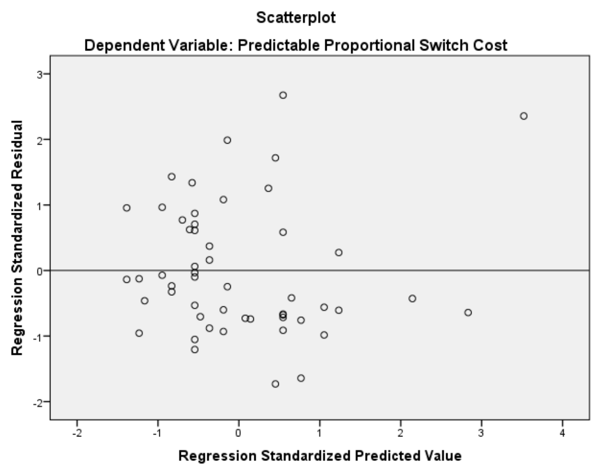
Appendix J

Log (Video Game Experience) Proofs for Homoscedasticity

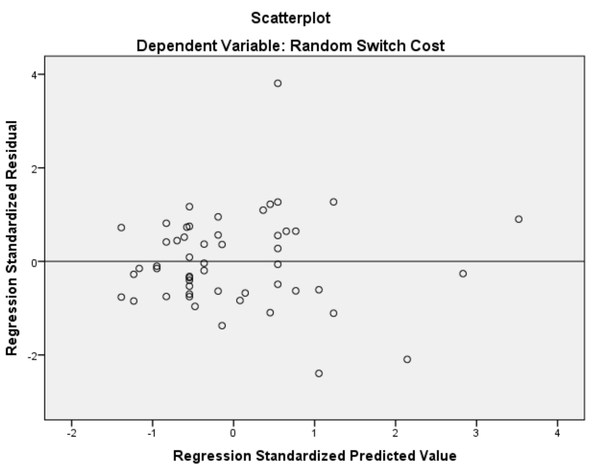
Predictable Switch Cost



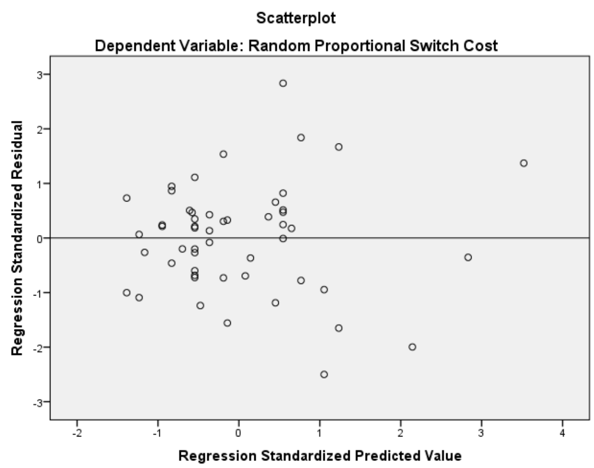
Predictable Proportional Switch Cost



Random Switch Cost



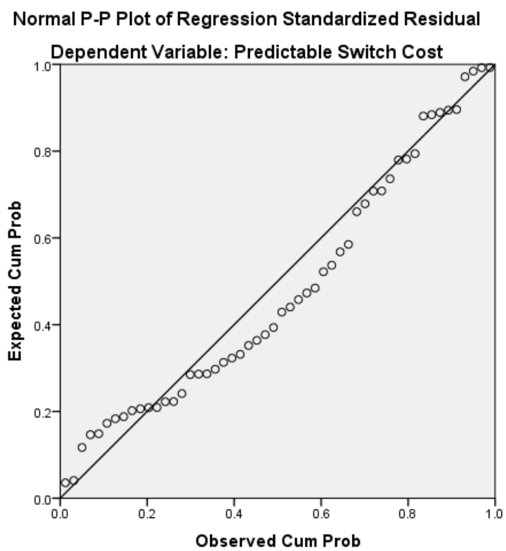
Random Proportional Switch Cost



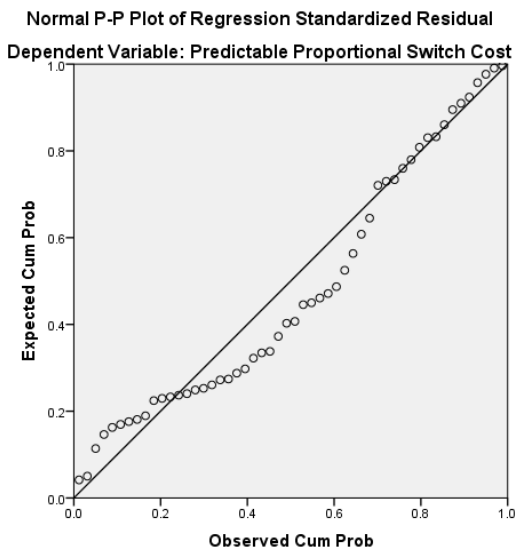
Appendix K

Log (Video Game Experience) Proofs that Residuals of the Regression Line were Approximately Normally Distributed

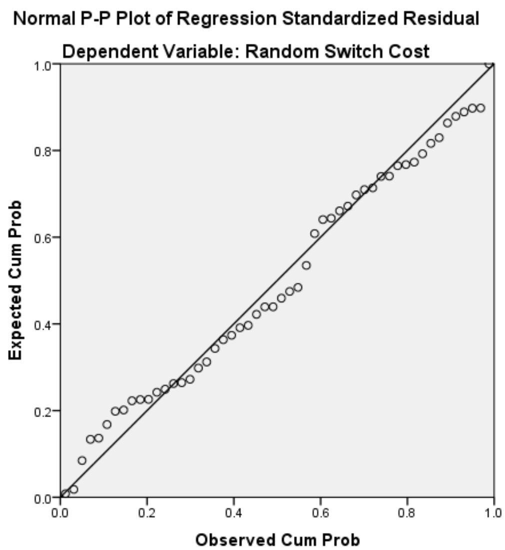
Predictable Switch Cost



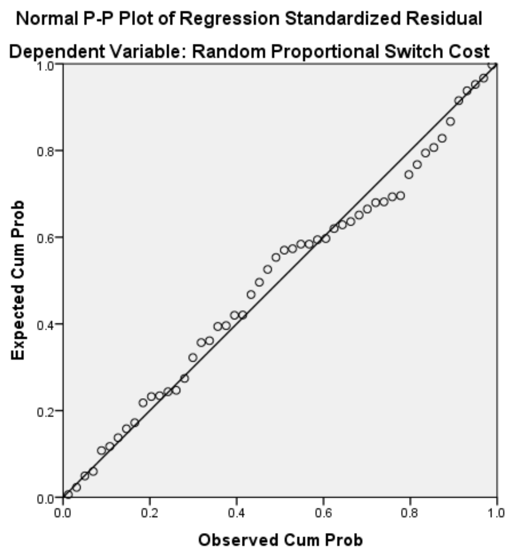
Predictable Proportional Switch Cost



Random Switch Cost



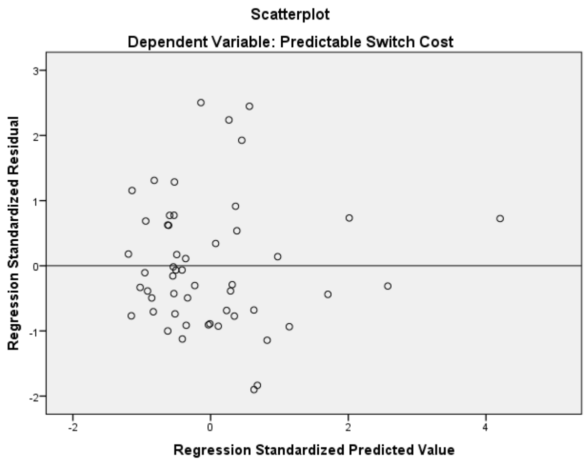
Random Proportional Switch Cost



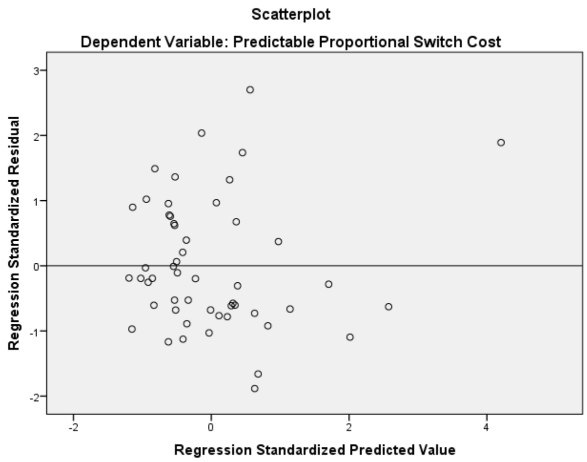
Appendix L

Log (Complexity Experience Index) Proofs for Homoscedasticity

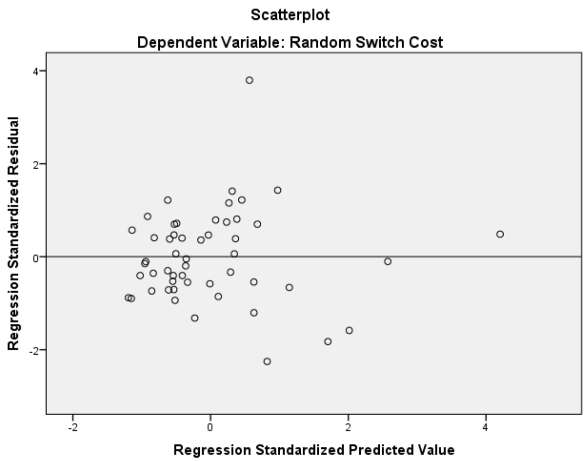
Predictable Switch Cost



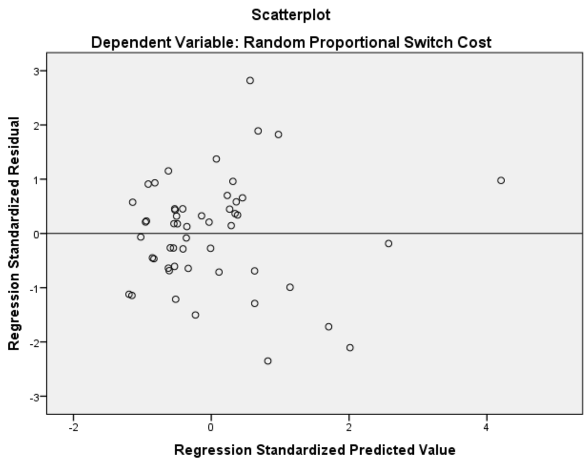
Predictable Proportional Switch Cost



Random Switch Cost



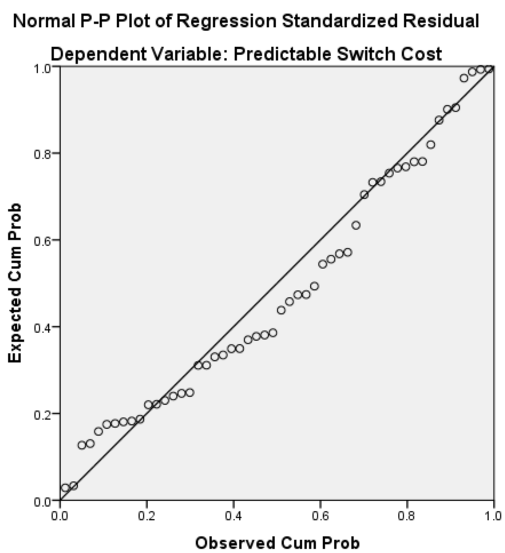
Random Proportional Switch Cost



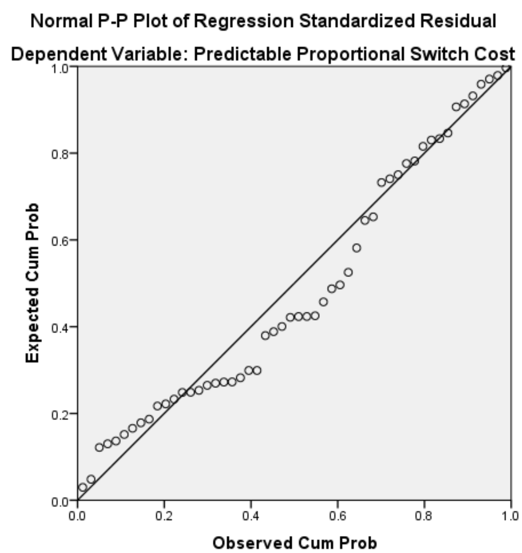
Appendix M

Log (Complexity Experience Index) Proofs that Residuals of the Regression Line were Approximately Normally Distributed

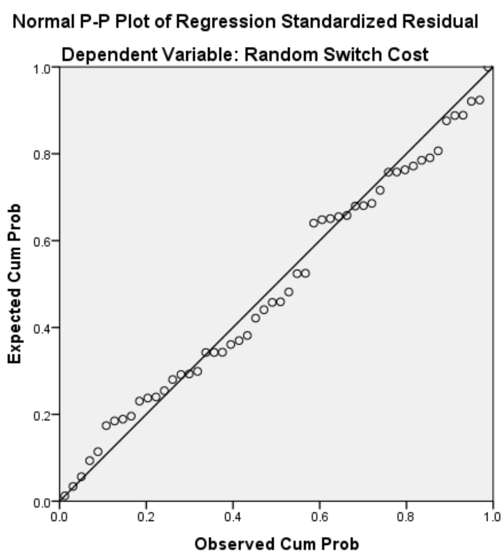
Predictable Switch Cost



Predictable Proportional Switch Cost



Random Switch Cost



Random Proportional Switch Cost