AMERICAN UNIVERSITY OF BEIRUT

ACTION VIDEO GAME PLAY AND COGNITIVE FLEXIBILITY IN LATE ADOLESCENCE AND EARLY ADULTHOOD

by

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A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Arts
to the Department of Psychology
of the Faculty of Arts and Sciences
at the American University of Beirut

Beirut, Lebanon
May 2014

AMERICAN UNIVERSITY OF BEIRUT

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ACKNOWLEDGMENTS

Forced diligence, procrastination, and caffeine. This is what it took.

I thank Dr. Nadiya Slobodenyuk for her patience and insistence. I thank her for editing my drafts on New Year's Eve, and for guiding me through this experience - because an *experience* is what it was. I thank my friends for their timeless support, and I thank them for sharing the (not so little) delights we always find lurking around Beirut!

As for my legend of a mother:

You made every effort to give us an education, and asked only for happiness in return. I would not know how to express my gratitude, and I will spend years trying to.

For now, I thank you by saying: I am happy, and it is because of you.

AN ABSTRACT OF THE THESIS OF

Sinine Samir Nakhle for Master of Arts

Major: General Psychology

Title: Action Video Game Play and Cognitive Flexibility in Late Adolescence and Early Adulthood

The industry of video games has substantially grown over the past decades, placing players in increasingly complex virtual scenarios in which cognitive flexibility is essential for rapid and accurate reactions to visual and auditory stimuli. Although it has been the hallmark of research in cognitive psychology and neuroscience, cognitive flexibility remains an ill-defined construct that has been associated with intelligence, problem solving, creative thinking, attention shifting, and working memory. The current study sought to test one of the accounts of cognitive flexibility as a general ability to shift attention, and to determine whether action video game play is associated with enhanced ability to shift attention between rules, sets, and strategies. Action video game players (AVGPs) and non video game players (nVGPs) were administered 3 computerized shifting tasks that assessed set, rule, and strategy-shifting abilities. Participants' visuospatial working memory capacity was also assessed and controlled for. The results indicated that the ability to shift attention between the sets of a task was associated with the ability to shift between the rules of a task, and with the ability to shift between strategies to solve a problem. The ability to shift between the rules of a task, however, was not associated with the ability to shift strategies to solve a problem. Results also indicated that action video game experience was not associated with enhanced set, rule, or strategy-shifting abilities. In fact, non players had faster reaction times (RTs) while switching on the set-shifting task, and were less prone to error on the strategy-shifting task. The possible factors underlying these findings are stated and discussed.

Keywords: Cognitive flexibility, action video games, attention shifting, rule-shifting, set-shifting, strategy-shifting, working memory.

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INTRODUCTION

Examining the cognitive and perceptual advantages of video games is essential, as studies have shown that skills learned and acquired in a virtual environment can transfer to real life abilities (e.g., Baranowski, Buday, Thompson, & Baranowski, 2008; Clark, Lanphear, & Riddick, 1987) . For example, arcade games improved information-processing in older adults (Clark, Lanphear, & Riddick, 1987), space-related action video games improved real flight performance in flight school cadets (Gopher, Weil, & Bareket, 1994), and high speed racing games enhanced skills of surgical residents in laparoscopic procedures (Rosser, Lynch, Cuddihy, Gentile, Klonsky, & Merrell, 2007). Interestingly, experience in video games has differential effects on cognition and behavior that are contingent on the types of video games being played. There is a variety of video game genres that determines the types of research questions raised.

The rapid increase in first person shooter video game consumption and availability raised alarming legal and ethical questions concerning the prospective influence of those games on child and adolescent behavior (Valadez & Ferguson, 2012). This is perhaps the reason why most of the psychological research examining video game play focuses on the link between violence exposure and expression of anti-social propensities such as delinquency (Fischer, Aydin, Frey, Kastenmüller, & Fischer, 2012), hostility (Hasan, Bègue, & Bushman, 2012; Valadez & Ferguson, 2012), or desensitization towards negatively charged emotional stimuli (e.g., images of disaster and accident scenes in Montag et al., 2012).

Prosocial video games, on the other hand, have been researched from the perspective of social benefits and transference of prosocial behavior. Greitemeyer and

Osswald (2010) found that after playing a prosocial video game such as *Lemmings*,in which the goal is to help other game characters overcome obstacles to reach a designated exit, participants were more likely to engage in helping behavior after the experiment (e.g., helping a confederate who allegedly dropped pens on the floor, or intervening in a situation in which the confederate was verbally harassed by another confederate). Greitemeyer, Osswald and Brauer (2010) found that playing a prosocial video game increased players' empathy towards others and decreased reported feelings of pleasure at their misfortune. Sestir and Bartholow (2010) also found that exposure to nonviolent video games such as *Zuma* or *Tetris,* which are tile-matching puzzle games, decreases aggressive thoughts, feelings and behavior.

Action video games have been consistently shown to enhance perceptual abilities (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Clark, Fleck, & Mitroff, 2011) as well as executive control functions (Basak, Boot, Voss, & Kramer, 2008; Boot et al., 2008; Green & Bavelier, 2006; Strobach, Frensch, & Schubert, 2012). The cognitive benefits of video games are of particular relevance to the current study and will be discussed in detail in the following chapters.

CHAPTER I

COGNITIVE FLEXIBILITY

A. An Overview of Cognitive Flexibility

Although cognitive flexibility has been extensively researched in cognitive psychology and neuroscience, there is no unifying conceptual account of it in the literature today. The ability to multitask, think creatively, solve problems, switch rules, switch languages, or switch strategies, could all theoretically reflect a flexible mindset. Early models from the 1960s to the 1990s provided broad explanations of cognitive flexibility that primarily pertained to individuals' ability to perform efficiently on a given task. Guilford (1962) defined cognitive flexibility as the ability to be free from fixedness and to deal with changes in presented information. These changes pertain to transformations, redefinitions, and revisions. Martin and Rubin (1995) accounted for cognitive flexibility in a similar fashion, adding the concepts of willingness and self-efficacy to the construct. Their account of cognitive flexibility refers to individuals' awareness of the available options of action in a given situation, to their willingness to adapt to that situation, and to their self-efficacy in being flexible. Karmiloff-Smith (1992) deviated from the performance efficiency approach to cognitive flexibility and viewed flexibility as a gradual shift from unreflective to reflective performance and from implicit to explicit knowledge.

While contemporary accounts of cognitive flexibility remain variable, they are nonetheless more targeted and parsimonious than earlier models of the construct. Macrae and Bodenhaussen (2000) explained that behavior is flexible when minds are responsive to the presentation of unexpected, novel, or surprising stimuli. Cañas, Antolí, Fajardo, and Salmerón (2005) referred to this responsiveness as the ability to adapt the cognitive processing strategies to new and unexpected environmental conditions. Choi, Novak, Hillier, Votolato, and Beversdorf, (2006) viewed cognitive flexibility as the ability to search a network of potential solutions to efficiently solve insight-based problem solving tasks. Bilalić, McLoed, and Gobet (2008) also explained flexibility as the ability to use new methods, techniques, or knowledge to deal with a problem. Chevalier and Blaye (2009) equated cognitive flexibility with the adaptive ability to select one among many representations of an object, strategies, or task sets, and adapt the use of those representations to the demands of the situation. Stemme, Deco, and

Busch (2007) also referred to flexibility as the essential ability to adapt behavior to the requirements of the situation. DeDreu, Baas, and Nijstad (2008), on the other hand, viewed cognitive flexibility as a measure of creativity that is manifested in the use of diverse cognitive categories and perspectives.

Recently, Ionescu (2012) divided the existing approaches to cognitive flexibility into two allegedly distinct ones. The author's rationale is that since the existing accounts of cognitive flexibility encompass attention shifting, problem solving, and creativity, the ill-defined concept of cognitive flexibility could be viewed either as an ability or skill, or as a function of independent cognitive processes.

1. *Cognitive Flexibility as a Specific Ability*

Cognitive flexibility is most commonly regarded as the well-delimited ability to switch between different tasks. The broad notion of task-switching typically designates any change in goal-directed behavior regardless of whether it specifically pertains to a shift in sets, rules, or tasks. In line with this view, Bennet and Müller (2010) focused on the ability to shift between responses and mental sets, and the ability to generate different strategies. Diamond (2006) also centered on shifting-ability, mainly the ability to switch perspectives and response mappings, while stressing the role of focused attention in cognitive flexibility. In the current research, the thorough distinctions between shifting sets, rules and strategies will be made in section 3.

As a specific ability or skill, cognitive flexibility is most commonly measured by the task-switching paradigm that identifies switch-costs. Switch-costs result from the interaction between the time required to reconfigure a mental set and the time required to manage the interference from the preceding set (Vandierendonck, Liefooghe, & Verbruggen, 2010). Cognitive flexibility as a switching ability has been considered to be one of the executive control functions. There is no single yardstick that best measures executive functions and no consensus on the exact number of executive functions (Welsh, 2002). ‘Executive functions’ is an umbrella term for cognitive processes including working memory, sustained attention, planning and flexibility (Niendam, Laird, Ray, Dean, Glahn, & Carter, 2012). These functions are essential for normal quotidian functioning and are particularly affected by delayed development, brain injury, and neurological diseases.

As one of the executive functions, cognitive flexibility is often studied from a perspective that takes into consideration the interplay between shifting abilities, working memory and attention. When a task requires switching between distracting or contradictory stimuli that are incongruent with the goal of the perceiver, such as reading the word "red" written in green, then reporting the color green in which the word “red” is written; the resulting interference is managed through the control processes of attention, inhibition and working memory (Braver, Gray, & Burgess, 2007). Moreover, if a task requires shifting attention from different elements or features of a stimulus to make an adequate response, the association between different properties of the stimulus and the type of response need to be retrieved from memory (Niendam et al., 2012).

Thus, optimal performance would involve interplay between different executive functions. This interplay is at the base of effective task-switching because it allows individuals to adapt to a new task by maintaining or inhibiting a response set, determine the saliency of stimuli, shift attention between properties of relevant stimuli and properly pick up on cues signaling the adequacy of the response style.

2. *Cognitive Flexibility as a Function of Several Processes*

In the literature, cognitive flexibility is often viewed as a property of different processes including categorization, language abilities, and inductive reasoning. With regard to the process of categorization, cognitive flexibility is the ability to adapt categories to a current situation, and to use one concept in several ways (Ionsecu, 2012). For example, depending on the goal at hand, a dog can be taxonomically categorized as an animal but thematically categorized as an element in a hunting scene. The ability to switch between simultaneously available yet incompatible categorical representations of an object has been specifically referred to as categorical flexibility (Blaye & Jacques, 2009).

Blair, Watson, Walshe and Maj (2009) extend categorical flexibility beyond flexible linguistic categorization to include the categorization of environmental stimuli. The authors posit that the categorization of regularities in the environment is an adaptive ability that all organisms possess. Through their capacity to learn, organisms can enhance the flexibility of their categorizations through attentional processes allowing perceivers to shift focus between categories depending on the demands of the context. For example, when one is discriminating lemons from limes, focusing attention on color might be more crucial than focusing attention on size. Thus, flexible categorization constitutes the ability to adapt the use of categories to the context and to categorize the environment in congruence with contextual demands.

Flexibility is also a property of language comprehension. Deák and Narasimham (2003) highlight that the capacity to shift inferences or strategies in response to changing cues and demands is essential for language processing, as referential and conceptual shifts are pervasive in everyday discourse. For example, the words “deficit” and “California” in the beginning of a dialogue can later change into “it” and “there”.

Similarly, a listener following a narrated story must activate and modify mappings to be able to shift between the conceptual entities of the story and the narrator's own comments. This ability necessitates selective attention to linguistic and paralinguistic cues signaling changes in reference and meaning. Typically, adults who speak fluently do not have difficulty in shifting their referential mappings and underlying meanings, and use dynamically changing cues to adapt their representations of meaning. Thus, cognitive flexibility is essential in the process of language comprehension because it allows individuals to make swift referential and conceptual shifts in a conversation.

In the context of induction tasks, flexibility is the ability to use different kinds of relations in different inferential contexts. When drawing inductive inferences, individuals use a broad range of relevant knowledge, including causal, taxonomic, or thematic relations that are made relevant by the context. This ability to use different relations flexibly depends on both the knowledge of the individual and on the inductive task at hand (Coley, 2005).

Murphy and Ross (2010) assert that individuals refer to two sources when categorization is uncertain and an induction is to be made. Predictions are either made regarding the category, or the feature of the objects. For example, if one hears an animal growling and wants to predict whether this animal is dangerous, one would try to classify the growl in a familiar category such as that of a bear, or a dog. Another possibility is to estimate the probability that each member of these categories will imminently attack (e.g., a bear is more likely to attack than a dog). To make either one of these inductions, one ought to have already existing knowledge about the relevant features and categories, such as knowledge about the different biological properties of bears and dogs. Individuals use various kinds of knowledge during an induction task, such as general similarity, shared features, and thematic relations (Ionescu, 2012). Cognitive flexibility is the ability to differentially use this knowledge to make categorical inductions depending on the contextual demands.

Research on particular cognitive processes and flexibility has analyzed flexible categorization, flexible language use and flexible responses in induction tasks. Although this approach classifies cognitive flexibility as a property of those processes, there is a crossover in the approaches to cognitive flexibility as a function of processes, and cognitive flexibility as the specific ability to switch between tasks. Flexibility remains essentially associated with shifting abilities even when it is studied as a function of separate processes. Although the research areas on cognitive flexibility are fragmented, the overlap between the approaches stresses the need for a unified framework of cognitive flexibility as a general ability.

B. Factors Affecting Cognitive Flexibility

When individuals are faced with an unfamiliar or unexpected situation, shifting strategies, rules or tasks is essential for their adaptation to the setting (Cañas et al., 2005). The continual use of a dominant response that is no longer relevant to a new rule or task is referred to as a perseverative error. Ridderinkhof, Span, and Maurits (2002) explain that perseverative behavior occurs when strong associations are formed between environmental stimuli and their relevant action schemas through past experience or regular practice.

The strong associations between external stimuli and actions are evident in everyday capture errors such as one picking up their toothbrush and automatically brushing their teeth when they merely meant to pack it. Newly formed associations can also cause perseverative errors when one is shifting between unpredictable task sets. For example, if participants are asked to classify cards according to one stimulus dimension like color, switching onto another dimension like shape becomes more difficult because it requires the reconfiguration of participants' task set.

On such measures of task-switching abilities, some individuals are more prone to error, exhibiting higher switch-costs and lower reaction times (RTs) compared to more flexible individuals. The factors underlying such cognitive rigidity pertain to specific task properties, knowledge regarding the task, and to the developmental level of the individual performing the task.

1. *Task Properties*

Participants’ switch-costs during a switching-task depend on specific task characteristics. These include the type of task, the complexity of the presented stimuli, the length of the response-stimulus intervals, and sequencing effects.

What constitutes the type of task in this context is whether the task required in a post-trial is different from the task required from the preceding trial. A trial in which a task is immediately followed by the same task is referred to as a repeat-trial, whereas a task followed by a different task is referred to as a switch-trial. Early research already established that switch-trials are more difficult than repeat-trials, making participants more prone to error (Spector & Biederman, 1976). Contemporary research confirmed the finding that switch-costs are always greater during switch-trials compared to repeat-trials, even after individuals sturdily practice the trials (Stoet & Snyder, 2007). Cañas et al. (2005) explain that this stems from the predictable nature of the repeat-trial that gives participants the opportunity to make continuous use of their strategy. When the target is unpredictable in a switch-trial, participants need to adaptively shift strategies; which comes at the cost of a lower RT.

Moreover, early research showed that the increased complexity of the presented targets significantly affects participants' RTs. For example, Sternberg (1966) gave participants lists of items to memorize, then presented them with a single item and asked them to determine whether this item had been in the list. Sternberg found that participants' mean RT increased linearly with the length of the list.

More recent research (e.g., Karle, Watter, & Shedden, 2010) also found convergent results. Hsieh and Liu (2008) compared participants' performance on repeat and switch-trials in three stimulus-conditions (neutral, congruent and incongruent). They found that switch-costs were larger when the trials contained incongruent stimuli compared to when trials contained congruent or univalent (neutral) stimuli. Thus, added task complexity (pertaining to the number of stimuli presented or to the presence and type of distractors) hampers participants' ability to inhibit previously learned information, which is an essential ability for efficient task-switching.

This raises the question of whether an increase in preparation time prior to the upcoming stimulus could decrease the interference from previously learned information. This would account for Rogers and Monsell's (1995) and Meiran's (1996) early findings of reduced switch-costs with long response-to-stimulus intervals. Sohn and Anderson (2001) found that switch-costs were lowest when the response-to-stimulus intervals were long. Bryck and Mayr (2008) more recently found similar results and attributed this asymmetry to an increase in the likelihood of losing no-longer relevant task sets when there is a long delay between trials.

Although task difficulty was constant across their conditions, Allport, Styles and Hsieh (1994) found that participants had higher RTs on a standard Stroop test and on a digit-numerosity judgment task compared to a reverse Stroop test and a digit-magnitude judgment task. Rubinstein, Meyer and Evans (2001) suggest that in Allport et al.'s (1994) experiment, the type of trial-block affected RTs because it influenced the stages of executive control. In other words, the difficulty and the type of block had additive effects on mean RT.

Thus, another task property influencing switch-costs pertains to additive factor effects. According to Hsieh (2012), the comparison of RTs across tasks should be done with caution, because mixed-tasks may impose greater working memory load compared to single-tasks. This could result in slower RTs which should be attributed to additive task effects (mixing-costs) instead of actual switch-costs.

2. *Age Factors*

Research has shown that cognitive functions are underdeveloped in preschoolers and begin to improve during the school years (Best, Miller, Jones, 2009). The underdeveloped executive functions in children involve deficient flexibility in the context of language use, categorization, novelty generation, and attention shifting.

Children have difficulties using cues when it comes to flexibility in lexical inference and make perseverative errors in rule use, word learning, and naming (Deák & Narasimham, 2003). Preschoolers also have difficulties in categorical flexibility because they must first master conceptual knowledge of categories, then acquire the necessary executive control skills to access alternative conceptual representations (Blaye & Jacques, 2009). Novelty generation and strategy use is also deficient in preschoolers, since they perseverate in the use of incorrect strategies even when their goal is not attained (Cutting, Apperly & Beck, 2011). Preschoolers have also been shown to have difficulty shifting between rules, which could be due to their failure to monitor the need for a switch (Chevalier, Wiebe & Huber, 2011).

Thus, deficiencies in cognitive flexibility may be age-related and affect flexible language use, categorization, novelty generation, and rule-shifting abilities. There is substantial evidence showing that older adults have similar deficiencies in cognitive flexibility (Ridderinkhof et al. 2002). Similarly to patients with dorsolateral frontal lobe lesions, older adults are susceptible to errors of perseveration on measures of cognitive flexibility, which is a reflection of inefficient prefrontal activity. Unlike preschoolers, older adults do recognize the need to change response sets and apply the new rule but are unable to switch between rules because of deficient prefrontal activity (Ridderinkhof et al. 2002).

Another explanation for poor shifting abilities in older adults and children is attentional inertia; the difficulty in suppressing a now-irrelevant rule. Participants often make continual use of previously correct responses that are no longer relevant (Dick , 2012).

Cognitive flexibility is therefore susceptible to age-related factors including underdevelopment of the prefrontal cortex in children or the decline in prefrontal activity in older adults. These deficiencies explain why children with better performing executive functions tend to behave more appropriately in the classroom (Riggs, Blair, & Greenberg, 2004) and why older adults report difficulty in adapting to changes in their routines and difficulty in responding rapidly and efficiently to shifting demands like those of traffic (Ridderinkhof et al., 2002).

3. *Working Memory Capacity*

Working-memory is one of the executive control functions, and underlies planning, effective problem-solving (Tsai, Chang, Hung, Tseng, & Chen, 2012) and academic skills; such as reading or mathematics (Spronk, Vogel, & Jonkman, 2012). Working memory refers to the ability to process and store information over brief time intervals (Nevo & Breznitz, 2013). It also refers to the ability to flexibly manipulate information that is no longer relevant in a given environment - such as abstract rules, goals for upcoming actions, or recent events (Bizon, Foster, Alexander, & Glisky, 2012).

While the ability to hold representations of previously learned information is necessary for optimal working memory, adaptive behavior also necessitates a system that allows flexible updating of those representations to respond to changing environmental demands (Bizon et al., 2012). Working memory is implicated in flexible task-switching because of the heightened need to simultaneously process and store information under switch-task conditions. In fact, during encoding and retrieval of memories, the allocation of selective attention, and the attenuation of proactive interference are essential for the maintenance of stable representations in working memory, and for the protection of those memories from distraction (Bizon et al., 2012).

Consistent with this theoretical account of working memory and cognitive flexibility, Gamboz et al. (2009) found that persevreative errors on a switching-task were predicted by participants' performance on a working memory task. Moreover, Berti and Schröger (2003) found that working memory was responsible for the control of attention and the handling of distractibility during a working memory task in which working memory load was manipulated. Blackwell (2011) also found that participants who adequately switched on a switching task had better working memory and interference control compared to participants who made perseverative errors on the switching task.

In the current study, working memory capacity was essential for the conduction of all tasks. Participants needed to memorize arbitrary rules for the set-shifting task (e.g., press the CTRL key if the letter is a vowel) and for the rule-shifting task (e.g., cards should now be matched by the dimension of color, not shape or number). Participants also needed to isolate trial-unique information from previously learned information and react to changing task demands while differentially processing irrelevant information. In the strategy-shifting task, for example, the numerical values that participants should adhere to change across trials. Previously learned information had to be isolated to make room for new, more relevant information. Thus, performance on switching tasks is highly dependent on working memory, especially when it comes to the instruments of the current study.

According to Baddeley and Hitch's (1974) multi-component model of working memory, verbal and visuospatial information is held by separate components of working memory. The description of those components is beyond the scope of this paper. The current study focused on visuospatial memory because of the saliency of spatial and visual information during video game play. Since cognitive flexibility as a switching ability is mediated by working memory capacity, the effects of visuospatial working memory capacity on participants' RTs were partialed out through the inclusion of visuospatial working memory capacity as a covariate in the analyses.

CHAPTER II

COGNITIVE CORRELATES OF VIDEO GAME PLAYING

A. An Overview of Cognitive Advantages of Video Game Playing

Several studies (Andrews& Murphy, 2006; Green & Bavelier, 2006; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Sungur & Boduroglu, 2012) have recruited AVGPs to investigate the perceptual and cognitive benefits of video games. These include numerous subtypes such as fighting games (e.g., *Mortal Combat* or *Street Fighter II*), maze games (e.g., Pac-*Man*) or shooter games. Shooter games also include sub-genres such as First-Person Shooter games (e.g., *Doom*, *Halo*, *Call of Duty*,or *Battlefield*), Third-Person Shooter (e.g., *Gear of War*), Shoot'em Up (e.g., *Space War*), tactical shooter (e.g., *Medal of Honor*) and rail shooter (e.g., *Gears of War*). Action video games usually require complex cognitive engagement that allows players to react to fast moving objects in the periphery of the display, to slow moving objects in the centre of the display, or to simultaneously moving objects (Sungur & Boduroglu, 2012).

Expert Video Game Players (VGPs) are typically familiar with several different video game genres. Green and Bavelier (2006) found that players of arcade, action and role playing games outperformed non-Video Game Players (nVGPs) on both an enumeration task (in which singleton stationary stimuli were flashed onto the display) and on a multiple object tracking task (in which multiple moving stimuli appeared on the display).

Boot et al. (2008) found that experts in action, role-playing, strategy and sports video games were faster than nVGPs in tracking moving objects, mentally rotating objects and detecting change. The authors also found that video game practice did not significantly enhance performance in nVGPs on those tasks. Because causality was not determined, the authors suggest that the experts' advantages might be due to prolonged video game experience or to pre-existing group differences.

Clark et al. (2011) found that first-person shooter, role-playing and puzzle VGPs were faster and more accurate than nVGPs on a change detection task. Interestingly, the advantages of the experts stemmed from their tendency to employ efficient search strategies. VGPs were more likely to search for the change in the entire display, whereas nVGPs were prone to fixating on a specific eccentricity of the display. This suggests that AVGPs have an enhanced ability to process and hold information, to selectively allocate attention to the requirement of the task, and to use efficient strategies when conducting a change detection task.

Sungur and Boduroglu (2012) found that AVGPs were more accurate than nVGPs in recalling the color of briefly presented objects, and were better able to track the numbers and identify the nature of the presented objects in a multiple identity tracking task. Players were also faster and more accurate than nVGPs on a detection task. These findings suggest that AVGPs have enhanced short-term memory resources and faster perceptual processing than nVGPs.Thus, research shows that video game experience improves performance on several perceptual tests requiring the deployment of attentional processes to relevant information and the activity of working memory to maintain information.

B. Cognitive Flexibility in AVGPs

Action video games require constant shifts between perceptually demanding tasks. For example, when the player is being attacked in *Call of Duty* zombie mode, he or she needs to attend to specific cues in the zombie's look because each type of zombie has different strengths and weaknesses that the players would have learned with experience. Some cues with the zombie's exterior trigger the player to use different kinds of weapons or approaches.

Similarly, in *Counter Strike*, the players are camouflaged as either counterterrorists (e.g., law enforcers) or terrorists and have to pick up on certain visual cues (e.g., the rival's costume) before attacking. When the players start a new game in which the roles are reversed, the visual cues that indicated the need to attack are no longer applicable because players would be now killing an ally.

In the zombie mode of *Call of Duty*, as long as the player is 'alive', he or she is faced with an ever increasing number of zombies. To be able to last longer, the player can use the strategy of attacking the zombies using different weapons. This is efficient in that the player can manage to kill a number of zombies before being overwhelmed by their exponential growth. The player can last substantially longer, however, if he or she switches between strategies. Instead of attacking the zombies, the player can run away, lure the zombies into one single room and blow it up, or lure them into an elevator and attack them from above, using high ground advantages that keep the zombies from spotting the player. Thus, even though some strategies such as direct attack can be efficient to some extent, good players can switch strategies to buy more time and earn a higher score.

Shifting also occurs under conditions of high cognitive load in action video games. While attempting to satisfy the specific goals of the game, players are exposed to irrelevant and distracting visual or auditory information that increases their perceptual load, like the graphics of blood splattering or the sound of wind blowing. Green et al. (2012) note that action video games differ from other genres in several aspects such as the high velocity of moving objects, the number of presented objects, the level of perceptual, cognitive, and motor load, the degree of peripheral processing, and the spatiotemporal uncertainty that necessitates players to predict when and where objects will appear on the display. AVGPs therefore constituted the most adequate participants for the assessment of cognitive flexibility.

Research on the relationship between video game experience and cognitive flexibility is extremely sparse. In fact, the APA PsycNET search engine yields only 3 peer-reviewed results with the keywords “cognitive flexibility” and “video games”, and 10 results with "switching" and “video games”. Some of those studies have established the association between video game experience and enhanced cognitive flexibility defined as a switching ability.

Andrews & Murphy (2006) gave action and strategy VGPs and nVGPs two switching tasks involving letter and digit classification. The results indicated that VGPs had smaller switch-costs compared to nVGPs when the response-to-stimulus interval was short. The authors suggest that VGPs were better able than nVGPs to anticipate the upcoming switch between tasks and use this time interval to prepare for the next trial.

Colzato, Leeuwen, Wildenberg and Hommel (2010) found that although first person shooter VGPs and nVGPs did not significantly differ when it came to speed and accuracy trade-offs during a switching task, VGPs were less affected by switch-costs than nVGPs since they made fewer errors on incongruent trials. The authors attribute this advantage to enhanced cognitive control skills. More specifically, VGPs' efficiency in controlling their episodic memory enhances their ability to selectively activate and update task sets.

Bailey, West, and Anderson (2010) found that VGPs and nVGPs' switch-costs were significantly affected by the length of the response-to-stimulus interval on a switching task. Interference caused by the switching task hampered the performance of both groups when the response-to-stimulus intervals were short. During trials with long response-to-stimulus intervals, however, VGPs were unable to uphold control and adapt to the interference. The authors suggest that video game experience is associated with a decrease in the efficiency of proactive control allowing players to maintain goal-oriented action in a changing environment.

Green et al. (2012) also found that VGPs had reduced switch-costs compared to nVGPs on a switch-task requiring vocal and manual responses. Interestingly, the results generalized to the vocal responses, indicating that the reduced switch-costs with VGPs are not simply due to a speeded manual response that VGPs have acquired through experience. Green et al. (2012) also found that training in video games significantly improved the participants' task-shifting abilities, which suggests a causal link between video game play and efficient switching-abilities. Authors attribute the advantages of video game play to the enhancement of executive control functions that allow players to reconfigure task sets more flexibly than nVGPs.

Cañas et al. (2005) found that the flexibility of VGPs depended on the relevance of the task-goal to the type of strategy being used. After having received training in specific games, participants' use of problem-solving strategies was only affected when training type was directly relevant to those strategies. Thus, cognitive inflexibility can be caused by contextual changes that interfere with the problem-solving strategy used.

This was of particular interest for the current study because strategy-shifting abilities were assessed using an instrument called the Water Jug Problem. The training that gamers receive through experience is somewhat incongruent with the problem-solving skills required for this instrument. The question, however, was whether VGPs would shift to new and more efficient problem-solving strategies if they had been contextually made to use less efficient but correct strategies.

Cain, Landau and Shimamura (2012) found that AVGPs had reduced switch-costs compared to nVGPs on a switching task in which the participants had to differently respond to displayed stimuli depending on previously explained rules. Karle et al. (2010) found that first-person shooter VGPs outperformed nVGPs on a switching task when a task cue was presented. Interestingly, this advantage failed when stimuli and responses overlapped, which suggests that even though VGPs were faster than nVGPs, the benefits of video game play experience do not generalize to the cognitive control processes required to handle increased proactive interference. Karle et al. (2010) concluded that VGPs have enhanced control and allocation of selective attention, but not enhanced cognitive control processes that are at the base of task-switching.

Strobach et al. (2012) found that AVGPs outperformed nVGPs on both a dual task and a switching task. The authors also found the same results when they provided nVGPs with training in video games. This establishes that there is a causal link between action video game play and enhanced cognitive control skills. These findings are particularly relevant to the current study which compared the performance of AVGPs to that of nVGPs on perceptual and cognitive switching tasks. One aim was to check whether AVGPs possessed enhanced cognitive control processes that would make them faster and more immune to proactive interference during three switching tasks.

The research available consistently shows that VGPs have an enhanced ability to switch between tasks. This advantage is at the base of enhanced cognitive control abilities that allow players to better adapt to new situational demands by maintaining or inhibiting a response set, determining the saliency of stimuli, shifting attention between properties of relevant stimuli, and picking up on cues that signal the adequacy of the response style. The current study measured several types of switching abilities to allow an integrative account of cognitive flexibility as the ability to switch sets, rules and strategies.

CHAPTER III

CURRENT APPROACH

Two approaches to cognitive flexibility have been overviewed: cognitive flexibility viewed as a specific ability to switch between tasks and cognitive flexibility as a function of several processes. Although the second approach classifies cognitive flexibility as a property of processes, there is an evident overlap between the approaches since flexibility remains essentially associated with general shifting abilities, even when it is studied as a function of separate processes. There have been attempts at providing unified accounts of cognitive flexibility. Ionescu (2012) provides such an account of flexibility as a property of the cognitive system that involves the interplay of several mechanisms responding to specific contextual demands. The interplay of the mechanisms includes executive functions (which are at the base of the view of cognitive flexibility as an ability) and processes such as categorization (which correspond to the second view of cognitive flexibility as a function of cognitive processes). Ionescu (2012), however, does not suggest a possible measure of the integrated account of flexibility that she put forward. The current study therefore adopted the approach of cognitive flexibility as a specific ability. The extension in this case pertained to the inclusion of set-shifting, rule-switching and strategy-shifting abilities.

The empirical partitioning of cognitive flexibility as an independent ability into several skills has never been done, and most recent studies equate cognitive flexibility with the specific ability to change behavioral goals (Cain et al., 2012; Cañas et al., 2005; Colzato et al., 2010; Green et al., 2012; Karle et al., 2010). Several terms have been used to designate this change, including task-switching, set-shifting, rule-switching, and attention shifting. Ravizza and Carter (2008) note that, in some studies, the same switching-paradigm is designated differently.

For example, Rubia et al. (2006), and Smith, Taylor, Brammer, and Rubia (2004) use “set-shifting” to designate a task in which participants have to classify the location of a stimulus as either horizontal or vertical. Brass et al. (2003), on the other hand, refer to this as “task-switching”. The conflation of these terms in the literature is inaccurate because there is evidence to suggest that different types of task switching require the interplay of different executive control functions and are associated with different cortical connections (Ravizza & Carter, 2008). It is for this reason that the current study used three instruments to respectively assess set, rule and strategy-shifting abilities. This empirical division allowed to test for the possible similarities between the skills required for those tasks. It also allowed the precise comparison of AVGPs and nVGPs' performance on three allegedly different switching abilities.

Ravizza and Carter (2008) provide the first attempt to explicitly state how the terms "set", "task" and "rule" differ. A set is a property of a stimulus relevant to a given trial. Set-shifting pertains to a change in the stimuli that requires a shift of the mental representations of the stimuli. For example, when the presented stimuli change from numbers to letters, the mental representation of numbers is no longer relevant and needs to shift to a representation of letters.

A "task" has not been properly defined, but may correspond to a change in the goal state of a task. For example, classifying a digit as odd or even, or as greater or less than 5 may count as a change in the goal state of a task. Note that on a trial, a task can repeat while the set shifts. For example, if a participant is to report the color then the shape of a stimulus, the set is shifting (from color to shape), but the task remains the same: the participant *always* needs to report the property of a stimulus.

Rule switching consists of any change in the rule in addition to a reversal of stimulus-response mappings. These refer to the learned associations between the stimulus and its corresponding response. Unlike set-shifting, rule-shifting does not require a shift in the perceivers' mental representations of the stimuli, because even though the dimensions of the stimuli are variable (e.g., color, shape or number), they are *always* important to focus on. According to Ravizza and Carter (2008), both rule and response switching are types of rule switching, since they involve changes in either the judgment or the response rules.

Ardiale and Lemaire (2012) provide a definition of strategy-shifting which can be used in addition to Ravizza and Carter's (2008) classifications of switching abilities. Strategy-shifting corresponds to the ability to stop using an ongoing strategy to select and execute an alternative strategy depending on the problem at hand. An example of strategy-shifting would be a participant endorsing the same efficient strategy for several consecutive trials then changing his or her approach on a new trial to save time.

The notion of "task-switching" is a general one that has not been formally defined, perhaps because of the difficulty in pinpointing the level at which a goal-state can be considered a task (Ravizza and Carter, 2008). Moreover, both rule and response switches are considered to be types of rule switching since they involve changes in either the judgment, or the response rules (Ravizza and Carter, 2008). The only difference between response and rule-shifting pertains to the motor component, which was not a salient variable in the current analyses. Thus, since the differences between set-shifting, rule-switching and strategy-shifting can be manifested in different measures of switching, the current study only incorporated measures of set-shifting, rule-switching, and strategy-shifting to assess overall switching abilities.

CHAPTER IV

AIMS AND HYPOTHESES

The purpose of the current study was to empirically test the account of cognitive flexibility as the general ability to shift attention, and to determine whether video game experience is associated with enhanced cognitive flexibility. The current study provided a new account of cognitive flexibility that breaks down attention shifting into: set-shifting, rule-switching, and strategy-shifting abilities. Set-shifting pertains to a change in the stimuli that requires a shift of the mental representations of the stimuli. In tasks requiring rule-shifting, the mental representation of the stimuli does not change because the same stimuli are presented to the participants. The change in this case pertains to the required stimulus-response mappings, depending on the inferred rule of the task. Finally, tasks that require a switch in strategy include the same stimuli, and the response to those stimuli should be made according to one same rule. The change here pertains to the way in which the participant approaches the problem.

If switching is considered as a general ability, then nuanced switching abilities should be based on similar processes that allow the adaptation of responses to contextual demands. Since set-shifting, rule-switching and strategy-shifting involve the general ability to switch, it was expected that players and nVGPs' *own* performance on measures of switching abilities (set, rule, and strategy) be correlated.

Hypothesis 1: There will be a correlation between the RTs on measures of set-shifting, rule-switching and strategy-shifting.

Set-shifting, rule-switching and strategy-shifting do not merely require enhanced working memory capacity but also the interplay of other executive functions such as attention, planning and inhibition (Braver et al., 2007). Moreover, video game experience does not only provide practice on simultaneous processing and information maintenance, but also familiarizes players with rapidly changing environments which allow them to selectively allocate attention to salient stimuli and use several efficient strategies when conducting tasks (Clark et al., 2011). Thus, it was conjectured that video game experience will have an effect on the dependent variables after controlling for working memory capacity.

Set-shifting pertains to a change in the presented stimuli that requires a shift in the mental representations of those stimuli. Action video games constantly present players with different visual cues to which speeded differential responses are required. In fact, AVGPs have been shown to switch responses faster than nVGPs to changing stimuli (e.g., shifting mental representations from letters to digits in Andrews &Murphy, 2006 and Karle et al., 2010). Players have also been shown to have the acute ability to detect and react to changes in a display faster than nVGPs (Boot et al., 2008; Clark et al., 2011; Sungur & Boduroglu, 2012). Since set-shifting requires a shift in mental representations of stimuli, since players have been shown to react faster than nVGPs to changing stimuli that require shifts in mental representations, and since players generally detect and react to changes faster than nVGPs, players were expected to perform faster than nVGPs on the measure of set-shifting.

Hypothesis 2: AVGPs will have <u>*faster RTs*</u> *than nVGPs on the measure of* <u>*set-shifting*</u> *while controlling for visuospatial working memory capacity.*

A task requiring rule-shifting involves the presentation of the same stimuli to which the responses change due to modification of the rule. To perform optimally, AVGPs are expected to focus attention on the entirety of the display and process all possible stimuli, because important targets most often appear unexpectedly. Players have been consequently shown to outperform nVGPs on tasks requiring the simultaneous processing of different stimulus dimensions (e.g., reporting the number *and* the color of different stimuli during multiple object tracking in Boot et al., 2008; Green & Bavelier, 2006; and Sungur & Boduroglu, 2012). Moreover, players' RTs have been shown to be less affected by a change in the rule while different stimuli are shown simultaneously (e.g., a change in the response rule to global vs. local stimuli in Colzato et al., 2010). This suggests that players are better able to inhibit the response-sets of previous trials that are no longer appropriate. Because players have an enhanced ability to process different dimensions of stimuli faster than nVGPs and because players have an enhanced ability to inhibit inadequate response sets when a task rule changes, players were expected to outperform nVGPs on the measure of rule-shifting abilities.

Hypothesis 3: AVGPs will have faster RTs than nVGPs on the measure of rule-switchingwhile controlling for visuospatial working memory capacity.

Because action video games usually require goal-oriented tasks (e.g., kill the zombies, or retrieve the flag), and because different obstacles hamper the players' ability to rapidly attain those goals; players are continuously expected to find new strategies to circumvent those difficulties (e.g., lure zombies to bomb them simultaneously instead of directly attacking several zombies). Players have been shown to be more resistant than nVGPs to the continuous use of strategies (e.g., players used more efficient search strategies compared to nVGPs who perseverated in focusing on the same eccentricities of the display in Clark et al., 2011). Since players have generally been shown to react faster to presented information compared to nVGPs (Cain et al., 2012; and Green et al., 2012), and since players have been shown to be less susceptible to perseverative strategy use compared to nVGPs, VGPs were expected to use new and more efficient strategies during the 7th and 8th trialof the Water Jug Problem[1], while nVGPs were expected to make continuous use of the old less efficient strategy.

Hypothesis 4: AVGPs will have faster RTs than nVGPs on the measure of strategy-shifting (Part I), and will be more likely than nVGPs to switch between strategies while controlling for visuospatial working memory capacity (Part II).

Because the strategy-shifting task is cognitive in nature, because AVGPs have been shown to outperform nVGPs on cognitive tasks, and because action video games

[1] The Water Jug Problem (Luchins, 1942) will be described in more detail in section 5.2 (Instruments)

require frequent switching between strategy-use, players were expected to be more 'flexible' in the strategy-shifting task. That is, players were expected to use new strategies when the context permitted it, even if another strategy was used on the preceding trials.

It has been established that the Water Jug Problem produces a specific mental set which makes participants more likely to continuously use one strategy even when more efficient strategies could solve the new problems (Luchins, 1942). It has also been shown that switch-trials increase switch-costs even for VGPs (Cañas et al., 2005), and that VGPs are also susceptible to the interference of previously learned information (Karle et al., 2010). Thus, although players are expected to be faster and more accurate than nVGPs on the strategy-shifting task, the conjectured group differences on the strategy-shifting task were expected to be less accentuated than the conjectured group differences on the set-shifting and rule-switching tasks.

Hypothesis 5: The group differences between the RTs of AVGPs and nVGPs will be larger for measures of set-shifting and rule-switching abilities compared to performance on strategy-shifting.

CHAPTER V

METHODS

A. Participants

A total of 107 students participated in the experiment. Three participants were excluded from the analysis because of unexpected technical problems during data collection, and a forth was also excluded because his colorblindness would have affected his ability to conduct the WCST. Non-players were student volunteers enrolled in the psychology introductory course (PSYC 201) in the American University of Beirut and VGPs were recruited from popular computer laboratories (commonly referred to as "networks") that provide access to online video games in Hamra. Sixty-six participants were recruited from AUB, and 37 from the Networks. The sample consisted of 65 males and 38 females. Of these, only one female was an Action Video Game Player (AVGP). Overall, 47 participants were categorized as AVGPs, 46 as nVGPs, and 10 as non AVGPs. Because the goal of the current study was to compare the performance of AVGPs to that of nVGPs, the 10 non AVGPs were not included in the analysis, leaving the sample size at $N = 93$. Table 1 in Appendix 4 contains information about sample characteristics.

Participants were aged between 18 and 26. This age range is representative of the population typically found in computer laboratories, and is developmentally adequate for the measurement of cognitive flexibility. There was no restriction concerning the gender of the participants because gender differences in performance were not expected. Upon approval from the Institutional Review Board, students from the American University of Beirut were recruited through posters distributed around campus and advertisements provided to the PSYC-201 pool by the instructor of the course. Students from computer laboratories in Hamra were personally approached. The researcher on-site held a laptop on which the pre-programmed tasks took place, and a package containing the consent forms and the questionnaires.

B. Instruments and Reaction Time Calculation

Participants were given a battery of instruments including a questionnaire about demographics and video game experience; and computerized measures of working memory capacity (The Sternberg Working Memory Task), set-shifting ability (Tharp and Pickering, 2011), rule-shifting ability (Wisconsin Card Sorting Test) and strategy-shifting ability (The Water-Jug Problem). Although task properties such as type of task, complexity of stimuli, and length of response-stimulus intervals were known to influence switch-costs, the current study did not manipulate these variables for purposes of simplicity.

It is important to note that although all measures used in the current study recorded average RTs, these measures were intended to measure different abilities (working memory capacity, attentional set-shifting, rule-shifting and strategy-shifting ability). Thus, the obtained chronometric data ought to be differentially interpreted. In other words, since only some of these instruments were simple stimulus-reaction perceptual tasks, while others more intricately involved other cognitive processes or executive control functions; caution must be taken in the cross-sectional comparison of the RTs. This section will explain in detail the way in which the stimuli were presented in each measure, how the RT data was computed into aggregate scores, and how the RT data was recorded.

1. *Demographics and Video Game Experience*

Participants were first asked to fill out a demographics questionnaire including information on gender, age, and level of education (see Appendix A for the questionnaire). The questionnaire was also be used to differentiate between expert AVGPs and non-expert VGPs. The current study followed the criteria used by Green et al. (2012) and considered participants to be expert VGPs if they spent a minimum of 5 hours per week for the past 6 months playing video games. Participants with little or no experience in playing action video games (less than 5 hours per week for the past 6 months) were considered nVGPs. AVGPs were also distinguished from other VGPs. AVGPs played games with a single player mode involving adventurous missions, and/or with a multiplayer mode focusing on the execution of an opponent rather than on the strategy used to execute an opponent.

2. *The Sternberg Working Memory Task*

This task was used to provide an estimate of the participants' working memory capacity, which was included as a covariate the analyses. Sternberg (1966) developed this task to examine the ways in which the retrieval of information from memory occurs when learning and retention are held constant. In this 16 trial task, participants were to focus attention on a sequence of successively flashing stimuli on the screen. At the end of the sequence and upon the presentation of a yellow digit, participants were to react as quickly as possible by pressing one of 2 keys to indicate whether that yellow stimulus had been presented in the previous sequence. For example, during the first trial, the list "4, 6, 1, 7, 8" would appear, followed by the digit "6". Since the digit was presented during the first trial, participants had to press the key that designated a "yes". If the digit "2" appeared, participants had to press the key that designated a "no" because "2" did not appear in the list of the first trial. After the participants responded, visual feedback was provided to indicate the accuracy of the response (a red "X" for false and a green "O" for correct). Appendix B includes the instructions of all the measures exactly as they were provided during the experiment.

To obtain 2 aggregate scores for this task, the average RTs and average accuracy of responses on the 16 trials were computed. The recording of the RTs for each trial started at the presentation of the yellow stimulus up until the participant pressed one of the keys. Thus, participants in this task were expected to react in a matter of seconds or milliseconds after the onset of the yellow stimulus, as the task is perceptual in nature and does not involve complex decision making or mathematical calculations; only the ability to process and store information over brief time intervals (Nevo & Breznitz, 2013).

3. *The Attentional Set-Shifting-Task*

To measure set-shifting abilities, an altered form of Tharp and Pickering's (2011) method was used. Participants performed letter and digit classification tasks comprised of 107 trials. Participants were to focus attention on flashing digits and letters and react to each stimulus alone by pressing one of 2 keys. The goal was to indicate if the digit was odd or even or if the letter was a vowel or a consonant. Unlike the Working Memory Task, the singleton stimulus in this case remained displayed on the screen until the participant made a response. This task could be considered as a set-shifting task by Ravizza and Carter's (2008) standards, because the properties of the stimuli (letters vs. numbers) change from trial to trial while the rule remains the same (e.g., always press red if the letter is a vowel). The task was therefore used as a measure of set-shifting abilities.

In this task, a switch-trial was characterized by a change in the *type* of stimulus (letter vs. digit); this change only occurred after 6 consecutive trials that contained the *other* type of stimulus. For example, participants would have been responding 6 consecutive times to letters (non-switch-trials) until they were presented with a *digit* (switch-trial). All in all, this task yielded 4 aggregated scores: average accuracy; overall RT (average RT on *all* trials); average switch-trial RT; and average non switch-trial RT.

On each trial, the recording of the RT started from the presentation of the stimulus until the participant's response.Since the fairly simple goal was to determine whether the digit was odd or even, or whether the letter was a vowel or a consonant; participants were also expected to react in a matter of seconds or milliseconds to each stimulus. Although this task does imply the interplay of several executive control functions (e.g., sustained attention and working memory), it essentially requires the fairly simple task of shifting mental representations of stimuli while reversing stimulus-response mappings. For example, the CTRL key could be used to designate both an odd digit and a consonant, depending on the type of stimulus that needs to be reacted to in the display. Thus, since this is a stimulus-response perceptual task, it was expected that RTs on this task be relatively fast compared to the RTs on the WCST and the Water Jug Problem.

4. *The Wisconsin Card Sorting Test (WCST)*

Participants completed the electronic version of the WCST, which provides a reliable measure of rule-shifting abilities. The instrument was initially developed by Grant and Berg in 1948 (Eling, Derckx, & Maes, 2008) and was later expanded by Heaton, Chelune, Talley, Kay and Curtiss (1993). The WCST was first developed to assess the ability to think abstractly and to shift strategies to adapt to changing contextual demands (Eling et al., 2008), and is now frequently used to assess rule-shifting abilities (Smillie, Cooper, Tharp, & Pelling, 2009).

The task is programmed to require more trials (a maximum of 128) in proportion to the participants' number of mistakes. Participants were presented with 5 cards; one occupying the top half of the display, while others occupied the bottom half of the display (see Figure 1 in Appendix C for a preview of the WCST). Participants were instructed to click on one of the four cards in the bottom of the display that was most similar to the card in the top of the display. The displayed stimuli would remain on the screen until participants made a response.

According to Ravizza and Carter's (2008) classifications of switching, the WCST could be considered as a measure of rule-switching because even though the dimensions of the stimuli (number, color and shape) are not homogenous, they are *always* important to attend to: the perceiver's mental representations of those dimensions do not change. As such, the instrument was used to assess the participants' rule-shifting abilities.

A switch-trial was characterized by a change in the *rule* according to which participants were to sort the cards. The output files of this task allowed for the inspection of *patterns* of responses. In addition to average RT and accuracy, the data set allowed the extraction of percentages of Categories Completed, Set Loss, Perseveration of the Preceding Criterion, Perseveration of the Preceding Response, and Non-Perseverative Errors. Table 2 (Appendix D) provides a brief explanation of these dependent variables.

On each trial, the recording of participants' RT started from the presentation of the stimuli until the participant clicked on a card. Once participants reacted by clicking on one of the cards, a new set of cards appeared, marking the start of a new trial. RTs were expected to be slower in this task compared to the Memory and the Attentional Set-Shifting Tasks, since this task implicated more intricate cognitive processes. For example, it required participants to infer a rule through trial and error, remember the computer's feedback regarding previous responses and patterns, and avoid error by predicting a future change in the rule. Thus, RTs in this task were expected to be slightly slower than those of the first two tasks.

5. *The Water-Jug Problem*

The Water-Jug problem was used as a measure of strategy-switching abilities. The task was developed by Luchins (1942) who demonstrated that mental sets can be contextually produced. The participants were presented with a display containing information about 3 jugs of water A, B and C. The information includes the volume of water that each jug can measure, and the final desired amount of water. Participants were to make the necessary steps to attain the final desired amount of water. To get the desired amount of water in jug B, for example, participants can pour water from jug B into jug A once, then into jug C twice. Participants had to use a simple formula to explain how they got the desired amount of water. A space on the bottom of the screen allowed participants to select a formula without using the keyboard. From 3 drop-down lists (one for each jug), participants would click on digits ranging from -5 to 5, that served as coefficients. It is only when participants click the “OK” button that the display changes to yield new different values.

The task consisted of 8 problems or trials. For the first 6 consecutive trials, the problems could be solved using the formula: desired quantity = 1B-1A-2C. On the 7th and 8th trials, however, simpler strategies can be used. On the 7th trial, participants can pour water from A and C to arrive at the desired amount (the formula here is: desired quantity = 1A+1C). Also, on the 8th trial, participants can fill jug A then pour water from A into C to get the desired volume of water (desired quantity = 1A-1C).

The rationale behind the Water-jug Problem is that the mental set in which the participants are put during the first 6 trials makes it more difficult for participants to switch to a new strategy during the 7th and 8th trials. Luchins (1942) showed that participants who started the problem from trial 1 were more likely to perseverate in using the strategy that requires more steps on the 7th and 8th trials. Participants who started at the 7th trial, on the other hand, tended to use the shorter strategy instantly. The Water-jug Problem was used to assess strategy-switching abilities because it assessed the participants' un-cued ability to switch between strategies.

In this task, the first 5 trials were considered to be non switch-trials and the last 3 were considered to be switch-trials. The last trials were regarded as such because they allowed participants the (uncued) option of switching to a new simpler formula. Over and above average overall RT, switch-trial and non switch-trial RT, this task allowed for the extraction of perseverative responses. Thus, on the last 3 trials, participants could either use the *correct* but *convoluted* formula they had been using for the last 5 trials (this would be a Correct Perseverative Response); they could switch to using a *correct* and much *simpler* formula (Correct Switching Response); or they could *switch* to a new but *incorrect* formula (Incorrect Switching Response).

This task was expected to take considerably more time to complete in comparison to all other tasks. Unlike all other tasks, the Water Jug Problem included a complex display that substantially increases cognitive load. Indeed, participants were to process the entirety of the display which contained more complex stimuli than other tasks. Moreover, the task required participants to make several calculations; replace the coefficients and check whether their response is mathematically sound (since no feedback is given regarding the accuracy of the response). The task was also expected to take longer since it had an insight component to it. Indeed, it is only after a couple of long trials that participants were expected to realize that one formula could work for all trials. Since this task is cognitive in nature and requires more complex cognitive processes compared to all tasks, it was expected that participants would take a number of minutes per trial before they could proceed to the following trial.

Thus, the comparison of RT data across tasks needs to be interpreted with caution. Although the original 'scales' of the RT data are all chronometric, they have different distributions that are due to the nature of the tasks rather than to the participants' own perceptual or cognitive abilities.

C. Procedure

Participants received 2 copies of the informed consent form (Appendix E). With the guidance of the researcher, participants read, signed and kept one copy of the consent form. Using non-technical terms, the consent form included explanations about: confidentiality, the purpose of the study, the procedures of the experiment, the possible risks and benefits of the experiment (both general and individual), the participant's right to leave out any items in the questionnaire, the participant's right to refuse participation or to terminate the experiment without providing any justification. The researcher assured the participants that their identity would remain anonymous, that all the information they disclose is completely confidential and that should they agree to participate in the experiment, they are entitled to terminate the experiment at any given point without having to provide any sort of explanation.

After receiving the consent form, the participants were asked to fill out the demographics and video game experience questionnaire. The participant who wished to continue the experiment and who did not meet any of the inclusion criteria (age range of 18-26 years, or enrollment in post-secondary education) they were asked to complete the rest of the tasks. Once the participant was ready, the researcher orally explained the specific requirements of the tasks, and invited the participant to ask any questions he or she might have had about the experiment.

CHAPTER VI

RESULTS

A. Preliminary Analyses

Prior to the investigation of sample descriptives, preliminary analyses were conducted, including a missing value analysis and inspection of univariate and multivariate outliers.

1. *Missing Value Analysis*

A missing value analysis revealed that the data set did not include any missing values. This was expected and was due to the automated nature of the computerized tests.

2. *Univariate Outliers*

The inspection of Z-scores revealed a total of 21 univariate outliers from 15 participants. The variables that contained one outlier each were: RT on the Sternberg Memory Task, RT on the Water Jug Problem, and RT on the switch-trials of the WCST. Variables that contained two outliers each were RT on the WCST, RT on non switch-trials of the WCST, RT on the switch-trials of the set-shifting Task, percent accuracy on the Set-shifting Task, RT on both switch and non switch-trials of the Water Jug Problem. The variables percentage of incorrect switching responses on the Water Jug Problem and percent accuracy on the Water Jug Problem contained 3 outliers each. Even though univariate outliers constituted 16.13% of the sample the cases were retained since the Z-scores were not substantially high, ranging from the absolute values of 3.41 to 5.29, and since they were not concentrated on select variables.

3. *Multivariate Outliers*

Multivariate outliers were inspected through Mahalanobis distances using with $p<.001$ as the criterion. Five multivariate outliers were found in the data set, all of which were also univariate outliers. The cases were all retained so as to preserve the power of the analysis.

4. *Sample Descriptives*

Participants were on average 19 years old (SD= 1.83) and were all enrolled in a university. AVGPs had approximately 11 years of experience playing action video games (M = 10.91, SD = 3.21), dedicating 24.50 hours a week (SD = 15.17) to video games and spending 3.60 consecutive hours (SD = 1.95) a day playing. Although nVGPs have had approximately 6 and a half years of video game experience (M = 6.53, SD = 4.64), they only dedicated an hour and a half per week (M = 1.56, SD = 1.40) to playing, and did not stay in front of the screen for more than an hour per session (M = .76, SD = .63).

B. Main Analysis Part I: Correlation

To test Hypothesis 1 which states that there will be a correlation between the RTs on measures of set-shifting, rule-switching and strategy-shifting, bivariate correlations between RT on the set-shifting Task, RT on the WCST and RT on the Water Jug Problem will be conducted.

1. *Normality of Sampling Distribution*

The inspection of Z-scores of skewness and kurtosis was used to test for the assumption of normality (see Table 3 in Appendix D for Z-scores per variable). An absolute value above 3.29 was considered to indicate a deviation from normality. RT on the rule-shifting task and RT on the Water Jug Problem were both positively skewed with a leptokurtic distribution, and RT on the set-shifting task was moderately positively skewed. Thus, the assumption of normality was breached for RT on measures of set-shifting, rule-switching and strategy-shifting; Spearman's correlation coefficient will be used, as it is a non-parametric statistic.

2. *Distributions of Reaction Time Data*

Before further analysis could be conducted, it is important to address the issue of normality in RT data. The distributions of RTs are often positively skewed, violating the assumption of normality that underlies the general linear model (Baayen & Milin, 2010). That is because RTs are amenable to the influence of several variables including age and handedness (MacDonald, Nyberg, Sandblom, Fischer, & Backman, 2008; Welford, 1977, 1980; Boulinguez & Barthelemy, 2000). RTs are also sensitive to changes within the experiment, due to participants' level of arousal, fatigue, amount of previous practice, or sequential effects (Broadbent, 1971; Welford, 1980; Sanders, 1998). Moreover, RT distributions may be affected by excessively influential values that compromise the model fit. Thus, when it comes to RTs, distributional variability is not uncommon; both on the level of individual subjects and on the level of the experimental task (Baayen & Milin, 2010).

Transformations are a possible solution to the violation of normality or unequal variances. Transformations could indeed lessen the impact of outliers or skewness while maintaining statistical power (Whelan, 2010). The inverse-Gaussian (Wald), the log-normal, and the Gamma distribution are possible transformations that could be applied to RT data. Two theoretical considerations arise, however, when it comes to the 'correct' choice of transformations. First, the optimal choice of transformation is not always easily recommended, as it is contingent on the goodness of fit of the different theoretical models which may vary across experimental tasks. Moreover, practical problems come to pass regarding the interpretation of the transformed data. That is because the transformation could change the original scale of the data (e.g., milliseconds), making the interpretation of the data more difficult (Baayen & Milin, 2010; Whelan, 2010).

A number of methodological studies on the analysis of RTs offer statistical recommendations regarding the violation of normality. Baayen and Milin (2010), for example, recommend the use of the Inverse Gaussian over that of the Log-Normal transformation when it comes to RT distributions. The authors warn, however, that this choice is not always the most optimal one. Whelan (2010) recommends the logarithmic transformation under the pretext of it normalizing the distribution more than the inverse transformation. The problem here, Whelan claims, is that this can possibly eliminate significant effects, and render the interpretation of data more difficult.

Thus, there is no absolute consensus regarding the optimal type of transformation. The decision is complicated, as it mostly depends on the model fit and on the type of skew that is to be corrected. There is consensus, however, regarding the variables that are to be transformed. It is generally agreed upon, that when the researcher is interested in “the differences between variables, [the researcher] must apply the same transformation to *all* variables” (Field, 2009, p.154).

In the case of the current study, there was a noticeable variability in the distribution of the variables. As Table 3 (Appendix D) indicates, some variables needed to be corrected for positive skew while others needed to be corrected for negative skew. The degree of skewness was also variable: while some variables were moderately skewed, others were substantially skewed. Before a transformation could be applied, it is important to determine whether the statistical models applied would perform essentially better on transformed data than they would when applied to untransformed data violating normality.

Glass, Peckham and Sanders (1972) wrote an extensive review in which they contended that transformations are not always the most favorable solution to the question of normality because "the payoff of normalizing transformations in terms of more valid probability statements is low, and they are seldom considered to be worth the effort" (p. 241). Since the choice of transformation depends on the *type* of skew, since the variables of the current study are *differentially* skewed, since the *same* transformation must be applied to *all* variables, and since transformations make the interpretation of the data more *difficult*; it was deemed more prudent to retain the original data in the current study rather than to transform it.

This decision was also based on Games' (1984) judgment that the consequences of misapplying transformations for the statistical model are worse than the consequences of analyzing untransformed data. Moreover, Field (2009) asserts that the question of whether or not to transform the data is linked to the robustness of the test. Since MANCOVA is robust to violations of normality (Tabachnick & Fidell, 2007), it was deemed more appropriate in the case of the current study to analyze the untransformed data. To preserve the statistical power of the analysis, the outliers were retained, because they constituted a considerable 16.13% of the sample and because they were not concentrated on select variables.

3. *Correlation*

RT on the set-shifting task was significantly correlated with RT on the rule-shifting task, $r_s = .17$, p (one-tailed) = .05, and almost significantly correlated with RT on the strategy-shifting task, $r_s = .16$, p (one-tailed) = .06. However, RT on the rule-shifting task was not significantly correlated with RT on the strategy-shifting task (see Figure 2 in Appendix C for a correlation graph). In other words, how fast participants were generally on the set-shifting task changed in accordance to how fast they were on the strategy-shifting task (the Water Jug Problem) and to how fast they were on the Rule-shifting Task (the WCST); but how fast they were on the Rule-shifting Task did not change in accordance to how fast they were on the Task. Thus, Hypothesis 1 which predicted a correlation between all RTs on the tasks was partially confirmed.

C. Main Analysis Part II: MANCOVA

To test Hypothesis 2 which states that AVGPs will have faster RT than nVGPs on the measure of Set-Shifting, a one way multivariate analysis of covariance was conducted, with action video game experience as the independent variable and RT on switch-trials, RT on non-switch-trials and percent accuracy on the set-shifting task as the dependent variables. Performance on the working memory task was controlled for, with average RT and percent accuracy on the Sternberg Memory Task entered as covariates. Along with the upcoming MANCOVAs, this analysis will also test for Hypothesis 5, which expected group differences between the RTs of AVGPs and nVGPs to be larger for measures of set-shifting and rule-switching abilities compared to RTs on the strategy-shifting task.

1. *Scale Descriptives*

It seems that AVGPs were on average slower than nVGPs on the set-shifting task (respectively, M = 897.18, SD = 201.59; M = 855.74, SD = 199.39). Interestingly, AVGPs' own performance on switch-trials (M = 887.44, SD = 197.34) was faster than their performance on non-switch-trials (M= 897.24, SD = 205.85); while nVGPs needed more time to complete switch-trials (M = 877.51, SD = 216.51) than non-switch-trials

(M= 851.29, SD = 197.99). AVGPs were faster (M = 897.24, SD = 205.85) than nVGPs (M= 851.29, SD = 197.99) on non-switch-trials, but slower than nVGPs on switch-trials (respectively, M= 887.44, SD = 197.34; M = 877.51, SD = 216.51). Overall, nVGPs (M = 97.06, SD = 2.52) were more accurate than AVGPs on the task (M = 94.85, SD = 7.87). The means and standard deviations of the set-shifting task descriptives are provided in Table 4 (Appendix D).

2. *Statistical Assumptions*

a. Unequal Sample Sizes

Sample sizes across cells were relatively similar, making adjustment procedures for unequal n unnecessary.

b. Normality of Sampling Distributions

Z-scores of skewness and kurtosis revealed that percent accuracy on the set-shifting task was substantially negatively skewed with a leptokurtic distribution. RT on switch-trials and RT on non switch-trials were both moderately positively skewed with a leptokurtic distribution. However, MANCOVA is robust to violations of normality (Tabachnick & Fidell, 2007), especially since the sample is not small (N=93) and since the smallest cell far exceeds 3, being the number of DVs.

c. Homogeneity of Variance-Covariance Matrices

Levene's test revealed that variances were equal for average RT on switch-trials, $F(1, 91) = .98$, *ns*; average RT on non-switch-trials, $F(1, 91) = .35$, *ns*. However, variances were not equal for percent accuracy, $F(1, 91) = 0.02$, $p < .05$. However, since group sizes are equal, the MANCOVA should be robust to the violation of this assumption (see Filed, 2008, p.604). Moreover, the Box's M value of 62.14 was associated with a *p* value of .000, which is significant even on the basis of Huberty and

Petoskey's (2000) guidelines (i.e., $p < .005$). Thus, the covariance matrices between the groups were not assumed to be equal for the purposes of the MANOVA. However, the Box's test is susceptible to deviations from multivariate normality and is also likely to be significant in a large sample (Field, 2008, p. 604). Since the group sizes are roughly equal, as per Field's recommendations, the Box's test will be disregarded and robustness will be assumed.

d. Homogeneity of Regression Slopes

The assumption of homogeneity of regression slopes was tested by checking for the significance of the interaction between gaming experience and the covariates (percent accuracy and average RT on the Sternberg Memory Task). For the dependant variable RT on switch-trials of the set-shifting task, the 2 interactions of Gaming_experience* Task_1_total_average_RT, $F(2, 86) = 5.58$, $p < .05$ and Gaming_experience *Task_1_percent_accuracy*Task_1_total_average_RT, $F(2, 86) = 6.77$, $p < .05$ were both significant. This means that variances in each group for RT on switch-trials of the set-shifting task were not equal, which breaches the assumption of homogeneity of regression slopes. However, according to Tabachnick and Fidell (2007), MANCOVA is robust to violation of homogeneity of regression.

3. *Main Analysis*

a. Effects of the Covariates

The covariates in this analysis were accuracy and average RT on the Sternberg Working Memory Task. Using Pillai's trace, the covariate percent accuracy on the Sternberg Working Memory Task almost reached significance, $V = .08$, $F(3, 83) = 2.55$, $p = .06$, partial $\eta^2 = .08$. In fact, separate univariate ANOVAs on the outcome variables revealed that accuracy on the Sternberg Working Memory Task significantly affected participants' RT on switch-trials of the set-shifting task, $F(1, 85) = 5.17$, $p < .05$, $\eta^2 = .06$, but not their RT on non-switch-trials or their overall accuracy on the set-shifting task. The covariate RT on the Sternberg Working Memory Task did not have a significant effect on performance on the Set-Shifting task, and separate univariate analyses also confirmed this result.

b. <u>Main Effects</u>

Using Pillai's trace, video game experience did not significantly affect the dependent variables. Separate univariate ANOVAs on the outcome variables confirmed that video game experience did not significantly affect non-switch trial RT[2] or accuracy on the set-shifting task. However, the univariate tests revealed that video game experience significantly affected switch-trial RT on the set-shifting task, $F(1, 85) = 3.95$, $p = .05$, partial $\eta^2 = .04$. Indeed, AVGPs were surprisingly slower than nVGPs on switch-trials of the set-shifting task, with adjusted means of 925.61 (SE = 29.61) and 874.82 milliseconds (SE = 27.84) respectively.

In other words, whether participants had experience in playing action video games determined how fast they reacted to the presentation of a new stimulus that required a change in the response. Although it was expected that video game experience would render participants faster on the set-shifting task, the opposite was found. AVGPs and nVGPs were equally fast on non-switch-trials, though nVGPs were faster than AVGPs when it came to switch-trials of the Set-shifting task, and Hypothesis 2 was thus disconfirmed. Even thought an unexpected group difference was found, further analyses are required to test Hypothesis 5 which pertains to the comparison of group differences regarding RTs on all tasks.

[2] A non-switch trial is also referred to as a repeat trial

D. Main Analysis Part III (A and B): MANCOVAs

1. *Main Analysis Part III, A*

To test Hypothesis 3, which states that AVGPs will have faster RTs than nVGPs on the WCST (measure of rule-switching), two main analyses were conducted. First, a one way MANCOVA with action video game experience as the independent variable and RT on switch-trials, RT on non-switch-trials and percent accuracy on the WCST as dependent variables. Performance on the working memory task was controlled for, with average RT and percent accuracy on the Sternberg Memory Task entered as covariates.

2. *Main Analysis Part III, B*

The second analysis was also a one way MANCOVA with action video game experience as the independent variable, average RT and percent accuracy on the Sternberg Memory Task as covariates. In this analysis, percentages of Categories Completed, Set Loss, Perseveration of Preceding Criterion, Perseveration of Preceding Response and Non-Perseverative Errors were entered as the dependent variables.

Since the dependent variables of both analyses pertain to the same task and since both analyses share the same assumptions, the descriptives and the statistical assumptions of analyses A and B will be jointly presented.

3. *Scale Descriptives*

Both AVGPs and nVGPs required roughly the same number of trials to finish the task (respectively, $M = 82.09$, $SD = 34.84$; $M = 81.98$, $SD = 30.96$) with both groups requiring approximately 3 seconds per trial to respond to stimuli (respectively and in milliseconds, $M = 3022.22$, $SD = 1468.49$; $M = 2948.19$, $SD = 1166.61$). As expected, all participants tended to be slower when a change in the rule took place. Both AVGPs and nVGPs were slower to react during switch-trials (respectively, M =

3238.04, SD = 1467.66; M=2938.82, SD = 1132.14) than during non-switch-trials (respectively, M = 2995.59, SD = 1491.93; M = 2920.96, SD = 1200.64).

Surprisingly, AVGPs appeared to be slower (M = 3238.04, SD = 1467.66) than nVGPs (M = 2938.82, SD =1132.14) when it came to both switch-trials and non switch-trials (respectively, M = 2995.59, SD = 1491.93; M = 2920.96, SD = 1200.64). AVGPs, however, seemed overall to be slightly more accurate in their responses (M = 53.93, SD = 12.76) compared to their counterparts (M = 52.70, SD = 12.20). AVGPs had a higher percentage of Categories Completed (M = 28.94, SD = 14.63) compared to nVGPs (M = 26.79, SD = 11.54) but both players and nVGPs had approximately the same percentage of Set Loss following the correct categories completed (respectively, M = 1.11, SD = 1.62; M = 1.00, SD = 1.04).

Interestingly, both AVGPs and nVGPs seemed susceptible to perseveration errors. AVGPs were slightly less susceptible to errors of Perseveration of the Preceding Criterion (PPC). In fact 25.13 % (SD = 7.44) of AVGPs' responses versus 26.29 % (SD = 11.54) of nVGPs' responses showed Perseveration of the Preceding Criterion (PPC). AVGPs also had a slightly lower percentage of Perseveration of the Preceding Response (M = 7.77, SD = 3.26) compared to nVGPs (M = 8.52, SD = 3.94). Also interestingly, AVGPs also made more non-perseverative errors (M = 12.14, SD = 9.03) than nVGPs (M = 11.60, SD = 9.11). The means and standard deviations of the WCST descriptives are provided in Table 5 (Appendix D).

4. *Statistical Assumptions*

a. Normality of Sampling Distributions

i. Analysis A

The inspection of Z-scores of skewness and kurtosis revealed that only percent accuracy on the WCST had a normal distribution. RT on switch-trials and RT on non switch-trials were both considerably positively skewed with a leptokurtic distribution (see Z-scores in Table 3, Appendix D). However, MANCOVA is robust to violations of normality (Tabachnick & Fidell, 2007), especially since the sample is not small (N=93) and since the smallest cell far exceeds 3, being the number of DVs.

i. Analysis B

The inspection of Z-scores of the dependent variables percentage of Categories Completed, Set Loss, Perseveration of Preceding Criterion, Perseveration of Preceding Response, and Non-Perseverative Errors, revealed that all variables were normally distributed.

b. Homogeneity of Variance-Covariance Matrices

i. Analysis A

Levene's test revealed that variances were equal for average RT on switch-trials, $F(1, 91) = .92$, *ns*; average RT on non-switch-trials, $F(1, 91) = .21$, *ns*; and percent accuracy, $F(1, 91) = 1.43$, *ns*. Moreover, Box's M value of 6.35 was associated with a *p* value of .41, *ns* and covariance matrices between the groups were thus equal for the first analysis.

ii. Analysis B

The Levene's test revealed that variances were equal for Set Loss, $F(1, 91) = 3.56$, *ns*, Perseveration of Preceding Criterion, $F(1, 91) = .02$, *ns*, Perseveration of Preceding Response, $F(1, 91) = .80$, *ns*, and Non-Perseverative Errors, $F(1, 91) = .24$, *ns*. However, variances were not equal for Categories Completed, $F(1, 91) = 6.31$, $p < .05$, but since group sizes are equal, the MANCOVA should be robust to the violation of this assumption (see Field, 2008, p.604). Box's M value of 26.03 was associated with a *p* value of .06, *ns*, and covariance matrices between the groups were thus equal for the second analysis.

c. Homogeneity of Regression Slopes

i. Analysis A

The assumption of homogeneity of regression slopes was tested by checking for the significance of the interaction between gaming experience and the covariates (percent accuracy and average RT on the Sternberg Memory Task). All three interactions (Gaming_experience*Task_1_percent_accuracy; Gaming_experience *Task_1_total_average_RT; and Gaming_experience *Task_1_percent_accuracy*Task_1_total_average_RT) were non-significant, and the assumption of homogeneity of regression slopes was thus met for the first analysis.

ii. Analysis B

For the second analysis, the same interactions for non-significant for the dependent variables Categories Completed, Set Loss, Perseveration of Preceding Criterion, Perseveration of Preceding Response and Non-Perseverative Errors, indicating that the assumption has been met.

E. Main Analysis A

1. *Effects of the Covariates*

The covariates in this analysis were Percent Accuracy and Average RT on the Sternberg Working Memory Task. Using Pillai's trace, there was no significant effect of memory task accuracy or RT on the dependent variables of the WCST.

2.*Main Effects*

Further investigation of Test of Between-Subjects effects showed that experience with video games did not affect participants' switch-trial RT, non switch-trial RT or accuracy on the WCST. In other words, whether participants had experience playing video games did not affect how fast or how accurate they were on a task that requires inferring a change in the rule. Thus, Hypothesis 3 was rejected.

F. Main Analysis B

1. *Effects of the Covariates*

The covariates in this analysis were also accuracy and average RT on the Sternberg Working Memory Task. Using Pillai's trace, both covariates did not significantly affect the dependent variables. However, separate univariate ANOVAs on the outcome variables showed that accuracy on the Sternberg Memory Task had an almost significant effect on the dependent variable Perseveration of Preceding Response, $F(1, 85) = 3.71$, $p = .06$, $\eta^2 = .04$, but not on the other dependent variables. Average RT on the Sternberg Working Memory Task also had a significant effect on Perseveration of Preceding Response, $F(1, 85) = 3.84$, $p = .05$, $\eta^2 = .04$.

2. *Main Effects*

Using Pillai's trace, video game experience did not significantly affect Categories Completed, Set Loss, Perseveration of Preceding Criterion, Perseveration of Preceding Response, and Non-Perseverative Errors. Separate univariate ANOVAs on the outcome variables confirmed these results. Thus, contrary to what was expected, experience in action video games did not affect performance on the WCST. Namely, AVGPs were not only as fast as nVGPs during switch and non-switch-trials; they were also as prone as nVGPs to making perseveration errors.

G. Main Analysis Part IV (A and B): MANCOVA and ANCOVAs

1. ***Main Analysis Part IV, A***

Two main analyses were conducted for the output of the Water Jug Problem. To test Part I of Hypothesis 4, which stated that AVGPs will have faster RTs than nVGPs, a one way multivariate analysis of covariance was conducted, with action video game experience as the independent variable and RT on switch-trials, RT on non-switch-trials and percent accuracy on the Water Jug Problem as the dependent variables. Again, performance on the working memory task was controlled for.

2. ***Main Analysis Part IV, B***

The second part of the analysis aimed to test Part II of Hypothesis 4, which states that AVGPs will be more likely than nVGPs to switch between strategies on the Water Jug Problem. Three separate univariate analyses of covariance were conducted with action video game experience as the independent variable and average RT and percent accuracy on the Sternberg Memory Task as the covariates. The dependent variables for each of the 3 ANCOVAs were respectively: percent of correct switching responses, percent of correct perseverative responses and percent of incorrect switching responses.

Again, since the dependent variables of both analyses pertain to the same task and since both analyses share the assumptions, the descriptives and the statistical assumptions of analyses A and B will be jointly presented.

3. ***Scale Descriptives***

It seems that AVGPs were slightly faster than nVGPs on average, requiring 53.44 seconds per trial (SD = 37.00) where nVGPs required 54.94 (SD = 26.40). On the first switch-trial, AVGPs were slower than their counterparts (respectively, M = 29.10, SD = 32.25; M = 23.54, SD = 15.70). This was also the case for all following switch-trials:

AVGPs were slower to react than nVGPs (respectively, M = 23.62, SD = 16.63; M= 20.81, SD = 10.66). Both AVGPs and nVGPs were faster on switch-trials (respectively, M = 23.62, SD = 16.63; M = 20.81, SD = 10.66) compared to non switch-trials (respectively, M = 71.34, SD = 58.32; M = 75.41, SD = 40.60). This would be usually unexpected, especially in comparison to the other tasks. However, this could be an early hint that participants from both groups gained insight with regards to the possibility of solving the problem using a simpler and faster strategy.

It seems overall that nVGPs, made fewer mistakes in their responses, scoring 88.86 % (SD = 15.86) on accuracy compared to AGVPs' 87.23 % (SD = 13.91). A closer look at the last trials in which it was possible to switch formulas might be insightful. On average, it seems that AVGPs were less likely than nVGPs to correctly switch their use of formulas to use a simpler one. Indeed, on 58.87 % (SD = 38.83) of the last trials (which are all considered the switch-trials), AVGPs made a correct switch of formulas, whereas nVGPs made that correct switch on 66.67 % (SD = 39.75) of the last trials. AVGPs were more likely to perseverate in their use of correct, but old and more time-consuming formulas compared to nVGPs (respectively, M = 33.3, SD = 36.12; M = 28.99, SD = 39.51). In fact, on average, AVGPs made incorrect switches of formulas on 7.80 % (SD = 19.92) of the last trials, while nVGPs only wrongly switched formulas on 4.35 % (SD = 15.09) of the last trials. The means and standard deviations of the Water Jug Problem descriptives are provided in Table 6 (Appendix D).

4. *Statistical Assumptions*

a. Normality of Sampling Distributions

i. Analysis A

The inspection of Z-scores of skewness and Kurtosis revealed that switch trial RT and non switch-trial RT were both substantially positively skewed, with a leptokurtic distribution. The dependent variable accuracy on the Water Jug Problem was slightly negatively skewed also with a leptokurtic distribution. However, MANCOVA is robust to violations of normality (Tabachnick & Fidell, 2007), especially since the sample is not small (N=93) and since the smallest cell far exceeds 3, being the number of DVs.

ii. Analysis B

The inspection of Z-scores revealed that percent of correct switching responses had a normal distribution, with a Z-score of 2.20. Percent of correct perseverative responses, however, was slightly positively skewed (Z-score of 3.47) and percent of incorrect switching responses was substantially positively skewed (Z-score of 13.07). However, ANCOVA is robust to violations of normality (Tabachnick & Fidell, 2007), especially since the sample is not small (N=93) and since the smallest cell far exceeds 3, being the number of DVs.

b. Homogeneity of Variance-Covariance Matrices

i. Analysis A

For the first analysis, Levene's test revealed that variances were equal for average RT on switch-trials, $F(1, 91) = .64$, *ns*; average RT on non-switch-trials, $F(1, 91) = 1.45$, *ns*, and percent accuracy, $F(1, 91) = 1.61$, *ns*. Moreover, the Box's M value of 18.24 was associated with a p value of .007, which is non significant on the basis of Huberty and Petoskey's (2000) guidelines (i.e., $p < .005$). Thus, the covariance matrices between the groups were equal for the purposes of the MANOVA.

ii. Analysis B

For the second part of the analysis, Levene's test revealed that variances were equal for percentage of correct switching responses, F (1, 91) = .00, *ns*, percentage of correct perseverative responses, F (1, 91) = .85, *ns*, and percentage of incorrect switching responses, F (1, 91) = 3.92, *ns*. Homogeneity of variance has thus been met for the 3 separate univariate analyses of covariance.

c. Homogeneity of Regression Slopes

i. Analysis A

The assumption of homogeneity of regression slopes was tested by checking for the significance of the interaction between gaming experience and the covariates (percent accuracy and average RT on the Sternberg Memory Task). For all dependent variables, the three interactions (Gaming_experience*Task_1_percent_accuracy; Gaming_experience *Task_1_total_average_RT; and Gaming_experience *Task_1_percent_accuracy*Task_1_total_average_RT) were non-significant, and the assumption of homogeneity of regression slopes was thus met.

ii. Analysis B

The assumption of homogeneity of regression slopes was also met for the dependent variable percentage of correct switching response, percentage of incorrect switching responses, and percentage of correct perseverative responses, as all interactions between the independent variable and the covariates were non-significant for all dependent variables.

5. *Main Analysis A*

a. Effects of the Covariates

The covariates in this analysis were accuracy and average RT on the Sternberg Working Memory Task. Using Pillai's trace, both covariates did not significantly affect the dependent variables. Separate univariate ANOVAs on the outcome variables confirmed the same results.

b. Main Effects

Using Pillai's trace, video game experience did not significantly affect the dependent variables. Separate univariate ANOVAs on the outcome variables confirmed that video game experience did not significantly affect switch or non-switch trial RT on the Water Jug Problem. However, the separate analyses revealed that video game experience significantly affected accuracy on the Water Jug Problem, $F(1, 85) = 4.05$, $p = .05$, partial $\eta^2 = .05$. AVGPs were significantly less accurate than nVGPs, with an adjusted mean of 88.67 % (SE = 2.32) compared to nVGPs' 89.89 % (SE = 2.18). In other words, video game experience did not affect how fast participants were on the switch-trials of the task, but did render AVGPs more prone to error compared to nVGPs. Thus, the first part of Hypothesis 4 was rejected. The second part of the analysis will determine whether AVGPs were more likely than nVGPs to switch formulas on the strategy-shifting task.

6. *Main Analysis B*

a. Effects of the Covariates

The three separate ANCOVAs showed that both covariates did not significantly affect the dependent variables percentage of Correct Switching Response, Percentage of Correct Perseverative Responses or Incorrect Switching Response.

b. Main Effects and Interaction Effects

Video game experience did not significantly affect the dependent variables percentage of Correct Switching Response, Correct Perseverative Responses, or Incorrect Switching Responses. Thus, when participants were put in a mindset in which the use of one strategy is efficient, whether participants were AVGPs or not did not affect their propensity to switch to a simpler strategy when the opportunity presented itself. The second part of Hypothesis 4 was then rejected.

Hypothesis 5 had expected group differences to be larger for RTs on set and rule-shifting compared to RTs on the strategy-shifting task. Since results revealed that AVGPs were significantly slower than nVGPs on the set-shifting task (see section 6.3), but that group differences on RTs were not significant on the rule-shifting task (see section 6.4.A), or on the strategy-shifting-task (current section), Hypothesis 5 was rejected.

CHAPTER VII

GENERAL DISCUSSION

The present study sought to show that action video game experience enhances the ability to switch between sets, rules and strategies. The study also sought to test the account of cognitive flexibility as the general ability to shift attention . The rationale was that if set-shifting, rule-shifting, and strategy-shifting were all abilities that fall under the same general ability to shift attention, then participants' own performance on one of the tasks should be similar to their performance on all others. Heterogeneity in a participant's own performance on the tasks could reflect inherent differences in the three types of attention shifting abilities.

Results showed that although participants' RTs on the set-shifting task were correlated to their RTs on the rule-shifting task, and on the strategy-shifting task; their RTs on the rule-shifting task were not correlated to RTs on the strategy-shifting task. The reason behind this finding could lie in the nature of the tasks. As explained in section 5.2, the set-shifting and rule-shifting tasks are mostly perceptual, as they require simple and quick responses to flashing stimuli on the display. Since both tasks are perceptual, it is not surprising that participants' performance on one of the tasks be associated to their performance on the other.

The strategy-shifting task (the Water Jug Problem), however, is the most cognitively demanding task of all the administered instruments. That is because it entails mathematical calculations that increase task difficulty, subsequently increasing the RT required for task completion. This would explain why participants' RTs on the rule-shifting task (the WSCT) were not associated with RTs on the strategy-shifting task.

On the other hand, the association between performance on the perceptual set-shifting task and performance on the more cognitive strategy-shifting task could have stemmed from the shared executive control processes required for the conduction of both tasks. In the set-shifting task, when the presented stimuli change from numbers to letters, the mental representation of numbers is no longer relevant and needs to shift to a representation of letters. This shift is possible because working-memory allows participants to manipulate information that is no longer relevant (Nevo & Breznitz, 2013). For example, the information of how to respond to a letter is stored, but is momentarily irrelevant when the stimulus shifts to a number.

Working memory plays an equally important role in the strategy-shifting task. Indeed, working memory has been shown to underlie effective problem-solving (Tsai, Chang, Hung, Tseng, & Chen, 2012) and mathematical skills (Spronk, Vogel, & Jonkman, 2012). Both of these skills were essential requirements for goal attainment in the strategy-shifting task. Working memory is also essential in the rule-shifting task, as it makes the reversal of stimulus-response mappings possible. Since no association was found, however, between participants' performance on the rule-shifting task and on the strategy-shifting task, it could be that the latter requires the involvement of different executive control functions, and that it is associated with different cortical connections (Ravizza & Carter, 2008). Thus, set and rule-shifting as opposed to strategy-shifting might not actually belong to the same category of cognitive flexibility as the general ability to shift attention.

Moreover, the study showed that video game experience did not affect non switch-trial RTs, but did affect switch-trial RTs on the set-shifting task. Contrary to expectations, AVGPs were slower than nVGPs to react to the display on the switch-trials of the set-shifting task. In other words, AVGPs and nVGPs did not differ on repeat-trials, in which the upcoming required response was predictable. AVGPs, however, were slower than nVGPs when the response was unpredictable. It could be that nVGPs were better able to shift mental sets and respond adequately to the change in stimulus type. However, the group differences found might have been accounted for by the different contexts in which the experiment took place. As will be explained in the Limitations section, AVGPs conducted the experiment in rather unfavorable conditions. The setting was noisy, and distractibility was significantly increased by the large number of people present. nVGPs, on the other hand, conducted the experiment in the laboratory of the psychology department of AUB, where focused attention was significantly more possible. This difference in experimental setting could have been responsible for the fact that AVGPs were slower than nVGPs when the response was unpredictable.

Moreover, the covariate RT on the Sternberg Memory Task did not affect performance on the set-shifting task. How fast participants performed the memory task did not influence how well they performed on the set-shifting task. However, the second covariate of accuracy on the Sternberg Memory Task did affect participants' RTs on switch-trials of the set-shifting task. The better working memory participants had, the faster they tended to be on the set-shifting task. This finding was expected, as working memory is needed for the swift shifting of mental representations (e.g., when numbers are no longer relevant, there is a need to shift to a representation of letters) which is essential for optimal performance on the set-shifting task.

Video game experience did not affect switch-trial RTs, non switch-trial RTs, or accuracy on the rule-shifting task. Also, video game experience did not affect participants' pattern of responses on that task. AVGPs needed as many trials as nVGPs to finish the task, completed the same number of correct categories, and were as likely as nVGPs to make perseverative and non-perseverative errors. Although they were unexpected, these results replicate Karle et al.'s (2010) finding that AVGPs are as susceptible to the interference of previously learned information as nVGPs. Why AVGPs and nVGPs performed similarly on the WCST might have related to the WCST itself. This will be elaborated shortly.

Both covariates of accuracy, and RT on the Sternberg Memory Task only affected participants' errors of Perseveration of Preceding Response on the rule-shifting task. Participants with enhanced working memory were more likely than others to repeat an incorrect and immediately preceding response on the WCST. It is unusual that working memory affects only Perseveration of Preceding Response in this particular manner, which is why a close examination of working memory could provide a useful conceptual framework for the interpretation of the results.

Working memory allows individuals to move mental sets fluidly by going backwards and forward in time to project the next action (Barceló & Knight, 2002). This ability is particularly essential in the WCST, because the presentation of negative feedback from the computer should prompt participants to shift categories. Recent information is to be held, new irrelevant categories are to be discarded, and one of the remaining categories is to be selected (Barceló & Knight, 2002).

Perseverative behavior, such as the Perseveration of Preceding Response, usually occurs when previously established rules become rigid and determine the responses of the early trials in a new series, even when feedback disconfirms the dominant response (Milner, 1963). Such a deviation from an 'ideal' pattern of responses could reflect disruption in the rule-shifting operations involved in card sorting. Such a deficit could be due to prefrontal lesions, distraction, interference, or problems in the integration of temporally separated events (Barceló & Knight, 2002). Loss of information from working memory for any of those reasons could lead to a random selection of the next card and deteriorate performance on subsequent trials.

It has been shown that normal subjects are forced to make errors in half of the trials following a shift in the rule to find the new sorting rule (Barceló, Sanz, Molina, & Rubia, 1997). This adds confusion to the interpretation of the data. The participant's failure to complete a category, for example, could reflect an inability to shift to a new rule, or an inability to maintain information about the old rule because of stimulus interference. This test scoring system has been said to cause a validity problem for the test, as the same score confounds both functional and dysfunctional processes (Barceló & Knight, 2002).

Moreover, instructions provided prior to the experiment have been shown to substantially affect performance on the WCST (Barceló & Knight, 2002). Instructions in the current study did not inform participants that a change in the rule would or could occur (see Appendix B), or that the rules are based on the dimensions of number, color, and shape. A large number of participants expressed irritation when the computer's feedback signaled that the dominant response, which had been correct for 4 trials, was now incorrect. During and after the experiment, a substantial number of AVGPs and nVGPs informally reported that they assumed the computer's feedback to be completely random. This prompted them to click on cards indiscriminately instead of trying to infer a rule or memorize a pattern through trial and error. Thus, although the results indicate that both AVGPs and nVGPs have similar rule-shifting abilities, it is possible that group differences did not emerge because of factors concerning the WCST's scoring system, or because of experimental control (e.g., instructions).

When it came to the strategy-shifting task, video game experience did not affect participants' switch or non switch-trial RTs. However, video game experience did significantly affect accuracy on the strategy-shifting task. AVGPs were more prone to writing incorrect formulas on the strategy-shifting task compared to nVGPs. AVGPs were as likely as nVGPs to switch to the use of a more efficient strategy, and as likely to perseverate in the use of the same strategy.

This finding is incongruent with Clark et al.'s (2011) results which showed that AVGPs are more resistant than nVGPs to the continuous use of strategies. The findings of the current study could be due to different factors. First, Luchins (1942) specifically designed the Water Jug Problem to put participants in certain mental sets. The perceptual training that AVGPs received through experience might not have sufficed to overcome the cognitive set that the Water Jug Problem prompts during the first trials.

Second, the strategy-shifting task requires high cognitive load. The ability to conduct this task could have been determined by already existing differences in mathematical abilities or general exposure to mathematical problems. In the analysis, the incorporation of participants’ majors in university and mathematical proficiency could have shed light on the group differences found on accuracy.

Third, during the experiment, AVGPs adopted an extremely dismissive attitude towards the instruments. This was particularly true for the Water Jug Problem which required more time and concentration compared to the other more lucrative tasks. The lack of incentive to complete the task properly could also explain why AVGPs made more mistakes than nVGPs. Thus, the lack of group differences on the strategy-shifting task could have emerged from the nature of the task itself, from already existing group differences which were not accounted for in the analysis, or from the lack of experimental control in the computer laboratories.

Working memory was expected to influence performance on the strategy-shifting task, as it is implicated in mathematical abilities and problem solving, which are both essential for optimal performance on the strategy-shifting task. Both covariates of accuracy and RT on the Sternberg Working Memory Task, however, did not significantly affect the dependent variables on the strategy-shifting task.

Note that the current study used the Sternberg Memory Task to assess visuospatial working memory capacity. Although solving the strategy-shifting task does require the visuospatial representation of numerical information, it also involves the workings of other related executive control functions. It requires the retrieval of basic arithmetic facts from long-term memory, and the use of developmentally unchallenging calculation procedures (Passolunghi & Siegel, 2004). Thus, it could be that the Sternberg Memory Task, which only targets visuospatial memory, did not fully represent the executive control functions required for the conduction of the strategy-shifting task.

All in all, it was shown that different types of switching are not all correlated, and that this might be due to the involvement of different executive control functions. Thus, the conflation of the terms “set-shifting”, “rule-shifting” and “strategy-shifting” ought to be avoided, as these abilities might involve different processes. It was also shown that experience in action video games is not associated with enhanced performance on either one of the set, rule or strategy-shifting tasks.

Before the conclusion that AVGPs and nVGPs are equally flexible can be drawn, it is important to note that the AVGPs recruited for the current study might not have been as proficient as expected. A cut-off point of 5 hours per week was used to categorize players as AVGPs. Players’ actual proficiency in action video games, however, was not assessed.

Moreover, as explained in section 5.2, the RT data calculated might not have reflected the processes intended to be measured. This is particularly true for the most cognitive task used: the Water Jug Problem. Slow RTs on this task, for example, could have indicated: a difficulty in calculation, lack of insight regarding the possibility of switching formulas, interference caused by additive effects, distraction, or fatigue. Thus, the interpretation of RT data ought to take into consideration the factors that might have affected the results.

Finally, nVGPs could have performed better than or similarly to AVGPs on the perceptual tasks because of their general exposure to technology. The regular use of smart phones requiring speeded responses could have provided nVGPs with an indirect form of perceptual training that could have accounted for their performance. The current study might have suffered from methodological problems that could account for the results. These issues will be discussed in section 8.

CHAPTER VIII

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The current study suffered from several limitations pertaining setting and sample characteristics. The most notable drawback pertained to the baseline group differences which were difficult to manipulate. First, the attitudes adopted by AVGPs and nVGPs towards the experiment differed. nVGPs were mostly PSYC 201 students who were offered extra credit on the course, a motivating incentive for participation. AVGPs were not only less motivated to take the experiment seriously because they did not receive any incentives, but also because the experiment interrupted the hour of gaming they had already paid for. This made AVGPs adopt an extremely dismissive attitude towards the experiment, as they were eager to finish and get back to playing their game. Also, the experiment with PSYC 201 students was always conducted in a quiet and secluded room with comfortable seating. The experiment with AVGPs, on the other hand, was conducted in loud and crowded computer laboratories where comfortable seating and focused attention were difficult to attain. These different experimental settings were not accounted for because of the difficulty of recruiting AVGPs. It was not possible to have players conduct the experiment in the psychology laboratory in AUB, as they were not given incentives to participate. Thus, the experiment had to take place in the crowded and loud computer laboratories in Hamra. This caused a discrepancy in the experimental settings between both groups, and might have seriously affected the results.

Moreover, the sample size of the current study (N = 93) might have not been large enough to insure statistical power for the MANCOVAs. Moreover, univariate and multivariate outliers constituted approximately 16.00 % of the final sample. These cases might have substantially influenced the data, but the cases were not removed and transformations were not used in an attempt to maintain statistical power and avoid the interpretative confusion of the data.

It is also possible that group differences did not emerge because of the somewhat lenient threshold that was used. A cut-off point of merely 5 hours of playing action video games per week was used to categorize participants as AVGPs. Even though the current study used the same criteria as the existing literature on video games, a more stringent cut-off point might have better accentuated group differences for future research. It might also be more prudent to include video game playing proficiency in the analysis, as it would ensure the recruitment of professional video game players, further accentuating group differences.

Thus, future research ought to insure standardized settings, which would allow for the control of extraneous variables in the experiment, such as distractibility. If it is difficult to recruit video game players to the laboratory in the university, one possibility would be to provide participants good quality noise canceling headphones during the experiment. This would at least decrease processing of external stimuli, allowing participants to focus their attention on the task. In the future, researchers could also provide monetary compensation (for the paid hour of gaming that the experiment interrupts), and monetary incentives. This would most probably motivate players to participate in the experiment, and to conduct the task seriously. Another recommendation for future research is to increase statistical power through a considerable increase in sample size. It also ought to accentuate group differences by using a stricter cut-off point of gaming experience, assessing proficiency in gaming, and insuring similar setting characteristics with stringent experimental control.

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Appendix A

Demographics and video game experience questionnaire

Personal Information

What is your age?

- ☐ -------- years old

What is your gender?

- ☐ Male
- ☐ Female

Are you currently enrolled in university?

- ☐ Yes
- ☐ No

What is the name of the institution in which you are currently enrolled?

- ☐ ------------------------------------

Video game experience

For how long have you been playing video games?

- ☐ I have been playing for -------- years

For the past **6 months ONLY**, approximately how many **hours** per **week**did you spend playing video games?

- ☐ -------- hours per week

For the past **6 months ONLY**, approximately how many **hours**per **session**do you spend playing video games?

- ☐ -------- hours per session

Please write the **name**(s) of the game(s) you usually play in the space provided:

1. --
2. --
3. --
4. --
5. --
6. --
7. --
8. --
9. --
10. --

Appendix B

Instructions

The Sternberg Memory task

"This sample demonstrates the Sternberg memory task. On the following trials, you will be see a sequence of digits presented one at a time printed in white. Immediately following each sequence, you will see a final digit printed in yellow. You task is to decide whether or not the yellow digit appeared in the preceding sequence. If the yellow digit appeared in the sequence, press the "F" key. If the yellow digit was NOT in the sequence, press the "J" key. If you are correct, you a green O will appear. If you are incorrect, a red X will appear. Press the space bar to begin."

The Attentional Set-Shifting Task

"Press SPACE to start the Task. You will be shown a series of letters and digits to which you should react as quickly as possible. Press CTRL when you see an even digit or a vowel. Press ENTER when you see an odd digit or a consonant. So:

CTRL → even + vowel

ENTER → odd + consonant

Press SPACE to start a practice trial".

The Wisconsin Card Sorting Task

"Your task is to sort the cards on the top of the screen into 1 of the 4 piles at the bottom of the screen. When you put the card into the right pile, the word "right" will appear on the screen. And if you put the card into the wrong pile, the word "wrong" will appear. The aim is to get as many cards into the "right" pile."

The Water Jug Problem

"You are given 3 types of measuring jugs A, B, and C. Each type can only measure one volume of water. You have an unlimited supply of water to fill the jugs with. Your goal is to measure a certain amount of water. To do that, you can transfer water from one jug to another, as many times as you want. To show how you got to the desired amount of water, use a formula with a series of additions and subtractions to represent addition and removal of water."

Appendix C

Figures

Figure 1

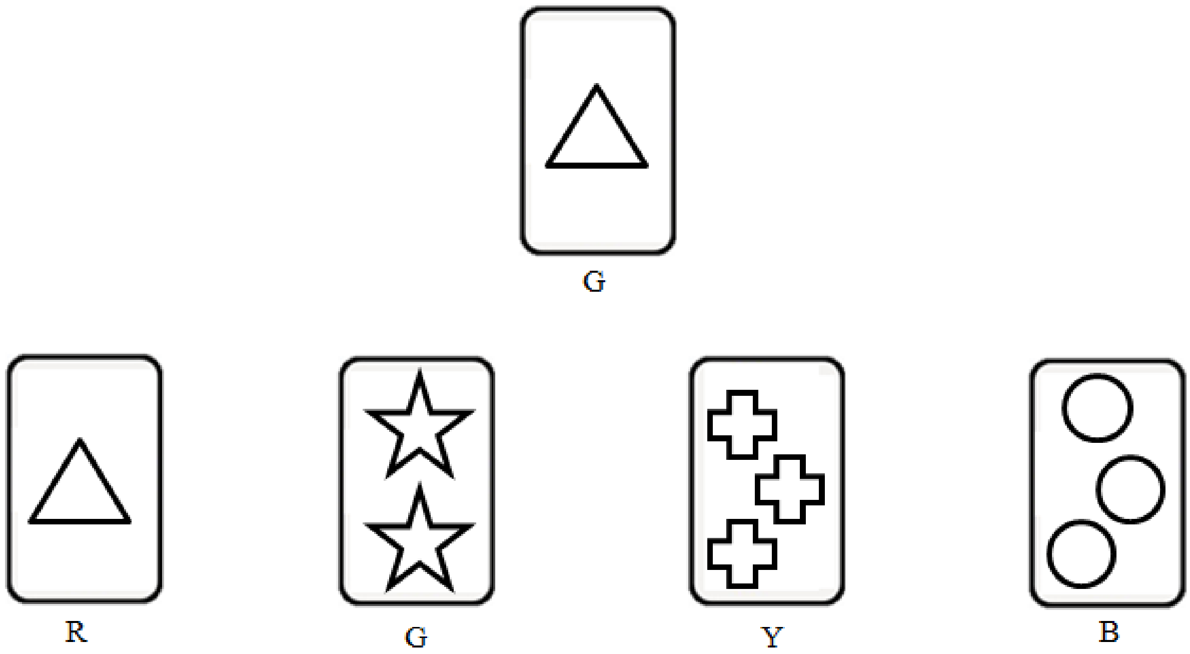

Figure 1. Preview of Stimuli on a Trial of the Wisconsin Card Sorting Task (WCST).

The capital letters designate the colors of the stimuli presented against a white background (Green, Red, Yellow, and Blue).

Figure 2

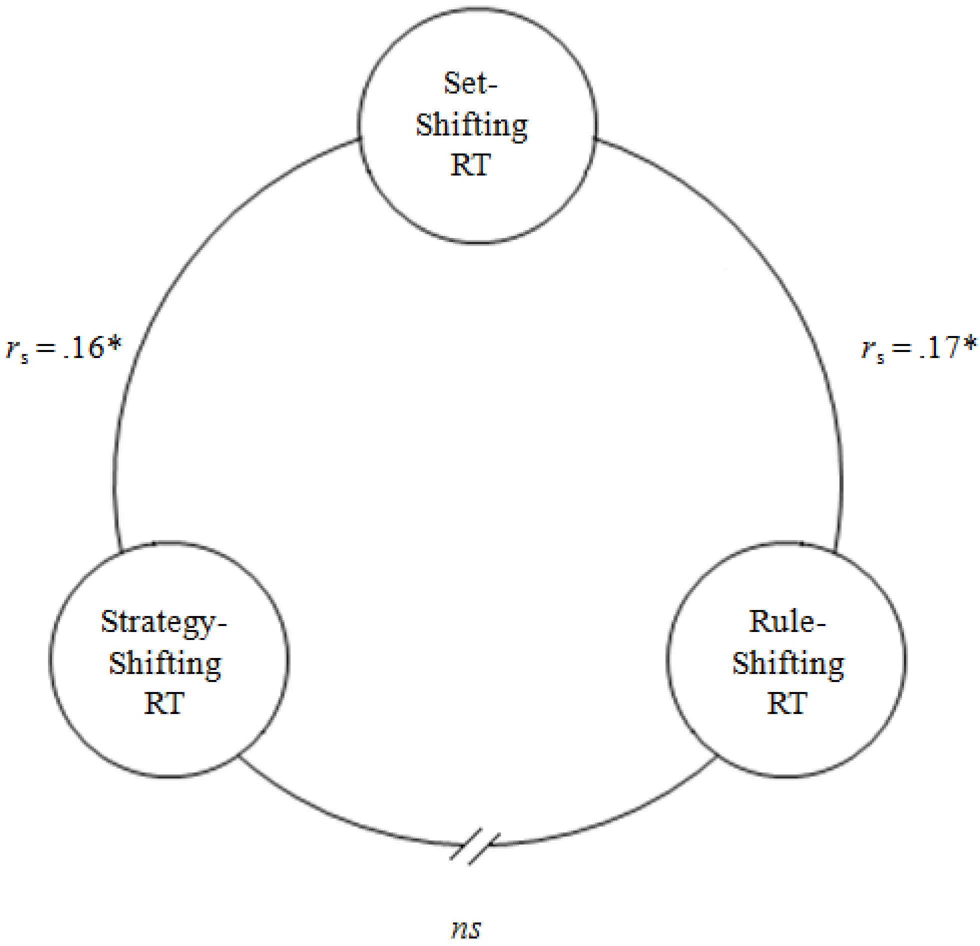

Figure 2. Spearman Correlation between RTs on the Set-Shifting, Rule-Shifting and Strategy-Shifting Tasks.

(* $p < .06$).

Appendix D

Tables

Table 1

Sample Characteristics: Means(Standard Deviations)

	Age	Experience (years)	Experience (hours/week)	Experience (hours/session)
All Participants	19.33 (1.83)	8.75 (4.53)	13.15 (15.78)	2.19 (2.03)
AVGPs	20.17 (2.23)	10.91 (3.21)	24.50 (15.17)	3.60 (1.95)
nVGPs	18.48 (.55)	6.53 (4.64)	1.56 (1.40)	.76 (.63)

Table 2

Wisconsin Card Sorting Task Variable Description

Dependent Variables of the WCST	Description
Categories Completed	Percentage of correct categories characterized by 3 correct consecutive responses
Set Loss	Percentage of times an incorrect response occurred after 3 or more consecutively correct responses
Perseveration of Preceding Criterion	Percentage of all incorrect responses that match the preceding no longer relevant rule
Perseveration of Preceding Response	Percentage of responses that are an exact repetition of the immediately preceding incorrect response
Non-Perseverative Errors	Errors that are non- perseverative and do not match any of the other criterion above

Table 3

Z-scores of Skewness and Kurtosis per Variable

Task	Variable	Skewness	Kurtosis
Sternberg Memory Task	Percent Accuracy	-12.08	20.53
	Average RT	7.75	10.30
Rule-Shifting Task (Wisconsin Card Sorting Test)	Average RT	10.41	20.76
	Switch-Trial RT	6.47	8.86
	Non switch-Trial RT	10.16	19.70
	Percent Accuracy	0.59	-0.05
	Percent PPC	-0.01	-0.67
	Percent PPR	2.40	2.10
	Percent CAT	1.08	-1.40
	Percent Set Loss	2.72	-0.51
	Percent NPE	1.91	-1.16
Set-Shifting Task	Average RT	5.17	2.62
	Switch-Trial RT	7.91	10.41
	Non Switch-Trial RT	4.74	1.71
	Percent Accuracy	-19.79	62.92

Strategy-Shifting Task (Water Jug Problem)	Average RT	9.07	16.22
	Non Switch-Trial RT	10.06	18.70
	Switch-Trial RT	10.91	21.27
	Percent Accuracy	-5.90	4.03
	Percent Correct Switch	-2.16	-2.5
	Percent Correct Perseveration	3.47	-1.44
	Percent Incorrect Switch	13.16	23.13

Table 4

Set-Shifting Task Descriptives

	Gaming Experience	
	AVGPs	nVGPs
	M (SD)	M (SD)
Average Reaction Time (milliseconds)	897.18 (201.59)	855.74 (199.39)
Switch-Trials Average Reaction Time (milliseconds)	887.44 (197.34)	877.51 (216.51)
Non Switch-Trials Average Reaction Time (milliseconds)	897.24 (205.85)	851.29 (197.99)
Accuracy (percentage)	94.85 (7.87)	97.06 (2.52)

Table 5

Wisconsin Card Sorting Task Descriptives

	Gaming Experience	
	AVGPs	nVGPs
	M (SD)	M (SD)
Number of Trials to Task Completion	82.09 (34.84)	81.98 (30.96)
Average Reaction Time (milliseconds)	3022.22 (1468.4)	2948.19 (1166.61)
Switch-Trial Average Reaction Time (milliseconds)	3238.04 (1467.6)	2938.82 (1132.14)
Non Switch-Trial Average Reaction Time (milliseconds)	2995.60 (1491.9)	2920.96 (1200.64)
Accuracy (percentage)	53.93 (12.76)	52.70 (12.20)
Categories Completed (percentage)	28.94 (14.63)	26.79 (11.54)
Set Loss (percentage)	1.11 (1.16)	1.00 (.95)
Perseveration of Preceding Criterion (percentage)	25.13 (7.44)	26.29 (7.68)
Perseveration of Preceding Response (percentage)	7.77 (3.26)	8.52 (3.94)
Non-Persevreative Errors (percentage)	12.14 (9.03)	11.60 (9.11)

Table 6

Water Jug Problem Descriptives

	Gaming Experience	
	AVGPs	nVGPs
	M (SD)	M (SD)
Average Reaction Time (seconds)	53.44 (37.00)	54.94 (26.40)
First switch-Trials Reaction Time (seconds)	29.10 (32.25)	23.54 (15.70)
Switch-Trials Average Reaction Time (seconds)	23.62 (16.63)	20.81 (10.66)
Non Switch-Trials Average Reaction Time (seconds)	71.34 (58.32)	75.41 (40.60)
Accuracy (percentage)	87.23 (13.91)	88.86 (15.86)
Correct Switching Responses (percentage of switch-trials)	58.87 (38.83)	66.66 (39.75)
Correct Perseverative Responses (percentage of switch-trials)	33.33 (36.12)	28.99 (39.51)
Incorrect Switching Responses (percentage of switch-trials)	7.80 (19.92)	4.35 (15.09)

Appendix E

Informed Consent Form

American University of Beirut

P.O. Box 11-0236

Riad El Solh, 1107 2020

Beirut, Lebanon

CONSENT TO SERVE AS A PARTICIPANT IN A RESEARCH PROJECT

Project Title: Action Video Game Play and Cognitive Flexibility in Late Adolescence and Early Adulthood

Project Director and Research Investigator: Nadiya Slobodenyuk, American University of Beirut (AUB)

Email: ns74@aub.edu.lb

Telephone: 01350000 ext. 4366

Research Collaborator (Co-investigator): Sinine Nakhle, American University of Beirut (AUB)

Email: ssn17@aub.edu.lb

Telephone: 70991353

Nature and Purpose of the Project:

The current study seeks to investigate the association between experience in video games and cognitive flexibility.

Explanation of Procedures:

As a research participant, you will have to read this oral consent form and consider carefully your participation. You will then receive a questionnaire from the research collaborator regarding your personal information and your experience with video games. You will later be asked to conduct four cognitive and perceptual tasks on a computer.

Your name will not be asked. Only the project director and the co-investigator will have access to the data. All results will be kept in a locked cabinet in the office of the research collaborator for a period of five years after which the data will be shredded.

It is expected that your participation in this survey will last no more than 30 minutes.

Potential Discomfort and Risks:

There are no more than minimal risks associated with participation in this survey, expect for the possibility of some unforeseeable risks.

Potential Benefits:

The potential benefit is that you will participate in a study that will contribute to the field of Cognitive Psychology. The results of this study, which will be based on approximately 200 video game players and nVGPs, will help determine whether there is a link between experience in video games and enhanced cognitive flexibility (i.e. the ability to switch between tasks).

Costs/Reimbursements:

Your participation in this survey incurs no costs and there are no monetary incentives. If you are currently enrolled in PSYC 201, however, you will receive credit in the course upon your full participation in the study.

Alternative Procedures:

If you decide not to give oral consent to respond to the questionnaire or conduct the computerized tasks, no alternative procedures will be offered. You may, however, contact the project director or co-investigator to learn more about the study conducted.

Alternatives to Participation:

There are no alternatives to participation if you were to decide not to participate in this survey.

Termination of Participation:

Should you decide to give oral consent to participate in this survey, the project director co-investigator might disregard your answers if the results show that you have not abided by the instructions given at the top of each set of questions.

Confidentiality:

The results of your participation will be kept confidential to the fullest extent possible. This means that only the project director and co-investigator will know about your specific results, which will be anonymous, as no identifying information would be linked to the data you provided. Only information that cannot be traced to you will be used in reports or manuscripts published or presented by the director or investigator.

Raw data on data-recording systems will be kept in a locked cabinet in the office of the co-investigator for a period of five years following the termination of the study. After the five years have elapsed, the hardcopy of raw data will be shredded and the soft copy deleted.

Withdrawal from the Project:

Your participation in this survey is completely voluntary. You may withdraw your consent to participate in this research at any point without any explanation and without any penalty. You are also free to stop answering the questionnaire or conducting the computerized tasks at any point in time without providing any explanation.

Who to Call if You Have Any Questions:

The approval stamp on this consent form indicates that this project has been reviewed and approved for the period indicated by the American University of Beirut (AUB) Institutional Review Board for the Protection of Human Participants in Research and Research Related Activities.

If you have any questions about your rights as a research participant, or to report a research related injury, you may call:

IRB, AUB: 01-350000 Ext. 5543 or 5540

If you have any concerns or questions about the conduct of this research project, you may contact:

Project Director and Research Investigator: Nadiya Slobodenyuk, Email: ns74@aub.edu.lb

Telephone: 01350000 ext. 4366

Or the Research Collaborator (Co-investigator): Sinine Nakhle

Email: ssn17@aub.edu.lb

Telephone: 70991353

Debriefing:

If you are interested in learning about the outcome of the study, you may contact Nadiya Slobednyuk (telephone: 01350000 Ext. 4366) or Sinine Nakhle (telephone: 70991353). After data analysis is complete, a summary of the results can be emailed to you upon request.

Oral Consent to Participate in this Research Project:

Only your oral consent is needed. By consenting you agree to participate in this research project. The purpose, procedures to be used, as well as, the potential risks and benefits of your participation have been explained to you in detail. You can refuse to participate or withdraw your participation in this study at any time without penalty. You will be given a copy of this consent form.

____

Printed Name of Research Director

_________________________________ _________________________________

Signature of Research Director Today's Date

INSTITUTIONAL REVIEW BOARD APPROVAL STAMP:

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