How expertise can modulate spatial attention within and across sensory modalities:

The case of video game players

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

Psychology

August 2011

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Keywords: Attention, Perception, Cognition

Dedication

It is often said that in life we meet a few people that will have such an impact on us that we are better people after having met them. Dr. Edward P. Chronicle was definitely one of those people. This dissertation is dedicated to Edward P. Chronicle, a professor who saw promise in me, an advisor who guided me, and a friend who is always with me.

Acknowledgments

I thank my parents, who have always believed in me. My mom for providing persistent reminders that I have a degree to finish and my dad for his quiet encouragement.

I thank Michelle Sagucio for always inspiring me to succeed and for always pushing me to be the best that I can be. Her words are always uplifting and she has the uncanny ability to provide hope when it seems like there is none.

I thank Joel Sabugo, a best friend and a true brother. He always provided sound encouragement and guidance. More importantly, he was always there whenever I needed a beer.

I thank the undergraduates who have helped with much of the grunt work associated with this dissertation – Chloe Dooley, Jessica Kosel, Devin Madan, Ronny Marotz, Nicole Muszynski, Jenna Nishita, and Jeremy Thacker. Their diligence and hard-work was definitely instrumental in the recruitment of participants and the completion of the training experiments. I thank each of them with much sincerity.

I thank Marvin Chandra for his unique wit and uncanny knowledge of SPSS. However, Marvin, "His Airness" will never be surpassed by the "Durantula" as the greatest basketball player to ever play the game. It just will not happen.

I thank all of the individuals who took part in this study; the time that they gave me (especially those who willing volunteered 14 hours of their time for a few extra credit points) is very much appreciated.

I thank all of the members of my thesis committee: Dr. Scott Sinnett, Dr. Patricia Couvillon, Dr. Alexander Doumas, Dr. Kentaro Hayashi, and Dr. Curtis Ikehara. I thank each of them for their knowledge and input in the development of this dissertation.

Finally, I especially thank Scott for becoming my major advisor during his first year as a faculty member, despite being advised not to. I truly appreciate him taking me on. His encouragement and honesty made the experience of working with him over the last three years very worthwhile. It would be an understatement to say that I learned a lot from him, because I gained so much more than can be written or said (especially random Canadian facts and an appreciation for the Canadian flag). I thank him for all of the impromptu meetings in his office. I especially thank him for missing the season finale of *The Office* so that he could finish correcting and reviewing this dissertation. I really hope that he DVR'd it. Most importantly, I thank him for his steadfast guidance because without it this research would not have been possible.

Abstract

Action video games have been shown to have a robust effect on modulating basic visual attentional mechanisms. Despite this, very little work has explored how spatial attention is modulated by video game play, and whether or not any potential enhancements in attention are seen outside of the visual domain. This dissertation addresses both of these areas, specifically, how spatial attention is modulated after habitual video game play was assessed using a temporal order judgment task coupled with exogenous (peripheral) and endogenous (central) cues. The experimentation was conducted within and across different sensory modalities (vision and audition) to partially address the debate of whether or not the human attentional system operates in a segregated manner allowing each sense individualized attentional resources, or, if instead, a supramodal attentional system dictates resources. An additional set of experiments was conducted that involved only participants who did not previously play video games, but were subjected to a video game play intervention separating pre and post-tests. The findings provide some evidence suggesting that video game play can modulate attentional processing across sensory modalities.

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List of Abbreviations

AB ..... Attentional Blink

ANT ..... Attentional Network Task

CSF ..... Contrast Sensitivity Function

fMRI ..... Functional Magnetic Resonance Imaging

JND ..... Just Noticeable Difference

MOT ..... Multiple Object Tracking

MRT ..... Mental Rotation Task

NVGP ..... Non-Video Game Player

PS3 ..... Playstation 3

PSS ..... Point of Subjective Simultaneity

RSVP ..... Rapid Serial Visual Presentation

SOA ..... Stimulus Onset Asynchrony

TOJ ..... Temporal Order Judgment

UFOV ..... Useful Field of View

VGP ..... Video Game Player

Chapter 1:

Introduction

Chapter 1: Introduction

1.1. Rationale for the Dissertation

The mechanisms of attention and perception have been empirically investigated for more than a century (James, 1890; Titchner, 1908). Yet, despite more than a century of scientific inquiry much is still left to learn. For instance, to what degree can mechanisms of attention and perception be modulated based on training? Recent evidence addresses this very question and suggests that expert video game players (VGPs) have modulated attentional and perceptual capabilities when compared with non-video game players (NVGPs). Broadly speaking, a number of findings demonstrate that VGPs process and respond to visual information more efficiently (i.e., faster and more accurately) when compared with NVGPs (Chisholm, Hickey, Theeuwes, & Kingstone, 2010; Colzato, Leeuwen, & Van Den, 2010; Donohue, Woldorff, & Mitroff, 2010; Dye & Bavelier, 2004; Dye, Green, & Bavelier, 2009; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Green, Li, & Bavelier, 2010; Green, Pouget, & Bavelier, 2010). However, there are two remaining questions that have yet to be thoroughly investigated: the potential effects of training, and whether these enhanced visual capabilities can be observed in other sensory modalities. The latter question is of particular interest, as the possibility that incorporating a potentially enjoyable task leading to enhancements in visual processing could lead to concomitant enhancements in other sensory modalities has implications at both theoretical and practical levels.

1.2. Summary of Dissertation Goals

This dissertation addresses two under-researched areas in the domain of information processing. First, the research explores how spatial attention is possibly modulated in a group of expert VGPs and NVGPs who have been trained with a video game. More specifically, the experimentation explores how exogenous and endogenous spatial attention can be modulated by distracting cues. The ability of the attentional system to inhibit irrelevant information and maintain goal directed behavior is of key importance to everyday functioning. The possibility that this could be enhanced by video game play is important when considering a number of practical applications (i.e., education, safety). To explore this, a traditional cuing paradigm (see Posner, 1980) was combined with a temporal order judgment (TOJ) task (refer to sections 2.2.2 for an in-depth discussion of the TOJ task).

Despite the multimodal presentation of video games and the multisensory world that we operate in, the investigation of the effects of habitual video game play on attention has focused nearly exclusively on the visual domain, with the exception of two recent studies (Donahue et al., 2010; Green et el., 2010). Therefore, the second goal of this dissertation explores the possibility that enhancements in one sensory modality could spill over to other sensory modalities, a notion that has received little investigation. The research presented here explored the question of whether or not the effects seen in the visual modality can lead to concomitant enhancements in the auditory modality and also across modalities (audiovisual presentations). An association could indicate that performance improvements seen

after action video game training or habitual video game play have the ability to affect a supramodal attentional system (Driver & Spence, 2004). To address this issue, expert VGPs and NVGPs (before and after training) were given basic tests of attention in not only the visual modality, but also the auditory sensory modality, as well as across modalities. These results have a direct impact on the debate as to whether attentional resources for different human senses have individualized access to separate reservoirs of resources (i.e., segregated system of attention; see Sinnett, Juncadella, Rafal, & Azañon, 2007; Soto-Faraco & Alsius, 2007; Wickens, 1984), or if a common reservoir of resources is available for all senses (i.e., supramodal system of attention; see Driver & Spence, 2004; Duncan, Martens, & Ward, 1997; Farah, Wong, Monheit, & Morrow, 1989).

If expert VGPs demonstrate enhanced performance when compared with NVGPs, this would provide initial evidence for an attentional system that can be modified through a cognitive intervention strategy involving video games. This is precisely what we explored (see Chapter 3). However, it is possible that any potential improvement is related to a self-selection bias in that those with enhanced attentional and perceptual capabilities gravitate towards video game play. In order to address this concern, a further set of experiments was conducted to determine if NVGPs could undergo a video game training regimen that would lead to enhancements based solely on the cognitive intervention (see Chapter 4). These experiments provided an opportunity to expand on current research involving video game players to determine whether video game play can increase basic visual attentional and perceptual capabilities.

Listed below are the major aims for this dissertation.

1. Assess the effects of habitual video game play on visual spatial attention using a TOJ task coupled with endogenous and exogenous cues.
2. Assess the possibility of enhanced attentional processing in separate modalities by expanding the TOJ paradigm to the auditory modality.
3. Assess crossmodal interactions by expanding the TOJ task to include a combination of visual cues and auditory targets.
4. Determine whether the attentional enhancements seen in VGPs can also be seen in NVGPs who are trained with action video games, as measured by the TOJ task within and across sensory modalities.

Before explicating the findings, a thorough review of relevant research on mechanisms of attention and perception is provided

1.3. Historical Overview of Attention Research

Prior to the founding of modern psychology, most of our understanding of attention was philosophical in nature (Johnson & Proctor, 2004). For instance, philosophers like Juan Luis Vives and Nicholas Malebranch provided conceptual analyses of attention and its role in perception and thinking. Vives proposed that the retention of stimuli in memory is dependent on the length of time spent attending to

the stimuli (Vives, 1538; Murray & Ross, 1982). A century later, Malebranche (1674, p. 412) suggested that:

> The mind does not pay equal attention to everything it perceives. For it applies itself infinitely more to those things that affect it, that modify it, and that penetrate it.

However, empirical investigation of these early ideas did not appear until the 19th century. For instance, a common thought in the 1800's was that people could not attend to more than one thing at once (Johnson & Proctor, 2004). However, Jevons (1871) created a primitive experiment in which beans were dropped into a box while observers were required to count as many as possible at a given moment (Jevons, 1871; Fernberger, 1921). Jevons estimated the limit to be four items. Critically, these early ideas demonstrated the limits of visual attentional information processing and provided a starting point for future research.

1.3.1. Early Selection vs. Late Selection Theories of Attention

It is often noted that the study of attention was given little emphasis during a period that spanned approximately forty years from 1910 to 1950 (Johnson & Proctor, 2004; Keele, 1967; Moray 1969; Neisser, 1976). In fact, Moray (1969) stated that attention research was nonexistent from about 1930 onwards (with the notable exception of Stroop, 1935). During this period of time, many major global events took place, including both World Wars as well as the Great Depression. Much of the focus in psychology had shifted to behaviorism, which dominated

psychological thought. A resurgence in the study of attention did not come until the mid-20th century.

A particularly influential investigation by Cherry (1953) set the stage for a number of seminal findings in the attention literature. The "cocktail party" effect is a phenomenon that shows that when someone is engrossed in a conversation in a situation where others are conversing simultaneously (i.e., a party), it is very difficult, if not impossible, to attend to other conversations. This demonstrates that attention can function selectively and aid in inhibiting irrelevant information. However, if a particularly salient word is said in a separate conversation (i.e., your name, see Moray, 1959), then sometimes you are able to notice that event[1]. This could seemingly suggest that although ignored, some level of processing, perhaps to a semantic level, of other conversations is ongoing.

Cherry (1953) used an auditory paradigm termed the dichotic listening task. In this classic test, participants listen (with headphones) to two different streams of auditory stimuli, with each stream being directed to a separate ear. The task typically requires participants to repeat aloud (i.e., shadow) what is spoken at a single attended message. After this initial shadowing task, a surprise test is given that determines what could be recalled from the unattended channel (i.e., the other ear). Cherry's findings showed that only the most basic physical characteristics of the unattended messages could be discerned, such as the gender of the speaker or the presence of a tone. That is, participants were unable to, for instance, determine

[1] Note, contrary to popular belief, this effect only occurs in approximately a third of participants in a dichotic listening task (Conway, Cowan, & Bunting, 2001).

if the language in the unattended channel switched (from English to German, or vice versa), or even if the message was presented backwards.

Broadbent (1958) provided converging evidence in support of Cherry's findings and developed an initial model of attention. In this seminal work he utilized the split-span technique (see Figure 1). In this task participants are presented with three single digit numbers read one after the other to one ear while simultaneously presented with a separate set of digits presented to the other ear. Participants are instructed to report all numbers that are heard in both ears. Broadbent's participants recalled items in sets, that is, the digits that were read in one ear before reciting the digits that were read to the other ear. Accordingly, Broadbent's filter theory posits that a selective filter allows information to be selected based on only the most basic physical characteristics (i.e., location). Such a filter would potentially help to protect against information overload and serve to allow only selected portions of incoming information to pass through. In this initial stage, physical properties are processed in a parallel manner before selection, after which each item is processed serially. Information that does not pass through the selective filter is blocked and goes unprocessed (i.e., not consciously perceived at a semantic level). All information that passes the selective filter is processed serially allowing for more complex properties such as the semantic meaning of the word to be processed, and ultimately guide goal directed behavior. Broadbent's filter theory is considered to be an example of an early selection theory because only one message can get selected for processing at a time (see Figure 2 for a conceptual diagram of Broadbent's original filter theory).

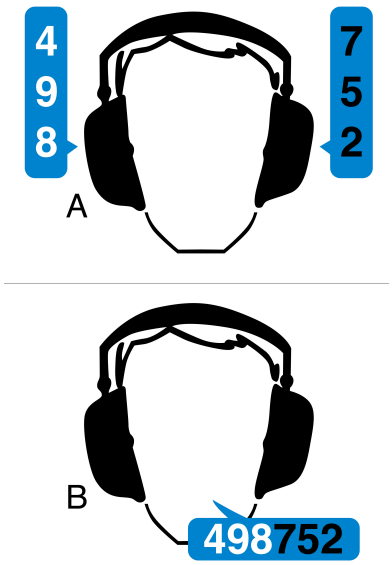


Figure 1. Broadbent's split-span experiment illustrating the digits being presented to each ear (A) and the participant's response (B). The numbers are presented at a rate of 2 simultaneous digits per second, with one digit presented to each ear. In this example, the order of presentation would alternate from ear to ear in the following order, 4, 7, 9, 5, 8, 2. The task for participants is to report all numbers. Participants reported numbers in groups based on the location that they were presented. In this example, the participant would report the numbers presented to one ear and then report the letters presented to the other ear.

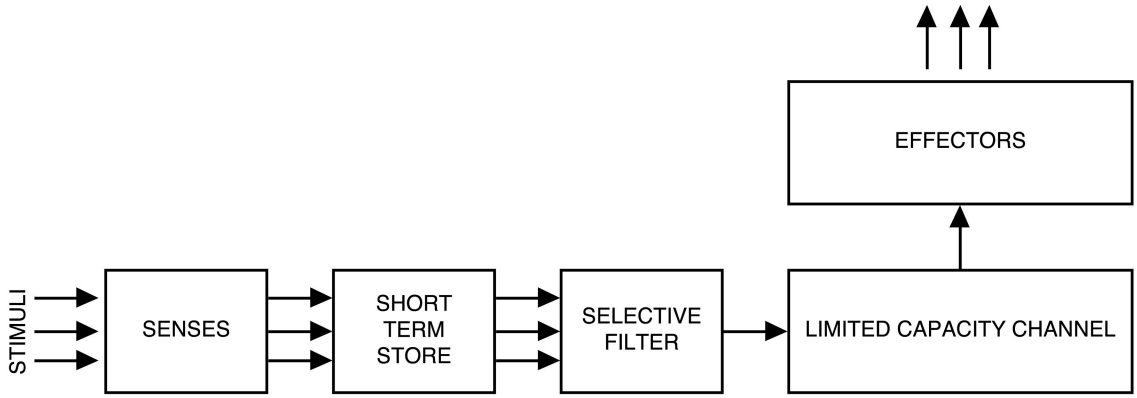


Figure 2. Broadbent's original filter theory of attention (an example of an early selection theory). Adapted from Broadbent (1958).

Moray (1959) immediately challenged Broadbent's (1958) filter theory after using the dichotic listening paradigm in his experiments. As previously mentioned,

Moray found that participants were able to recognize their own name when it was presented to the unattended ear. According to Broadbent's filter theory, this should not be the case since limited capacity only allows for the filtering of information based on physical attributes such as gender voice and pitch. This finding demonstrated that some level of processing had to occur for the information presented at the unattended ear (see Wood & Cowan, 1995 for a more recent example).

Directly addressing the notion that the unattended message undergoes a certain degree of semantic processing, Treisman (1960), who ironically was a graduate student of Broadbent, used dichotic listening tasks similar to previous examples to demonstrate that information presented to an unattended ear can pass through the supposed filter. In her seminal investigation, participants were told to shadow a story in one ear and ignore another story that was simultaneously read to the other ear (1960). The shadowed story would then be switched to the unattended ear. But rather than simply switch the channels, an entirely new story was presented to the attended ear. Again, according to Broadbent's theory, when the stories switched, participants should have immediately carried on and shadowed the new story, as the message would be selected by location (i.e., the attended ear), thereby not allowing information from the story that was previously presented to the attended location to reach conscious perception after the switch occurred (as it was now presented to the unattended ear). As expected, Treisman found that participants were able to recall information after the switch from the new story (i.e., the attended ear). However, and more importantly, participants were also able to

recall some information from the story that was switched to the unattended ear even after the switch had been made, despite task instructions being to attend to the other ear. Treisman's critical findings led her to develop a competing model of attention that extended Broadbent's (1958) original filter theory.

Treisman's (1960) attentuation theory posits that a filter preceding identification is still present early in processing (like Broadbent's original filter theory), however, she suggests that the filter attenuates unattended stimuli rather than completely blocking it. Under this assumption, the ability to recognize one's own name when presented at the unattended ear (see Moray, 1959) could be explained because very salient material at the unattended channel would reach threshold and consequently be processed to conscious levels of perception. Although Treisman's filter-attenuation theory posited that unattended information is able to be processed later than was suggested by Broadbent, Treisman herself still considered her attenuation theory to be a variant of early selection, rather than late selection theories, while some (see, for example, Driver, 2001) consider her theory to be a compromise between both models (i.e., Deutsch & Deutsch, 1963; see below for discussion). Whereas Broadbent's filter theory supposed that unattended information that reaches the filter is lost and therefore not consciously perceived, Treisman's research suggested that unattended information can pass the selective filter and be consciously perceived.

Directly opposing the early selection theory (Broadbent, 1958), Deutsch and Deutsch (1963; see also Duncan, 1980; Norman, 1968) proposed that there was limited awareness for all unattended stimuli. According to Deutsch and Deutsch,

there is no early selection filter and therefore attention is not required to perceive and process items. This stance assumes that stimulus identification is performed in parallel over the visual field, while the serial stage is concerned only with selection for response and/or memory. So, unlike early selection theory, late selection proponents posit that information could be perceptually processed and identified without attention. The caveat is that this information will rapidly decay if attention is not placed on it. Please refer to Figure 3 for a schematic depiction of the three theories of attention discussed in this section.

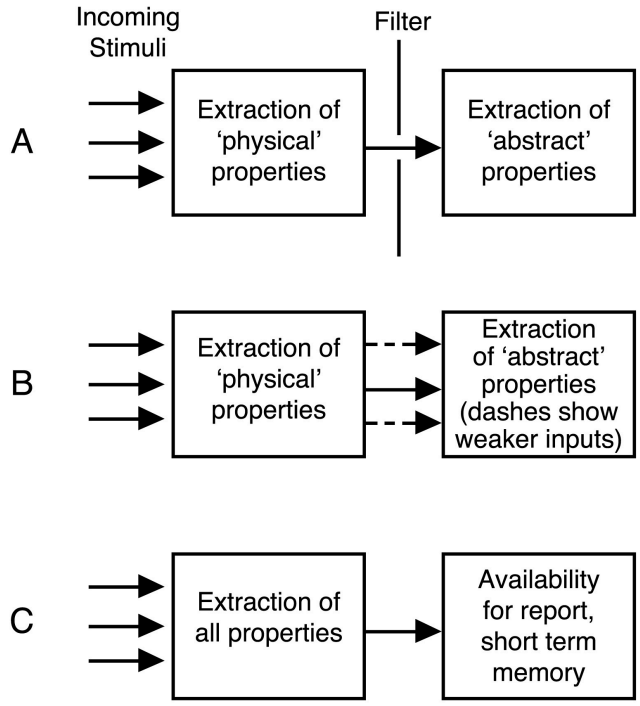


Figure 3. Schematic depiction of three influential accounts of selective attention adapted from Driver (2001). The figure illustrates the similarity of various theories of attention to Broadbent's original filter theory. A = Broadbent's original early selection filter theory (1958), B = Treisman's attenuation theory (1960), C = Deutsch and Deutsch's late selection theory (1963).

1.3.2. Perceptual Load Theory

The debate between early selection theorists and late selection theorists has been a controversial topic for decades. Recently, Lavie (1995) provided insight into this topic by examining how the processing of irrelevant information is modulated by perceptual load levels (Lavie & Tsal, 1994; Lavie, 1995, 2005). Perceptual load theory posits that the degree to which irrelevant information is processed is inversely related to the perceptual processing load of the relevant information that is being attended to. Therefore, when the processing load for a task is low (the task is easy), then it is more likely that irrelevant information will be captured and processed (i.e., late selection theory). Instead, if load is high, then only the attended information will be processed (i.e., early selection theory).

Demonstrating this relationship between load and attentional processing, Lavie (1995) presented participants with a go-no-go task in which they were asked to make responses to letters under both low and high load conditions (see Figure 4). For instance, in a low load situation (i.e., easy task), participants would be cued with a "go" cue (i.e., respond to the blue shape) or a "no-go" cue (i.e., restrict responses to the red shape). Trials that included the "go" cue required participants to identify the targets (i.e., H or U) by pressing the respective letter on a keyboard. Trials that included the "no-go" cue did not require a response. The high load conditions manipulated the cues to be a combination of shapes and colors. For instance, the "go" condition could be either a red circle or blue square, while the "no-go" condition could be either a red square or blue circle. Of key interest is the degree to which

task-irrelevant information was processed across conditions. The results demonstrated that increasing the demands of the task resulted in a decreased perception for irrelevant distractors (i.e., the facilitated performance seen for congruent conditions was eliminated). Generally speaking, when attentional capacity is reduced by a difficult task, limited resources are available to be directed to irrelevant information.

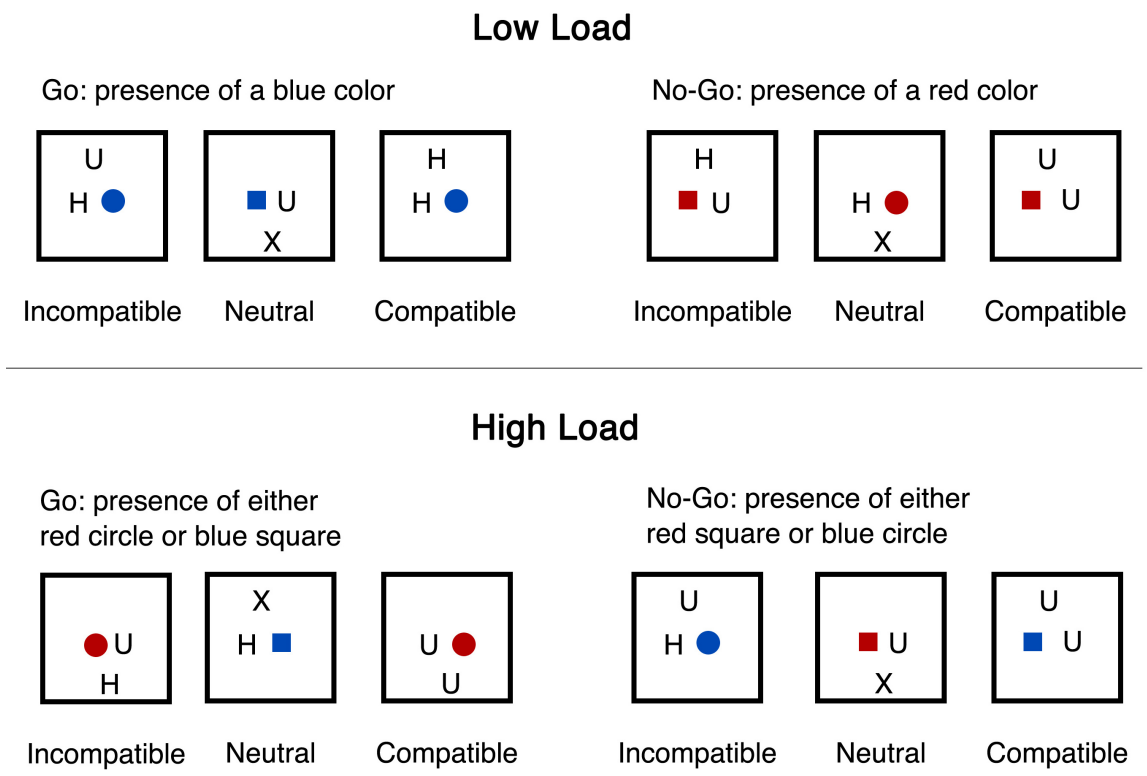


Figure 4. Presented here are examples of the stimuli used in Lavie's (1995) go-no-go experiments on perceptual load (adapted from Lavie, 1995). When a "go" signal was presented, participants were asked to respond to the letters horizontally flanking the cue, while ignoring letters that appeared above or below.

Lavie's (1995) experiments on perceptual load provide a possible resolution to the early vs. late selection debate. The basic premise is that when perceptual load is high, selection occurs early (early selection). Conversely, when perceptual load is

low, sufficient attentional resources are available and in effect spill over to process irrelevant information (late selection). The proposed experiments for this dissertation have the potential to build on the work that Lavie has done in regards to perceptual load theory. Furthermore, perceptual load theory might provide a possible explanation for the visual attentional enhancements seen in video game players.

1.3.3. Space Based Attention

Exogenous vs. Endogenous Orienting

Much of the contemporary discussion in the literature investigating attention has centered on space-based versus object-based models of attention. The space-based approach to attention posits that there is a supposed "spotlight" that favors processing for everything within its field (Posner, Snyder, & Davidson, 1980). In this seminal article, Posner et al. (1980) used different types of cues to orient participants to different areas in visual space. In one experiment, participants were asked to identify 1 0f 10 target uppercase letters that appeared either to the left or to the right of fixation. Prior to the presentation of the target letter, Posner et al. (1980) presented either a central location cue (arrow pointing left or right; a plus sign served as a neutral cue) or a central form cue (one of the uppercase target letters). The cue would therefore indicate either the identity of the target letter, the location of the target letter, or both the target letter and location. Posner et al. found that response latency was fastest when participants were provided with valid location information, intermediate when provided with a neutral cue, and slowest when provided with an invalid cue. Posner's classic cueing paradigm lead to a

number of basic concepts still referred to when describing how the attentional system functions (Posner, 1980). Klein & Shore (2000) would later suggest that different types of cues serve to direct movement of the attentional spotlight.

When discussing spatial attention it is important to address the differences between exogenous and endogenous orienting. Exogenous orienting of attention is controlled by the environment and is thought to arise in situations where attention is reflexively (i.e., automatically) captured by some sort of event (Posner, 1980). For instance, a loud sound or crash would capture one's attention in an obligatory manner requiring the individual to automatically orient towards the direction of the origin of the sound or crash. An analogous laboratory design involves peripheral presentations on the screen, such as a flashing box or star. This type of orienting can be contrasted with endogenous attentional orienting, or volitional orienting. Endogenous orienting is thought to be controlled by specific instructions or intentions and is therefore directed by the individual. In the laboratory, endogenous orienting is often represented by presenting items in the center of the screen, such as an arrow pointing to the left or right[2]. Experiments investigating attentional orienting in space often require participants to respond to a target that is either peripherally (exogenously) or centrally (endogenously) cued. In a congruent trial, the cue will indicate the location of the target stimuli, whereas incongruent trials will have cues that indicate the incorrect position. Participants are simply required to respond to stimuli (often by pressing a key) as quickly as

[2] Although recent research by Ristic and Kingstone (2006) suggests that central cues can trigger reflexive shifts in attention in a similar manner as peripheral cues.

possible. Participants in these types of investigations are significantly faster to respond to congruent trials than they are to incongruent trials (Posner, 1980).

Within each type of orienting (exogenous or endogenous), attention can be moved overtly or covertly. Overt orienting refers to reflexive or controlled movements of the eyes or head in the direction of where attention is to be directed (Posner, 1980). The classic example of overt orienting is when, for instance, someone points a finger and says "hey, look here." The person to whom the attention is being directed, typically, quickly responds by moving his or her head in the direction of the finger. Unlike overt orienting, covert orienting tends to be much more controlled with no movements of the head or neck. Covert orienting is the act of filtering out irrelevant information and focusing on one of several sensory stimuli. If one were asked to focus attention on a specific word within a paragraph, one would still be able to read words above and below the target word as well as words to the left or right.

Posner's Three Network View

Posner's conceptualization of attention has influenced the field greatly since the 1980s. Recently, he has suggested a revised way of conceptualizing how attention operates in what has been termed the Three Network View. (2004). According to Fan and Posner (2004), attention can be seen as its own system complete with its own anatomy and circuitry. Traditionally, attention was thought to be modular in nature in that specific regions of the brain were dedicated to specific components of attention (Posner & Peterson, 1990). Furthermore, Posner

and Peterson (1990) suggested that attention is comprised of three separate functional components or networks: alerting, orienting, and executive control. Alerting refers to the ability to stay focused in anticipation of an expected event, such as a runner waiting for the gun to go off signaling the start of a race. Of course, if the alerting mechanism of the runner falters, then he may not fare so well in the race. The orienting function serves to select one source of information to process amongst many possible sources. The runner might orient his or her attention to only the starting sound and the finish line while ignoring noisy fans in attendance. Finally, executive function refers to more complex functioning that usually involves performing a novel task or multiple things at once. The runner must not only focus his or her attention on the finish line but must also make sure he does not step outside of the boundary line and must be aware of the place of his or her opponents.

The Attentional Network Task (ANT) was developed to measure the three aforementioned components of attention (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & Raichle, 1994). The ANT has been explored using a combination of the cued reaction time (Posner, 1980) and flanker tasks (Eriksen & Eriksen, 1974) (see Figure 5). For instance, alerting and orienting functions are tested using four cue conditions. While the efficiency of the alerting network is examined by changes in reaction time that are a result of a warning signal, the efficiency of orienting is measured by changes in reaction time that accompany cues that indicate where the target will occur. In the spatial cue condition, the cue indicates the likely position of the target location (alerting and orienting involved). To test executive function, participants are presented with a central target arrow in the middle of a computer

screen that either points to the left or the right and an arrow that appears either above or below a fixation point. Participants are required to press either the left key when the arrow points to the left or a right key when the arrow points to the right. While this obviously measures orienting, executive functioning is also involved as some trials also involved additional stimuli that are irrelevant to the task. These stimuli must therefore be inhibited. Specifically, flanker arrows are presented simultaneously with that of the central target arrow. These arrows can either be congruent or incongruent to that of the central target arrow. In the congruent condition, the flanker arrows points in the same direction as the central target arrow. In the incongruent condition, the flanker arrow points in the opposite direction of the central target arrow. Fan et al. (2002) found that the ANT produced reliable estimates of alerting, orienting and executive function. Results from this study suggested that the three networks are dissociable, and that the three functions of attention (alerting, orienting, and executive function) are regulated by separate brain mechanisms.

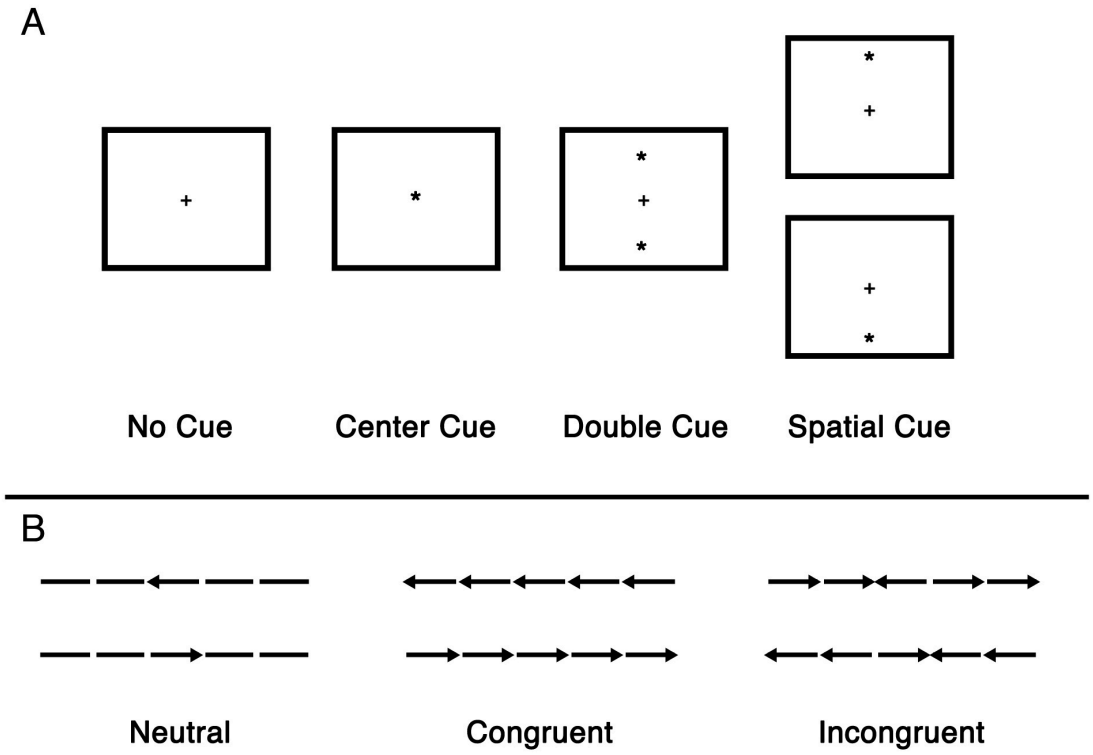


Figure 5. The attentional network test. (a) The four cue conditions used in the portion of the ANT that tests for alerting and orienting mechanisms; (b) The six stimuli used in the portion of the ANT that tests for executive function; and (c) An example of the procedure. Adapted from Fan et al. (2002).

1.3.4. Supramodal vs. Segregated Systems of Attention

As discussed in the upcoming chapter, behavioral studies on spatial attention in general have only considered one sensory modality at a time. However, there is evidence that suggests that different sensory modalities (i.e., vision, audition, haptic) potentially share attentional resources. Indeed, Driver and Spence (1998) demonstrated that driving attention to one sensory modality can actually enhance and facilitate the processing of stimuli in other sensory modalities (see also McDonald, Teder-Salejarv, & Hillyard, 2000; Spence, Nicholls, Gillespie, & Driver, 1998). The evidence for multisensory links between separate sensory modalities

has prompted the idea of a supramodal attentional system, theoretically serving as a common reservoir of attention that is shared amongst the different sensory modalities (see Farah et al., 1989).

Along with the behavioral evidence for a supramodal attentional system, there are also numerous neuroimaging studies that support this hypothesis. For instance, in a study utilizing functional magnetic resonance imaging (fMRI) incorporating visual and tactile stimuli, researchers were able to demonstrate that a common area of the brain (premotor cortex and intraparietal sulcus) becomes activated regardless of the sensory modality being discriminated (Macaluso, Eimer, Frith, & Driver, 2003).

Despite the evidence in support of a supramodal attentional system, there are a number of findings that seemingly point towards a segregated system, with individual modalities having specified resources. For instance, patients suffering from hemispatial neglect often have a dissociation in deficits across modalities (i.e., limited visual attention with spared auditory attention, and vice versa; see Sinnett et al., 2007).

As discussed thus far, there is evidence to support both a supramodal and segregated model of attentional distribution across the senses. One of the goals of this dissertation was to directly address this issue by exploring the effects of video game play on separate sensory modalities. In the following chapter, a thorough review of the current literature will focus on the recent evidence suggesting that habitual action video game play leads to enhanced attentional and perceptual capabilities.

Chapter 2:

Modulating Attention After Video Game Play

Chapter 2: The Development of Attentional Skills in Video Game Players

Video game play is a worldwide phenomenon with retail revenue in the US alone reaching 19 billion dollars in 2009 (NPD, 2010). Advancements in gaming hardware and software have made it possible for very realistic game play and have been the impetus for growth within the gaming industry. According to The Entertainment Software Association (2010), more than two-thirds (68%) of all American households play video games. Given that many people now have extensive video game experience, investigators have been able to use this sample to explore the malleability of the human attentional system. Indeed, a number of studies have demonstrated enhancements in basic perceptual and attentional mechanisms in habitual video game players (Green & Bavelier, 2003, 2006a, 2006b, 2007).

2.1. What Are Action Video Games?

As attentional enhancements have thus far only been observed after experience with *action* games, it is important to distinguish these types of games from other genres. The category of action video game typically includes subgenres like fighting games, shooting games, and platform games. When recruiting participants, researchers tend to create groups that include people who primarily play action-shooting games that are either first-person shooters (e.g., *Halo, Medal of Honor, Call of Duty*) or third-person shooters (e.g., *Gears of War, Grand Theft Auto*). First-person shooters are set in that perspective, that is, the game player experiences the game through the eyes of the player's character. A third-person

shooter is very similar to a first-person shooter, with the main difference being that the player's character is visible on the screen.

Green, Li and Bavelier (2009) have suggested that action video games share a particular set of features, such as extraordinary speed, a high degree of cognitive load, unpredictability, and an emphasis on peripheral processing. It is possible that these components of the game are able to train players to have enhanced perceptual and attentional capabilities when compared with NVGPs. Indeed, a number of visual attentional paradigms (Donohue et al., 2010; Dye & Bavelier, 2004; Dye, Green, & Bavelier, 2009; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Green, Li, & Bavelier, 2010; Green, Pouget, & Bavelier, 2010; West, Stevens, Pun, & Pratt, 2008) have been used to measure different aspects of attention in action VGPs (and also after training NVGPs with games).

2.2. Paradigms Used In The Study of Action Video Game Players

The following section will discuss a selection of paradigms that have been used to study the effects of action video game play. In order to facilitate understanding, the paradigms discussed here will be divided into sections based on the aspects of attention that they measure. Specifically, these include capacity, temporal, and spatial aspects of visual attention.

2.2.1. Measuring attentional capacity

At any given time we are bombarded with a multitude of stimuli, however, only a small subset of that information ever reaches our conscious awareness (i.e., the ability to know something is there and respond to it). As you are reading this

text there might be a number of other things happening that you are actively (or passively) ignoring (i.e., a television in the background, telephone ringing, cell phone vibrating, email notifications, a bee buzzing nearby, etc.). Many of these potential items of interest compete for limited attentional resources. That is, attention is considered to be a limited-capacity resource (Cowan & Nelson, 2001; Kaufman, Lord, Reese, & Volkman, 1949; Kahneman, 1973; Miller, 1956; Oyama, Kikuchi, & Ichihara, 1981). In the laboratory, researchers have been able to replicate some of these real world conditions in order to create tasks that potentially measure attentional capacity, and interestingly habitual action video game play appears to lead to enhanced performance (i.e., increased capacity, see Green & Bavelier, 2006b).

The multiple object tracking (MOT) task (Pylyshyn & Storm, 1988) measures the number of moving objects that can be tracked within an array of moving distracting items (see Figure 6). The typical MOT task presents eight to sixteen identical items (e.g., green balls) on a display. A subset of these items (the targets) is then made distinctive (i.e., by flashing them or changing their color, see Green & Bavelier, 2006b) for a short period of time (e.g., 2 s). Following this, the items return to their previous state (indistinguishable) and continue to move in a random fashion. When the display stops, one of the balls would be highlighted (by changing color). The participant is required to determine whether this item was one of the original cued balls. The task requires visual attention to be distributed amongst a number of targets and is therefore analogous to a measure of capacity (i.e., enhanced performance is indicated by the ability to track more items amongst more distractors). Green and Bavelier (2006b) demonstrated that action VGPs

outperformed NVGPs in this task. Furthering this finding, Green and Bavelier (2006b) tested a group of NVGPs trained with either an action video game (i.e., *Medal of Honor*) or a control game (i.e., *Tetris*) and found there to be significant improvement in MOT performance following training on the action game. These findings indicate that VGPs may have a larger attentional capacity enabling them to track an increased number of simultaneously presented items.

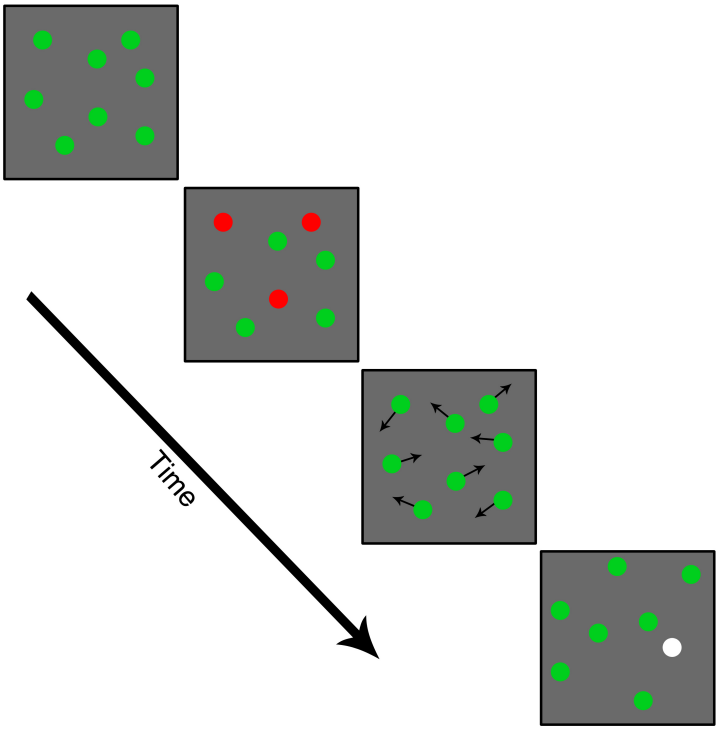


Figure 6. A single trial from Green & Bavelier's (2006b) adaptation of the MOT task. Sixteen green balls are initially presented at the start of the trial and for a few moments 1-7 balls (depending on difficulty) are cued by changing color (red) to indicate that they are the target balls to be tracked. Following this, the cued balls return to their original color (green) and then randomly move for several seconds. When the display stops moving, one of the cued balls turns white in color. The participant is then asked to press either a "yes" or "no" key to indicate whether the white ball was one of the cued balls.

Also an indirect measure of attentional capacity, the enumeration task is commonly used to determine the subitizing capabilities of participants (see

Kaufman et al., 1949 for early work on subitizing). The task requires participants to respond to the number of items (e.g., squares) that are presented in a briefly flashed display. Trick and Pylyshyn (1993, 1994) demonstrated that participants have a distinct pattern of accuracy and response latencies. For instance, when participants are presented with a relatively small number of items (1 to 4), they are able to subitize with high accuracy and fast reaction times. However, as the number of presented items increases, accuracy decreases and reaction time increases. With regards to VGPs, they outperformed NVGPs in all aspects, subitizing more items accurately and more quickly. Again, these findings suggest that action video game play can increase processing capacity (Green & Bavelier, 2003, 2006b). Interestingly, when the experiment was repeated with two groups of NVGPs, one trained with an action video game and the other trained with a non-action video game, Green and Bavelier (2006b) demonstrated similar results. That is, even with a small amount of video game training (10 hours), enumeration performance was again enhanced for those trained with the action game when compared to those trained with the non-action game.

Collectively, the results from the MOT and enumeration tasks (Green & Bavelier, 2003, 2006b) suggest that video game play can increase the number of items an individual can process at one time, and by extrapolation, attentional capacity. These findings fit well with perceptual load theory (see section 1.3.2), perhaps suggesting that attentional capacity is increased in VGPs, enabling them to process more items in parallel without a decrease in performance.

2.2.2. Measuring the temporal characteristics of visual attention

Evidence for faster visual processing by VGPs can be derived from studies that have used the attentional blink (AB) task (Green & Bavelier, 2003). The typical AB task involves the use of rapid serial visual presentation (RSVP) of stimuli (see Figure 7). Specifically, participants are presented with a sequence of visual stimuli such as letters or numbers. The task requires participants to first identify a target (i.e., a different colored letter, referred to as T1) and then respond to the presence of a subsequently presented target (referred to as T2). Generally speaking, it is more difficult to detect the second target when it is presented very close in time to the first target (100-500 ms; see Raymond, Shapiro, & Arnell, 1992). Performance for the second target becomes easier as it moves farther away (in time) from the first target. In the Green and Bavelier (2003) adaptation of this task, participants were required to respond to a single white letter that appeared within a stream of rapidly presented black letters. Additionally, participants were told that on half of the trials an "X" would appear in the stream of letters after the presentation of the white letter. The task was to report the identity of the white letter and whether or not the "X" had been presented. The findings demonstrated that VGPs had a much smaller "attentional blink" when compared to NVGPs. That is, they more accurately judged the presence of the second target when compared with NVGPs when the time separating both targets was reduced. Therefore, it could be argued that frequent video game play enhances the ability to process rapidly presented information over time. Interestingly, Green & Bavelier (2003) carried out the same task with a group of NVGPs who were trained with either an action video game or a non-action video

game. Once again, the participants trained with the action video game outperformed those who had been trained on a non-action game.

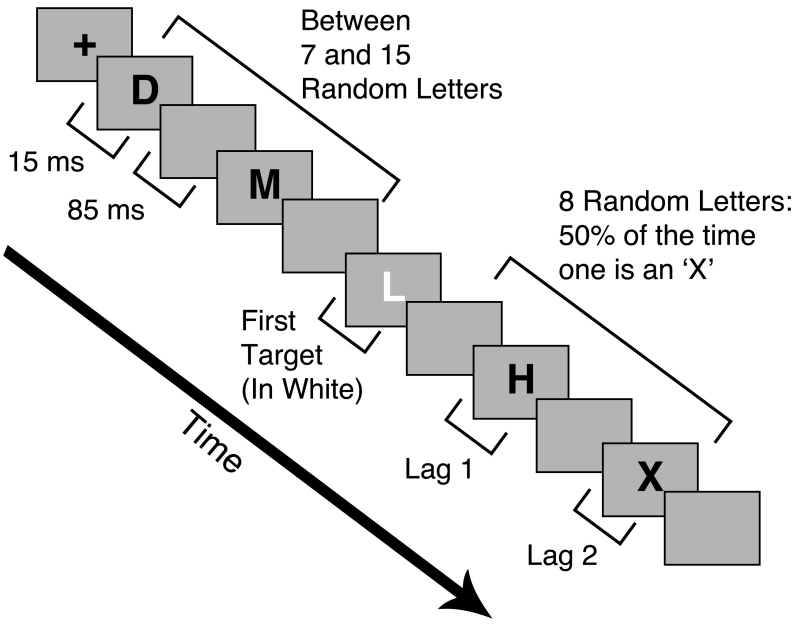


Figure 7. A schematic representation of a single trial in an attentional blink task. A fixation cross is initially presented and is then followed by a set of random letters. Following this, the first target (white letter) is presented. 50% of the time an 'X' (the second target) is present. The participants' task is to identify the first target (i.e., the 'L' above) and then indicate whether the 'X' was present.

Of particular interest for the measurement of temporal processing, and to this dissertation specifically, is the TOJ task. The TOJ task has been used by researchers to investigate the temporal processing capabilities of the human sensory system since as early as Exner (1875; see Spence, Baddeley, Zampini, James, & Shore, 2003 for a more recent review). Despite the simplicity of the task, it has undoubtedly helped to increase our understanding of attentional processing, specifically in regards to temporal aspects of attention and as we will see later, spatial aspects of information processing. In a typical TOJ task, participants are

presented with two stimuli either simultaneously or with one preceding the other by some predetermined amount of time, with the simple requirement to determine which one had been presented first (see Figure 8). The temporal interval between the presentation of the two stimuli is known as the stimulus onset asynchrony (SOA).

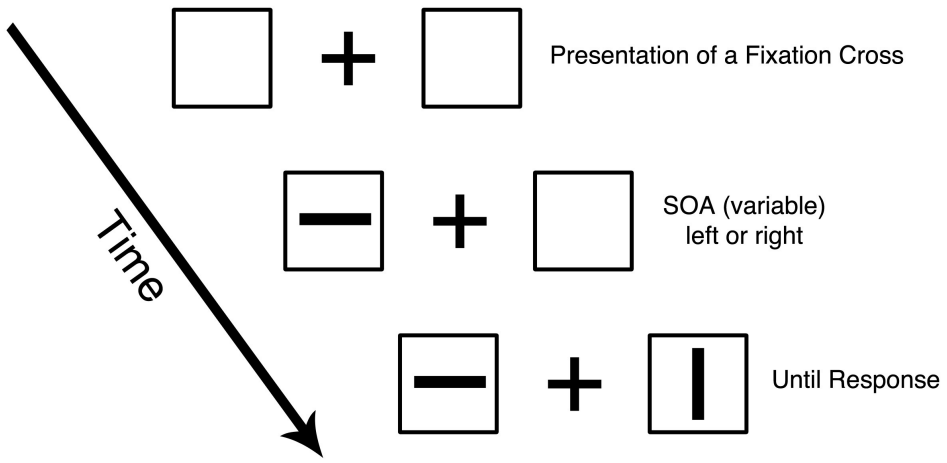


Figure 8. Representation of the TOJ task. Participants are first presented with a fixation cross followed by a horizontal and vertical bar separated by some amount of time. Participants must indicate which of the two stimuli appeared on the screen first.

The results of this task can be used to calculate the just noticeable difference (JND). The JND represents the smallest temporal interval needed to separate the two stimuli in order for participants to accurately judge the temporal order 75% (on average) of the time. While the research presented in this dissertation does not measure JND, it will use a variation of this paradigm to explore spatial attention using visual and auditory cues and targets (see below).

To delineate multisensory temporal processing in VGPs, Donohue et al. (2010) used two variations of the TOJ task. In the first task, participants were presented with two stimuli (visual and auditory) and asked to judge which stimulus

had been presented first. In the second task, participants determined whether the two stimuli had been presented simultaneously[3]. Using these two tasks, Donohue et al. demonstrated that VGPs were able to distinguish multisensory stimuli as being temporally distinct at closer intervals than were NVGPs. They also found that participants with more video game experience were more likely to perceive simultaneity when the auditory stimuli preceded the visual stimuli, while participants with less video game experience were more likely to experience simultaneity when the visual stimuli preceded the auditory stimuli. According to Donohue et al., these findings may indicate that the NVGPs attention is captured to a greater degree by the visual stimulus because it is the most salient (i.e., the checkerboard pattern used as the visual stimuli in the task has more features than the simple auditory tone used as the auditory stimuli) of the two stimuli. Likewise, this would suggest that VGPs attention was captured to a lesser degree than the NVGPs (i.e., they were less affected by the distracting visual stimuli). However, it should be noted that Donohue et al. did not replicate these effects in a group of NVGPs that were trained on video games (see section 2.4). This does leave open the possibility that the effects seen here are due to a priori attentional enhancements present in habitual VGPs.

2.2.3. Measuring spatial characteristics of attention

The TOJ task was discussed above in terms of measuring the temporal aspects of visual attention. However, for the purpose of this dissertation, the TOJ

[3] Note, however, that the JND is still the dependent measure regardless of whether the task is to determine order or simultaneity.

task was used to examine spatial characteristics of attention. In order to accomplish this, the basic TOJ task was extended by including exogenous (peripheral) and endogenous (central) cues, similar to those used by Posner (1980). Posner's classic cueing experiment, which included only endogenous cues (see Jonides, 1981 for an example with exogenous cues), provides a paradigm that continues to be extensively used today. As mentioned in the previous chapter, endogenous orienting is understood to be volitional and participant driven. Conversely, exogenous attentional orienting is thought to be obligatory and stimulus driven (see 1.3.3). For example, a flashing box in the periphery would result in attention being exogenously captured, while the directional properties of a centrally presented arrow would act as a central (endogenous) cue (see Figure 9; Theeuwes, 1991). Response latencies are significantly faster to congruent trials when compared with incongruent trials (Posner, 1980; Theeuwes, 1991; Spence & Driver, 1994).

Introducing a cue to the TOJ task allows for the measurement of the point of subjective simultaneity (PSS). The underlying logic is that the cue directs attention to the same side that the target will appear (valid trial), or to the opposite side from where a target will appear (invalid trial). Thus, the PSS represents the amount of time (on average) that the uncued (invalid) target needs to be presented before the cued target for both items to be perceived as being presented simultaneously. Accordingly, a shift in PSS can reflect the degree to which a peripheral or central distraction (irrelevant and nonpredictive cue) can affect spatial processing.

While VGPs have robustly demonstrated increased performance for most tasks (i.e., capacity or temporal; see section 2.3 below), how spatial attention is

potentially modulated has led to conflicting results. For instance, a recent study by Chisholm et al. (2010) demonstrated that VGPs experienced reduced attentional capture when compared with NVGPs. Participants were required to discriminate the orientation of a target line in both distractor-absent and distractor-present conditions. The distractor was a non-target item that was colored opposite to the other items in the display. VGPs were found to respond more quickly than NVGPs to targets presented in both the presence and absence of the distractor. That is, while NVGPs were distracted, VGPs' attention was not captured to the same extent.

West et al. (2008) required participants to determine the temporal order of two spatially presented stimuli in a TOJ task and demonstrated findings contrary to Chisholm et al. (2010). In their display, a vertical and horizontal line was presented inside a box in the periphery at different SOAs. Critically, the box non-predictively flashed, either validly or invalidly cueing the position of the target (line). Their findings demonstrated that VGPs had a *larger* PSS than NVGPs. This indicates that attention was captured to a greater extent for VGPs as compared to NVGPs. The authors posit that VGPs potentially have an enhanced attentional system that processes peripheral information more efficiently, thereby potentially leading to larger capture effects. Although, it could be argued based on previous research that these results are surprising, there is indeed a body of research suggesting that the enhanced attentional capacity of VGPs enables them to actually be less influenced by the effects of peripheral distractors. For instance, Green and Bavelier (2003) presented participants with a flanker task (see Eriksen & Eriksen, 1974) and found

that VGPs were better than NVGPs at inhibiting distracting information when the task was easy (for further discussion see section 2.3).

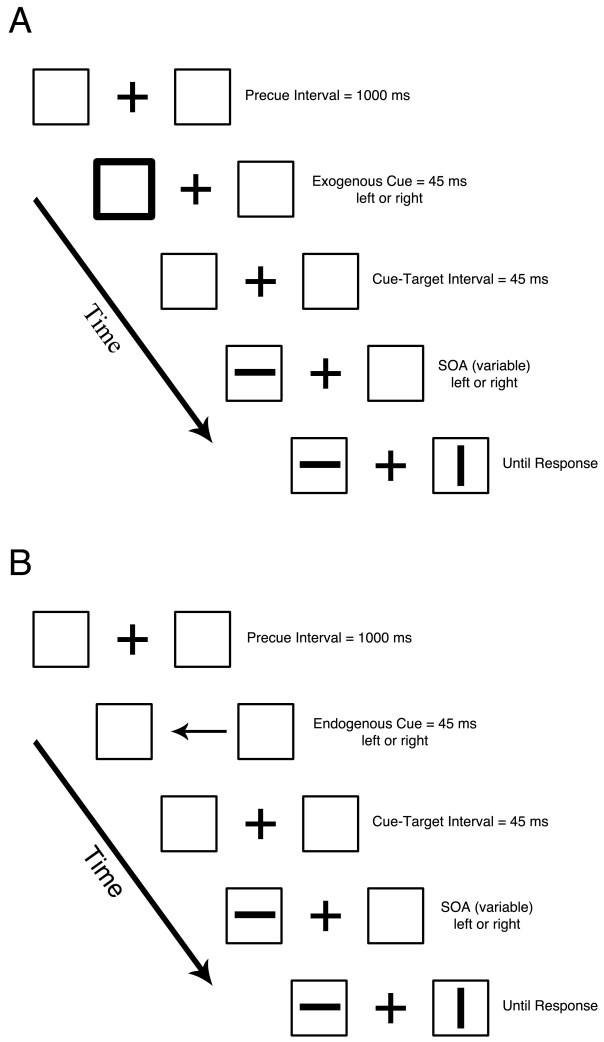


Figure 9. The stimuli and procedure for both the exogenous (A) and endogenous (B) cued TOJ conditions is outlined here. Note that the only differences between the peripheral and central conditions are the placement of the cue (peripheral or center) and the cue itself (peripheral box brightening or central arrow). In both conditions, participants are presented with placeholders (boxes) on both sides of the central fixation cross. Following that, one of the placeholders is randomly cued (by thickening the lines of the square, or by a central directional arrow). The target (horizontal or vertical) is then presented in one of the placeholders, followed by the presentation of the second stimulus at an SOA contingent on the previous trials response.

2.3. Attentional Enhancements Related to Action Video Game Play

Green and Bavelier's (2003) seminal investigation examined the potential effects that extensive video game play has on perceptual and attentional capabilities. Notably, the authors demonstrated that experience with action games was found to modulate a range of basic visual attentional and perceptual mechanisms. Prior to this, psychophysical research had suggested that increased performance in one task was modulated only after training in the same task (Fiorentini & Berardi, 1980; Karni & Sagi, 1991, see also Seitz & Watanabe, 2003, Seitz, Nanez, Holloway, Tsushima, & Watanabe, 2006). It is for this reason that Green and Bavelier's work generated such interest, as it represented an opportunity to observe training based enhancements based on a completely different medium of training than that of the testing. Their experiment utilized four well-known paradigms of visual attention; the flanker compatibility task, enumeration task, useful field of view (UFOV) task and the AB task (see above).

The flanker compatibility task is used to measure the effects of irrelevant information (i.e., distraction) on attentional processing (Eriksen & Eriksen, 1974). In this classic task, participants are presented with a target in the center of a display that is "flanked" by two (or more) distractor items (see Figure 10). In the standard flanker compatibility task, there are two responses. For instance, a participant might be asked to press one key every time the letters 'S' or 'F' appear on the screen, or instead another key every time the letters 'H' or 'T' appear on the screen. These letters can be flanked by compatible (i.e., the same response key), incompatible

letters, or neutral letters not associated with any response type. The compatibility effect shows that responses are slowest when subjects are presented with the incongruent condition when compared with the neutral or congruent conditions, with the fastest reaction times being observed in the latter condition. The flanker compatibility effect has been said to be reflective of late selection theory (see section 1.3.1), as it shows that irrelevant information can be processed in parallel with attended stimuli. However, demonstrating the capacity limited nature of attention, Lavie and Cox (1997) found the compatibility effect to be large when the task was easy, and reduced when the task was difficult. That is, when increasing task difficulty the effect diminishes demonstrating that sufficient attentional resources are not available to process irrelevant information (i.e., in line with the early selection theory).

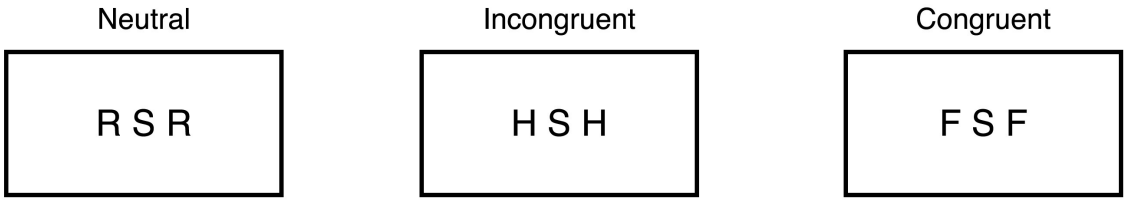


Figure 10. In the Flanker task, participants must respond to the central target letter while ignoring the surrounding flanker letters. In this example, subjects would press one key whenever the 'S' or 'F' key appears, or another key when the 'H' or 'T' key appears. The letter 'R' is a neutral letter. In the above example a congruent trial of FSF is presented, however, a congruent trial could also be presented as 'HTH'. Likewise, an incongruent trial could also be presented as 'TFT'.

Green and Bavelier (2003) used a version of the flanker compatibility task, requiring participants to decide whether a target shape (square or diamond) appeared within an array of six circle placeholders (see Figure 11). Importantly, the target shape was flanked by either a congruent or incongruent shape that was

presented outside of the array. VGPs performed significantly differently than NVGPs, continuing to demonstrate a compatibility effect, even when the task was made substantially more difficult, whereas the compatibility effect for NVGPs disappeared in the more difficult task. That is, when the perceptual load of the task was increased, NVPGs did not have sufficient resources to continue to process the flankers, whereas VGPs did. This finding is demonstrative of an increase in attentional resources and attentional capacity in VGPs as compared to NVGPs.

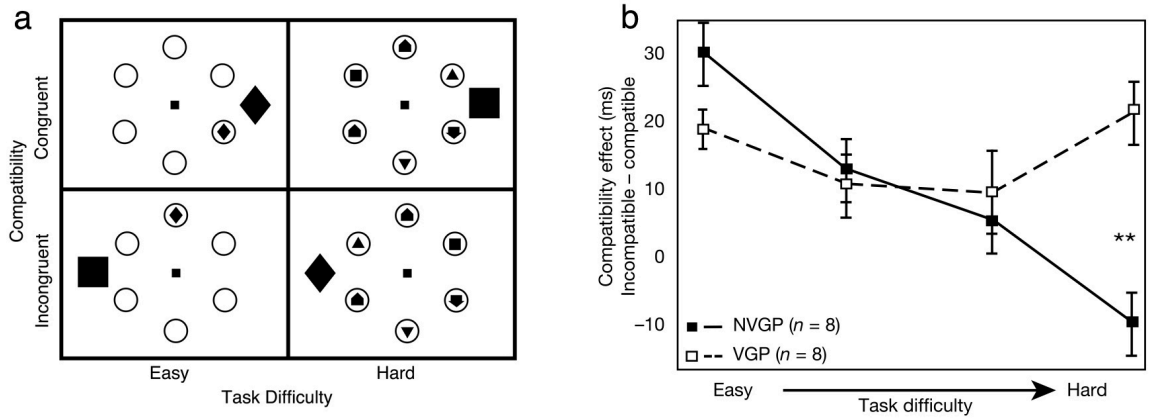


Figure 11. The flanker task used by Green and Bavelier (panel A; 2003). For each trial, participants determined whether a square or a diamond appeared in one of the six circles. (b) Compatibility effects taken from Green and Bavelier (2003). VGPs show a greater compatibility effect than NVGPs when the flanker task was difficult, suggesting that VGPs have an increased availability of attentional resources.

The first two experiments of the Green and Bavelier (2003) investigation were important in that they demonstrated enhanced attentional capacity in video game players. However, both tasks were presented within what Green and Bavelier considered a "training zone." That is, video game play involves focusing on a character in the display that is placed within a "zone" of 0-5° from fixation. To account for this, Green and Bavelier (2003) used the UFOV task to examine visual processing outside of this purported training zone. The results clearly showed that

VGPs outperformed NVGPs at all angles, thereby demonstrating an enhanced allocation of spatial attention over the visual field, despite the training zone being much smaller.

In a final experiment, Green and Bavelier examined the temporal characteristics of video game play by using the AB task (see section 2.2.2). Again, VGPs outperformed NVGPs by demonstrating an enhancement in detection performance for the second target. Critically, Green and Bavelier (2003) were able to replicate their findings with a group of NVGPs that were trained with an action video game (i.e., *Medal of Honor*). The group of NVGPs trained with the action video game outperformed the group of NVGPs trained with the non-action game (i.e., *Tetris*), in all tasks.

Thus far, Green and Bavelier (2003, 2006a, 2006b, 2007) have convincingly shown that VGPs outperform NVGPs on several tasks of visual attention. Furthermore, NVGPs trained with action video games show the same improvements in performing complex visual tasks. The next question that Green and Bavelier explored was whether or not these changes were due to simply strategy from experience with video games or due to specific changes in the way that VGPs process visual information. To explore this question, Green and Bavelier (2007) used a crowding paradigm (see Figure 12) to see whether spatial resolution is altered in a sample of VGPs. In this task, participants are asked to determine the orientation of a center "T" in the presence of irrelevant but distracting "T's" located above and below the target at different eccentricities (0°, 10° and 25°). The findings

showed that the spatial resolution of vision in VGPs was enhanced, exhibited by more accurate detection rates for all eccentricities.

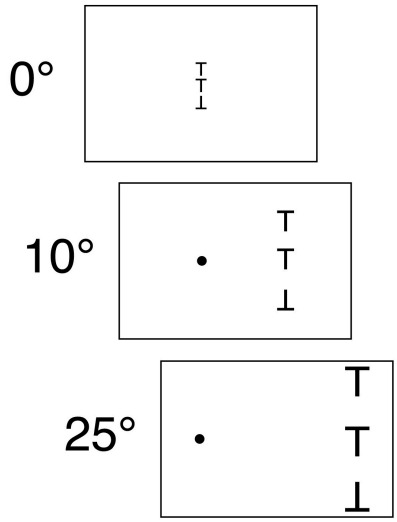


Figure 12. The crowding paradigm shown at three different eccentricities (0°, 10°, and 25°). The participants' task was to identify the orientation of the center T by pressing either an "up" or "down" key.

To further solidify the claim that VGPs indeed gain an enhancement in visual acuity, Green and Bavelier (2007) again trained one group of NVGPs with an action video game, while a separate group of NVGPs were trained with a non-action game. While both the experimental and control group demonstrated improvement in the training task (game play), only the group trained with the action video game had a significant reduction in crowding thresholds. Furthermore, NVGPs trained with the action video game performed significantly better than NVGPs trained with the control game at 25° eccentricity, which is far outside of the so-called video game training zone. This finding led Green and Bavelier to suggest that action video game play can alter visual perception. They purport that their results demonstrated that the increased performance at the 25° eccentricity (which is considered to be outside

of the training zone) for VGPs but not NVGPs was likely due to fundamental changes in visual processing, and not simply due to strategy and experience with video games. If the improvements were due to video game experience then this result would be unexpected since the literature suggests robust spatial specificity in training tasks (see Fahle, 2004, 2005; Karni & Sagi, 1991 for examples), meaning that training would have only caused improvement to be seen at the 0° eccentricity (the training zone). By using the crowding paradigm, Green & Bavelier showed that the improvements that have been seen in VGPs (Green & Bavelier, 2003, 2006a, 2006b, 2007) might possible be due to fundamental changes in their visual perceptual system, in particular, spatial resolution.

2.4. Video Game Training

Exploring whether extensive video game play can modulate spatial attentional capabilities is one of the major aims addressed in this thesis. However, it is possible that individuals who engage in habitual video game play have inherently better attentional skills than NVGPs, a concern also voiced by Green and Bavelier (2003). Specifically, VGPs may be more attracted to video game play because of their greater natural ability, whereas NVGPs might avoid video games because of their inherently limited skill set. In fact, this has been shown to be the case in music (Hetland, 2000; Rauscher, Shaw, Levine, Wright, Dennis & Newcomb, 1997) and sports (Kioumourtzoglou, Kourtessis, Michalopoulou, & Derri, 1998; Lum, Enns, & Pratt, 2002). In order to address this question, the research here utilized a training

regimen with groups of NVGPs, comparing pre- and post-test measures of spatial attention both within and across sensory modalities.

A typical training study would include NVGPs trained on either an action video game or a non-action video game. Performance on a separate task is assessed prior to and after the training session (at least a full day after the last training session). In some instances, participants are re-tested again long after the cessation of the original training regimen (Feng et al., 2007; Li, Polat, & Bavelier, 2009). In these cases the enhancements due to training have been observed even after a significant period of time has passed. For instance, Feng et al. (2007) found that female performance in the UFOV task was maintained after a 5-month follow up, while male performance actually improved (though this may be due to the fact that two men in the sample continued to play video games prior to the follow-up). Li et al. (2009) tested a group of NVGPs trained with either an action video game or a non-action video game either 5 months or 1 year after training had ended. Again, there was still a significant improvement in the UFOV task seen in the group trained on action video games in the second post-test when compared to the pre-test (though the effect was reduced by 23% from the initial post-test). It should be noted, however, that the participants from the Li et al. (2009) study engaged in a very intense training period that consisted of 50 hours of video game play over a nine-week period. Please refer to Table 1 for a review of the training conditions used in past studies of action video game training.

Study	Participants tested (experimental/control)	Hours of total training time	Games used (experimental/control)	Paradigm
Green & Bavelier (2003)	n =not mentioned n=8	10 hours (1 hour per day for 10 days)	*Medal of Honor: Allied Assault* *Tetris*	Flanker UFOV AB Enumeration
Green & Bavelier (2006a)	n=32	30 hours (max 2 hours per day, min 5 hours per week, max 8 hours per week)	*Unreal Tournament 2004* *Tetris*	UFOV
Green & Bavelier (2006b)	Experiment 2: n=20	10 hours (1 hour per day for 10 out of 15 days)	*Medal of Honor: Allied Assault* *Tetris*	Experiment 2: Enumeration (two angles)
Green & Bavelier (2006b)	Experiment 5: n=32	10 hours (1 hour per day for 10 out of 15 days)	*Medal of Honor: Allied Assault* *Tetris*	Experiment 5: MOT
Green & Bavelier (2007)	n=32	30 hours (max 2 hours per day, min 5 hours per week, max 8 hours per week)	*Unreal Tournament 2004* *Tetris*	Crowding
Feng, Spence & Pratt (2007)	n=20	10 hours	*Medal of Honor: Pacific Assault* *Ballance*	UFOV MRT
Li, Polat & Bavelier (2007)		50 hours		
Li, Polat, Makous & Bavelier (2009)	Not mentioned ("Small group")	50 hours (over 9 weeks)	*Unreal Tournament 2004* *Call of Duty 2* *The Sims 2*	CSF
Gonzales Dissertation (2011)	n=30	10 hours (max 3 hours per day over a 14 day period)	*Call of Duty 4: Modern Warfare* *Pinball Hall of Fame*	Visual TOJ Auditory TOJ Crossmodal TOJ

Table 1. Conditions used in past studies of action video game training effects. Paradigm acronyms are as follow: Attentional Blink (AB), Contrast Sensitivity Function (CSF), Multiple Object Tracking (MOT), Mental Rotation Task (MRT), Useful Field of View (UFOV), Temporal Order Judgment (TOJ) task.

Chapter 3

Experiments 1-3

Chapter 3: Experiments 1-3

3.1. Chapter Overview

The experiments presented in this chapter explore the possibility that the human attentional system can be modulated due to extensive video game play. Specifically, the experimentation assesses how previous video game experience may possibly enhance spatial attention manifested within and across sensory modalities. In order to accomplish this, the TOJ task (see section 2.2.3) was modified to include both peripheral (exogenous) and central (endogenous) cues, thereby gauging the influence that these types of distracting spatial cues have on attention. While the combination of exogenous cues and the TOJ task has been used in the past (West et al., 2008), the experimentation presented here is novel in that the effects of central cues have not been explored in a video game population, in addition to the multimodal aspect of the experimentation, which has never been investigated with the exception of two recent investigations (see Donohue et al., 2010; Green et al., 2010).

If VGPs do in fact have an enhanced attentional system, as previous evidence suggests (Green & Bavelier, 2003, 2006a, 2006b, 2007), then they should have a smaller PSS score than NVGPs. That is, attention will be more efficiently distributed allowing them to more quickly process uncued targets (i.e., the peripheral or central will not have as much of an effect). But note, West et al. (2008) showed the exact opposite of this, therefore, based on their work, one would hypothesize larger PSS

scores for visual exogenous cues (i.e., more attentional capture). Lastly, if the effects of habitual video game play do indeed affect other sensory modalities, NVGPs trained on a video game should also demonstrate modulations in auditory and audiovisual PSS scores. This would be indicative of a supramodal attentional system with the different senses possibly sharing resources and having some degree of association, although, it is difficult to determine if the VGPs had a pre-existing disposition leading them to choose such activities (see Section 2.4 and Chapter 4).

The first experiment described in this dissertation replicates the exogenous TOJ experiment conducted by West et al. (2008), and also explores the effects of endogenous cues on attentional capture in action video game players.

3.2. Experiment 1: The effects of peripheral and central distraction on the visual spatial attention of video game players

When judging the temporal order of successively presented stimuli that were preceded by either congruent or incongruent spatial cues, video game players had a larger PSS than non-video game players (West et al., 2008). The authors claimed that peripheral cues have more of an effect on expert video game players, effectively capturing their attention to a greater extent than NVPGs, hindering responses to uncued targets. The present research expands on this by introducing central (endogenous) cues in addition to peripheral (exogenous) cues. Based on West et al., it was predicted that PSS scores would also be significantly larger for VGPs when compared to NVGPs. However, it should be noted that there is reason to doubt this hypothesis. Indeed, based on other research one could possibly hypothesize the

complete opposite. That is, if action VGPs are better able to inhibit distracting stimuli (as seen in Green & Bavelier, 2003; 2006b, 2007), then perhaps they are not as susceptible to attentional capture as previously suggested. This account is further bolstered by recent evidence by Chisholm et al. (2010) who demonstrated that VGPs are *less* susceptible to the effects of attentional capture (i.e., opposite of West et al.'s findings, albeit with a different paradigm).

3.2.1. Methods

Participants

A total of twenty-two (n=22) undergraduate student participants were recruited from the University of Hawaiʻi at Mānoa in exchange for course credit. The participants were split into two groups, a VGP group (n=12, average age of 21, 1 female) and a NVGP group (n=10, average age of 22, 6 females). To be considered a VGP a minimum of 6 hours per week of action video game play for at least 6 months was required (e.g., *Assassins Creed, Call of Duty 4: Modern Warfare, Gears of War 2, Halo 3, Resident Evil*). Participants categorized as NVGPs self-reported as having no video game experience within the last 6 months and no history of regular video game play prior to the previous six months. All participants underwent Experiments 1, 2, and 3 (counterbalanced).

Stimuli and apparatus

The stimuli were presented on a 2.66 GHz Intel Core 2 Duo Apple/Windows (dual boot) iMac with a 20" screen using DMDX Version 3.2.6.6 software (http://www.u.arizona.edu/~kforster/dmdx/dmdx.htm). Observers sat approximately 60 cm from the computer monitor and made a key press response

with the "Z" and "/" keys on the computer keyboard to make "horizontal target first" and "vertical target first" responses, respectively. Each trial contained placeholders (2 cm x 2 cm) in the periphery of the screen with a thickness of 1 mm, separated by 10.5 cm. The horizontal stimulus had a width of 1 cm and a height of 1 mm. The vertical stimulus was identical, but rotated 90 degrees.

Procedure

In each trial of the peripheral condition, the display consisted of two boxes and a fixation cross that remained on the screen throughout the trial (see Figure 9). Following a pre-cue interval of 1000 ms, a non-predictive peripheral cue was presented by thickening the placeholder box from 2 to 8 pixels. After 45 ms the box returned to its original size. Each peripheral location (left and right box) was equally likely to be cued. After the cue, the first stimulus (either a horizontal or vertical line) was presented 45 ms later in one of the placeholder boxes, after which the second stimulus was presented in the other box at specific SOAs contingent on the previous trial's response (see the description of the step-function design below for SOAs). Participants pressed the "Z" key to indicate that the "horizontal target" appeared first, or the "/" key if they thought the vertical line had appeared first. Peripheral location and stimuli were both equally likely to be cued. Stimuli had an equal chance of appearing in either the left or right boxes and of being presented first.

The centrally cued condition was identical with the exception that an arrow was displayed in the middle of the display instead of a box brightening in the periphery. Accordingly, after the precue interval of 1000 ms, the central fixation cross changed to an arrow pointing either to the left or the right for a period of 45

ms. Again, each location (left or right) was equally likely to be cued. The peripheral and central conditions were presented separately and counterbalanced across participants.

Like West et al. (2008), an adaptation of Stelmach and Herdman's (1991) step-function procedure was used. Participants began with an SOA of 267 ms that would increase or decrease depending on whether the participant made a correct or incorrect response. On trials where an invalid cue was presented and a correct response was made, the SOA would decrease by 16.7 ms. Accordingly, the SOA would increase by 16.7 ms if they made an incorrect response. The experiment was terminated when a total of fourteen correct/incorrect reversals was recorded.

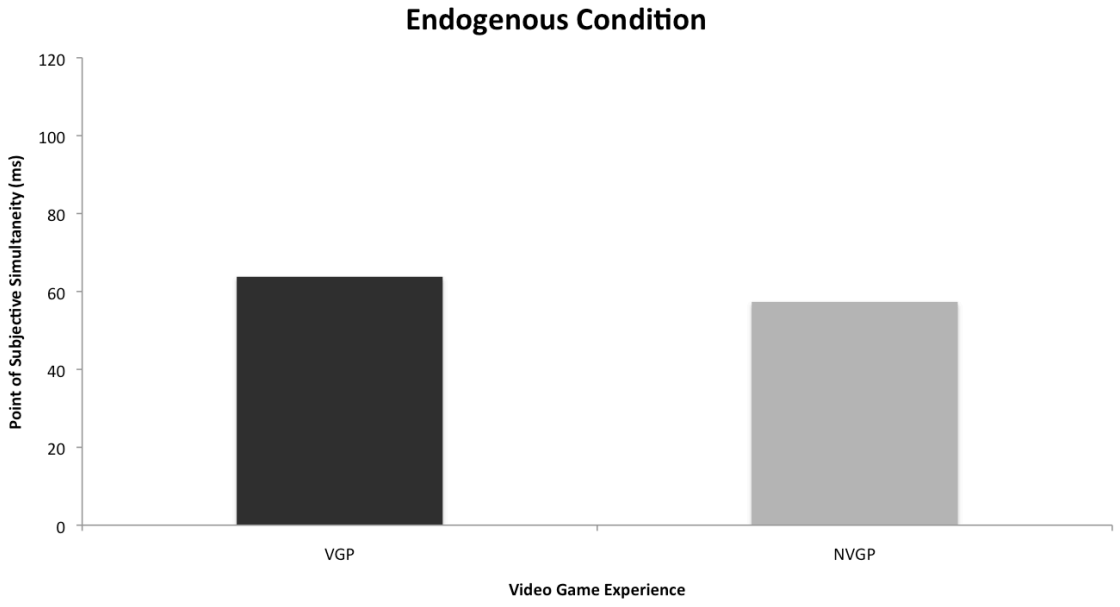
3.2.2. Results

The PSS for all of the experiments in this dissertation was calculated by averaging the SOAs of the last six reversals in the staircase design in order to determine the amount of time that the uncued item needed to appear before the cued item in order for both items to be subjectively perceived as appearing simultaneously. Considering that endogenous and exogenous cues are dissociable and thought to be governed by different attentional mechanisms (see Jonides, 1981), each condition was analyzed separately.

Experiment 1a (Endogenous cues): The PSS for the endogenous cue was 64 ms for VGPs and 58 ms for NVGPs (See Figure 13). Both of these scores were significantly different from zero, suggesting that the cues successfully directed attention for both groups (VGPs: $t(11) = 5.71$, $p < .001$; NVGPs: $t(9) = 5.57$, $p < .001$). Average PSS scores were analyzed with an analysis of variance with Participant

Type (VGP or NVGP) as the between-subjects factor. The effect of video game experience was not significant (64 ms vs. 58 ms; $F[1, 21] = .174$; $p = .681$).

Experiment 1b (Exogenous cues): The PSS for the exogenous cue was 67 ms for VGPs and 77 ms for NVGPs (See Figure 13). Both of these scores were significantly different from zero, suggesting that the cues successfully directed attention for both groups (VGPs: $t(11) = 8.24$, $p < .001$; NVGPs: ($t(9) = 8.45$, $p < .001$). Mean values for the PSS in the exogenous task for both VGPs and NVGPs were similarly analyzed with an analysis of variance with Participant Type (VGP or NVGP) as the between-subjects factor. The analysis revealed that there was no significant effect of video game experience (67 ms vs. 77 ms; $F[1, 21] = .751$; $p = .396$).



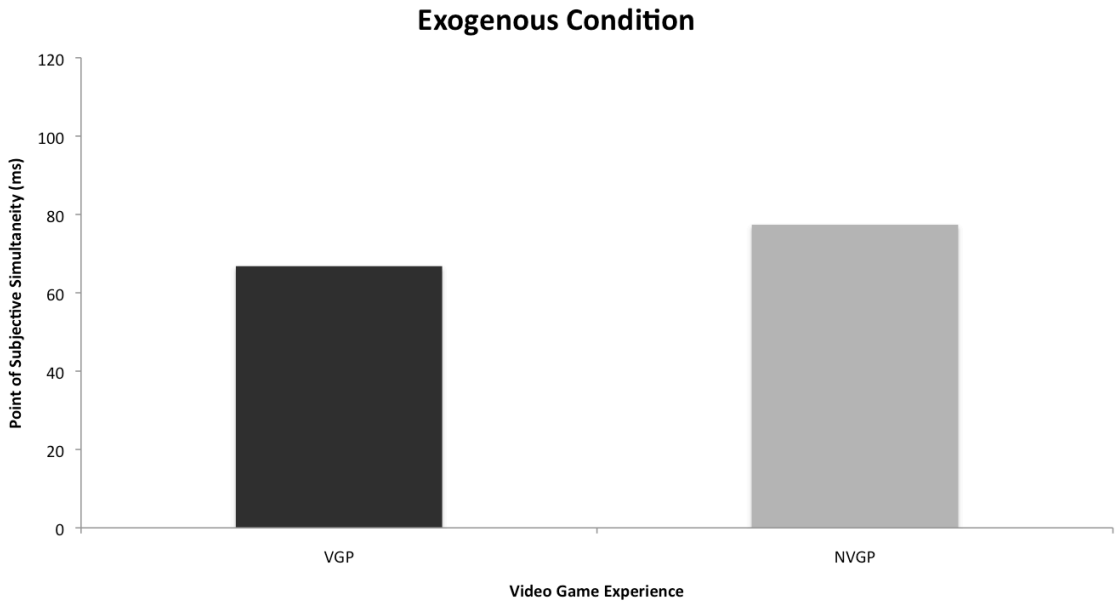


Figure 13. The average point of subjective simultaneity (PSS) for both video game players and non-video game players in the endogenous and exogenous TOJ tasks.

3.2.3. Discussion

Despite the lack of significant findings between VGPs and NVGPs in the visual domain, it should be noted that both the endogenous and exogenous cues effectively directed attention. That is, if the cue failed to capture attention then the PSS should theoretically be zero, as participants would have no reason to consistently choose one side over another as having appeared first (see Sinnett et al., 2007 for a similar example comparing hemispatial neglect patients' PSS scores to zero). While trivial to the discussion of how performance is modulated by video game experience, this finding nonetheless validates that both central and peripheral cues were capable of directing attention in this paradigm. This is important, however, as traditional research using central cues has consistently reported that longer intervals between cue and target are necessary for strong cuing effects (see Jonides, 1981; Posner, 1980; Shore, Spence, & Klein, 2001). However, the findings here demonstrate that

this might not be the case, with the short SOA of 45 ms leading to equivalent capture effects for central and peripheral cues (see also Ristic & Kingstone (2006) for a similar example).

When compared with West et al.'s (2008) results, the findings here are slightly contradictory. That is, the exogenous distraction led to an increase in attentional capture (i.e., larger PSS scores) for VGPs when compared with NVGPs in their experiment, however this effect does not appear here. While the findings are not completely opposite, in that PSS scores were reduced in the VGP group, as demonstrated by Chisholm et al. (2010) using a different capture paradigm, it is nevertheless important to note the increase in VGPs' PSS scores was not observed here.

There are possible reasons as to why the results of the present experiment yielded non-significant results. First, it should be noted that in the West et al. (2008) investigation only males were enrolled in both VGP and NVGP groups. Here, males and females participated. Furthermore, when removing females from the analysis there are too few males (4 males) to get a clear picture from the data. However, despite this methodological difference, it should be noted that there is precedence for the use of females in similar studies of visual attention in video game players. For instance, in a study by Feng et al. (2007), females demonstrated significant enhancements in performance in both the MRT and UFOV tasks (see sections 2.4) following a modest amount (10 hours) of action video game training.

In addition to the exogenous cuing condition, we extended West et al.'s (2008) research by including an endogenous cueing condition (central arrow). To

the best of my knowledge, this is the first time that endogenous cueing effects have been examined in VGPs. In seminal work on visual prior entry, Shore et al. (2001) demonstrated that, when using a similar TOJ paradigm, peripheral cues led to larger effects than central cues. A possible reason for this null effect in VGPs would be that traditionally, cuing effects with central cues require longer intervals than the 45 ms SOA used here. For instance, in Shore et al.'s (2001) experiment, the peripheral condition had a 60 ms SOA, while the central arrow condition had a 405 ms SOA. While perhaps initially a methodological error, the present finding that a short SOA for central cues led to significant cueing effects is theoretically important by itself.

In Experiment 2 the question of how video game experience can modulate performance in a separate modality was explored by examining exogenous cueing effects of VGPs in the auditory domain. Two separate studies have investigated the effects of habitual video game play on spatial processing in the auditory domain with both suggesting that concomitant modulations in other sensory modalities are present in VGPs (Donohue et al., 2010; Green et al., 2010).

3.3. Experiment 2: The effects of peripheral distraction on the auditory spatial attention of video game players

For the past decade, research that has investigated the effects of habitual video game play on attention has focused nearly exclusively on the visual modality. This makes sense considering that the visual display of the game is essential to game play. As discussed in Chapter 2, empirical evidence does suggest that visual attention is modulated in a number of ways after habitual video game play. However,

the question of whether or not concomitant enhancements of auditory attention can be observed has received little investigation, despite practical and theoretical reasons to explore this. For instance, the auditory component of video games has become quite advanced, often with peripheral and rear sounds highlighting the location of an enemy. Furthermore, expanding the exploration to other sensory modalities will help shed light on the debate regarding whether the attentional system operates in a supramodal or segregated manner (see Section 1.3.4).

3.3.1. Methods

Stimuli and apparatus

The basic paradigm and apparatus was identical to Experiment 1, with the following differences. Rather than using horizontal and vertical lines for targets, participants determined the presentation order of two auditory target sounds. The sounds used were the bark of a dog and the caw of a crow edited with auditory editing software to achieve equivalent duration (350 ms) and average amplitude. All auditory stimuli were presented from a pair of speakers connected to the computer. Unlike Experiment 1, central cues were not used in Experiment 2. This is due to limitations in making auditory central cues with directional properties (i.e., analogous to a visually presented arrow). Note, this does not diverge from other experiments using an auditory TOJ task.

Procedure

The procedure and stimulus presentation of Experiment 2 was identical to Experiment 1, with the exception of auditory stimuli being used instead of visual stimuli (see Figure 14). Participants pressed either the “D” key to indicate that the

bark of a dog was presented first, or the "C" key to indicate that the caw of a crow was presented first. Both stimuli had an equal chance of being cued, of being presented in either the left or right speakers, and of being presented first.

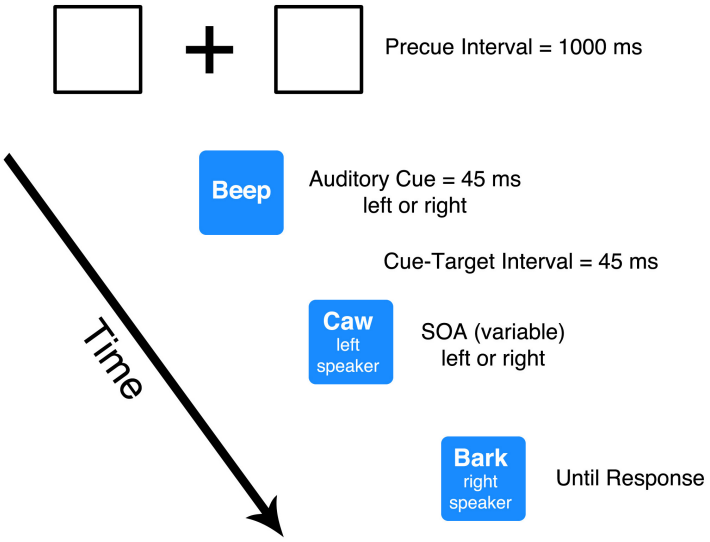


Figure 14. Auditory TOJ procedure used in Experiment 2.

3.3.2. Results

The exogenous auditory cue successfully directed attention for both VGPs (72 ms; $t(11) = 5.53$, $p < .001$) and NVGPs (60 ms; $t(9) = 4.89$, $p = .001$). Mean values for the PSS (See Figure 15) in both the peripheral and central cue conditions were analyzed with an analysis of variance with Participant Type (VGP or NVGP) as the between-subjects factor. The analysis revealed that there was no significant effect of video game experience (72 ms vs. 60 ms; $F[1, 21] = .401$; $p = .534$).

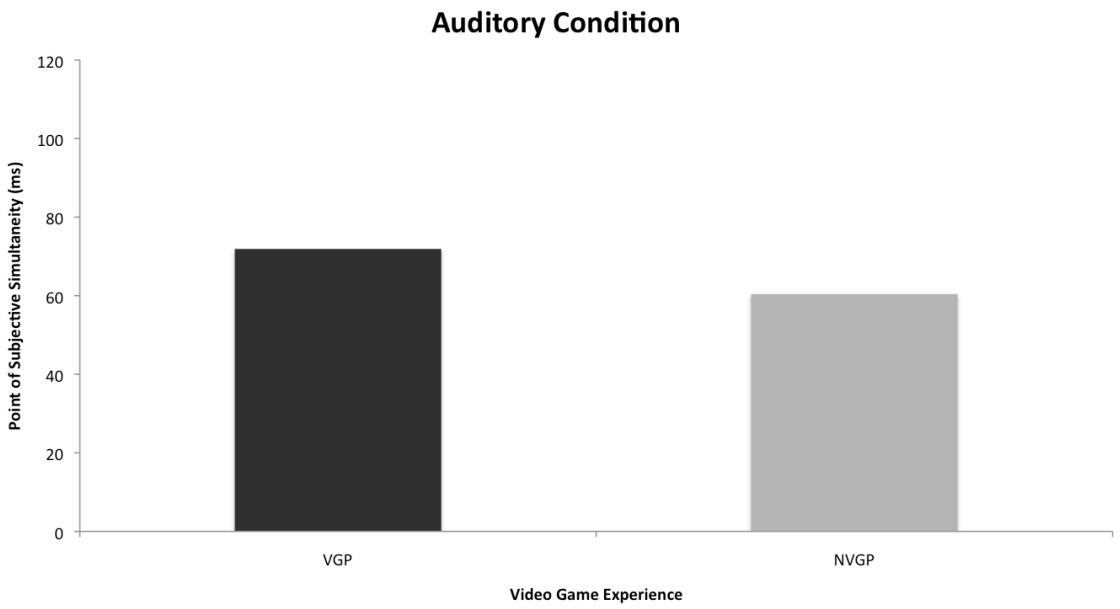


Figure 15. The average point of subjective simultaneity (PSS) for both video game players and non-video game players in the auditory TOJ task.

3.3.3. Discussion

Despite visual spatial attention having been explored extensively in action video game players, there has been little research exploring any crossover effects that might lead to enhancements or changes in processing spatial attention within the auditory domain (but see Donohue et al., 2010; Green et al., 2010). It should also be noted that this is the first time that the effects of exogenous (auditory) cues in a TOJ task have been investigated in a group of habitual video game players. It appears that there are no crossover effects from the visual domain, however, the null results make it difficult to conclude this.

3.4. Experiment 3: The crossmodal effects of peripheral distraction on the visual and auditory spatial attention of video game players

Experiment 3 explored the effects of habitual video game play on multisensory processing. Indeed, there is growing evidence to support the notion that spatial attention in one modality can impact information processing in a separate modality (Buchtel & Butter, 1988; Spence & Driver, 1997; Ward, 1994). Furthermore, exploration into multimodal effects is warranted, considering video games (and more importantly most of everyday living) include multimodal events, rather than only unimodal circumstances. The notion that a single supramodal system of attention distributes attentional resources has been supported by various crossmodal cuing studies (Buchtel & Butter, 1988; Driver & Spence, 1998; Frassinetti, Bolognini, & Làdavas, 2002; Spence & Driver, 1994, 1997). Experiment 3 builds on these previous studies by exploring the crossmodal effects of peripheral distraction by using a cuing paradigm that utilizes visual cues and auditory targets. If there are indeed differences in the way that VGPs and NVGPs process multisensory information then this could indicate that attention is controlled by a supramodal system.

3.4.1. Methods

Stimuli and apparatus

The apparatus used in Experiment 3 was identical to that of Experiment 2.

Procedure

Experiment 3 combined the procedures used for Experiment 1 and Experiment 2. Each trial was identical to the exogenous condition in Experiment 1, with the difference being that auditory targets followed the visual cue. The auditory targets were presented in the same way as in Experiment 2 (see Figure 16).

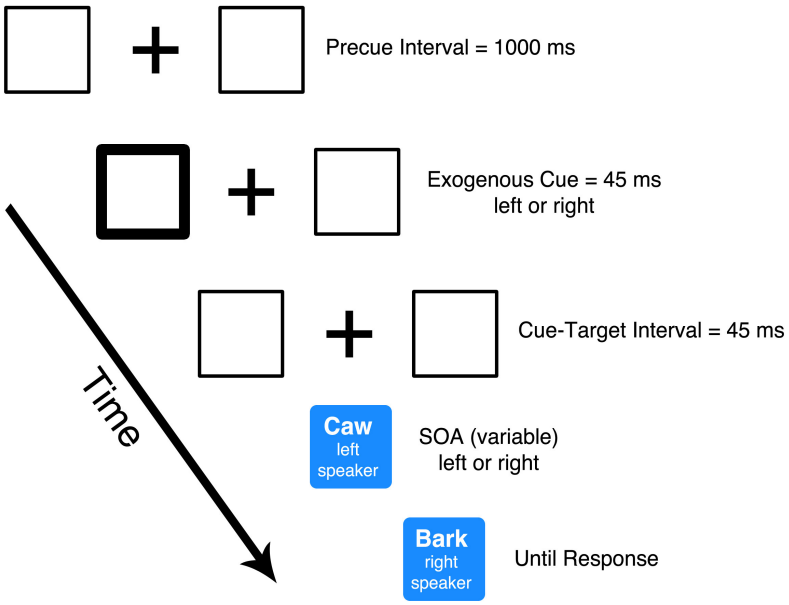


Figure 16. The stimuli and procedure for the crossmodal TOJ task is presented here.

3.4.2. Results

The exogenous visual cues successfully directed attention for both VGPs (33 ms; $t(11) = 8.67$, $p < .001$) and NVGPs (61 ms; $t(9) = 5.81$, $p < .001$). Mean values for the PSS (see Figure 17) in the crossmodal condition for both VGPs and NVGPs were analyzed with an analysis of variance with Participant Type (VGP or NVGP) as the between-subjects factor. The analysis revealed that there was a significant effect of video game experience ($F[1, 21] = 7.169$; $p = .014$).

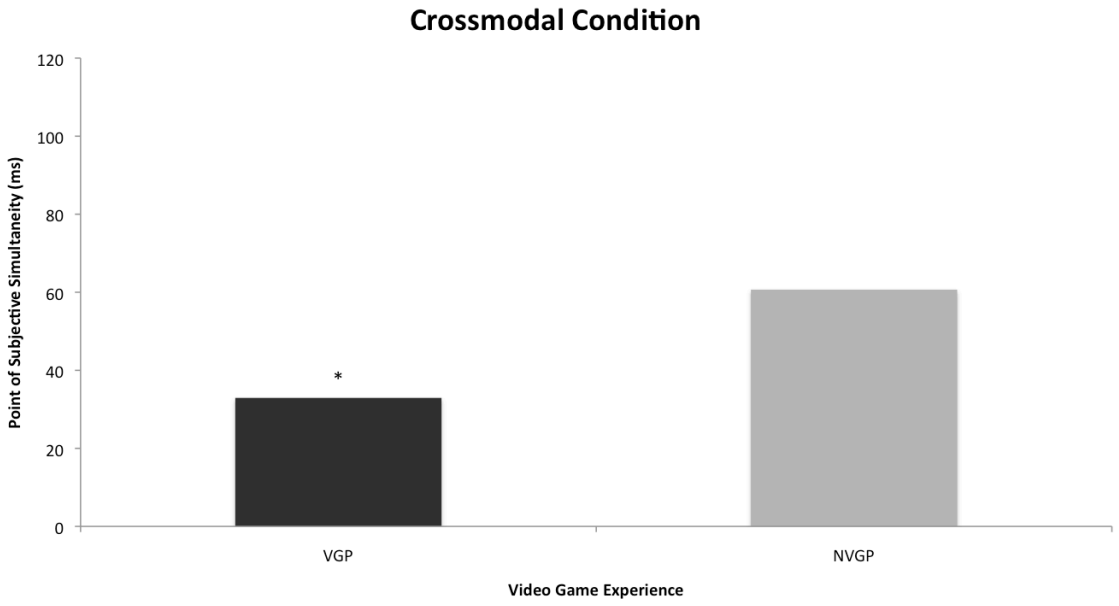


Figure 17. The average point of subjective simultaneity (PSS) for both video game players and non-video game players in the crossmodal TOJ task.

3.4.3. Discussion

Experiment 3 moved beyond the unimodal presentation of cues and targets within a single sensory domain, and instead presented visual (exogenous) cues and auditory targets. Interestingly, VGPs demonstrated a significantly smaller PSS value in the crossmodal TOJ task as compared to NVGPs. This finding is particularly interesting when noting that the unimodal visual condition (exogenous) PSS scores for VGPs were significantly higher than when using visual cues and auditory targets here ($t(9) = 8.24$, $p < .001$). Furthermore, the auditory PSS scores for VGPs in Experiment 2 were also significantly higher than those observed here ($t(9) = 8.67$, $p < .001$). Accordingly, this suggests that the crossmodal presentation has some sort of additive effect, as the observed PSS scores were much different than to be expected by either unimodal result. This would align with numerous findings of super-additivity suggesting that multisensory presentations often lead to larger effects

than to be expected by summing the unimodal components (see Molhom, Ritter, Javitt, and Foxe, 2004; Sinnet, Soto-Faraco, & Spence, 2008; Stein & Meredith, 1993; Stein & Stanford, 2008).

3.5. Chapter Discussion

The central aim of Experiments 1-3 was to explore differences in spatial attention between VGPs and NVGPs in the visual and auditory domain, as well as across sensory modalities. The findings of Experiments 1-2 failed to reach conventional levels of significance. Although, it is also important to note that the cues used in Experiment 1 and 2 were indeed effective. The lack of results in the visual domain could possibly suggest that a methodological issue was the cause for the non-significant results. Specifically, the study reported here enrolled a combination of males and females, unlike West et al. (2008) and Chisholm et al. (2010), both of whom enrolled only male participants. Future research should ensure using a completely male sample.

In regards to the findings in Experiment 2 with auditory cues, one could conclude that any enhancements in visual processing are not carried over to auditory processing. However, it would be imprudent to make this conclusion as Experiment 1 (visual) failed to demonstrate significant findings. Furthermore, it does appear that multisensory processing is modulated based on the findings from Experiment 3.

Of most importance to this chapter are the results of Experiment 3. In this case, VGPs were found to be significantly less distracted by the exogenous visual

cues when they were paired with auditory targets in a crossmodal TOJ task. This finding is important because it provides insight into the mechanisms by which attention integrates and coordinates information that is arriving at different sensory modalities (for other examples see Driver & Spence, 1994, 1998). The much smaller PSS values observed in the VGP group were surprising considering that performance in Experiment 1 and Experiment 2 yielded no significant differences between the two groups. If habitual action video game leads to enhanced crossmodal processing then one would likely expect unimodal enhancements as well. However, as mentioned previously, it is possible that some sort of super additive response was the reason for this difference.

An important issue regarding conclusions based on separating the groups as done here warrants discussion. That is, it is possible that any potential enhancement is not due to video game play itself, but instead related to some sort of pre-existing difference that draws these people to play such games. Therefore, the experiments conducted in Chapter 4 will address this possibility by incorporating a training condition. That is, only NVGP participants will be recruited, but will then be required to play an action video game for a certain number of hours. Their performance on pre and post-tests will be compared, thereby better elucidating the question of whether or not video game play itself is responsible for any performance modulation.

Chapter 4

Experiments 4-6

Chapter 4: Experiment 4-6

4.1. Chapter Overview

Despite only Experiment 3 (the crossmodal experiment) yielding significant results in the previous chapter, there are a number of reasons to continue this line of research. First of all, it is important to note that overall, the visual findings from Experiment 1b (with exogenous cues) were not in line with West et al. (2008). That is, the increased PSS scores observed in their experiment for exogenous cues was not replicated here, despite largely similar paradigms. Secondly, this finding did not extend to central cues or to the auditory modality, at least in the current experimentation. As mentioned previously, perhaps our short SOA (for endogenous cues), or the inclusion of female participants played a role in our null results (with the exception of Experiment 3). Lastly, a pervasive problem in Experiments 1-3, and the majority of research involving VGPs, is that it is difficult to determine if the effects are simply due to some pre-existing difference between VGPs and their non-playing counterparts. The only way to circumvent this issue would be to train NVGPs and then measure any performance differences between pre and post-tests. This is precisely what was done in Experiments 4-6.

Although a significant difference was found only for Experiment 3 of the first series of experiments, I elected to also test visual (exogenous and endogenous) and auditory conditions in these training experiments. This was important to do in order to maintain the exact testing conditions of Experiments 1-3 (counterbalanced).

However, if the training intervention leads to a significant effect in the unimodal conditions, it would be difficult to explain why no such effect was observed in the previous experiments, unless the previous separation of VGPs from NVGPs was flawed. Indeed, one potential difference here would be the greater control that can be exerted on how much time is spent playing video games, and which ones. That is, it is possible that some participants were mistakenly placed in the VGP group previously, either because they exaggerated the amount of play in their self-reports, or they included non-action games in the game play they reported. Lastly, it should be noted that recent video game experiments might be subject to concern as advances in hand held devices requiring attention to be directed to various items in the display (i.e., smart phones with games, texting, internet, etc.) could potentially lead to enhancements in attention even in NVGPs.

Each of the experiments (4-6) discussed in this chapter utilized NVGPs trained with either an action video game (*Call of Duty 4: Modern Warfare*), or a non-action video game (*Pinball Hall of Fame*). In keeping with the findings of West et al., it was hypothesized that NVGPs trained with the action video game would be more distracted by both the peripheral and central distraction, leading to higher PSS values and providing further evidence to support the claim that habitual action-video game play makes one more susceptible to attentional capture. Despite this, the literature seems to be conflicted on the effects of habitual action video game play on spatial attention, in particular exogenous attention (Chisholm et al., 2010; Dye et al. 2009; West et al., 2008). Preliminary results indicate that VGPs are less prone to the effects of attentional capture as compared to NVGPs (see also Chisholm et al.).

However, as Green and Bavelier (2003) pointed out, by selecting such a specific population, it may be that VGPs simply possess a better attentional skill set as compared to the non-video game playing population (i.e., not due to any extensive training or experience). The following set of experiments train groups of NVGPs with video games and compare pre and post-tests using the TOJ task in different sensory modalities (see Green & Bavelier, 2003, 2006a, 2006b for related examples).

Lastly, it should be noted that I elected to continue recruiting female participants. This was done for two reasons. First, as the training experiment is rather long (10 hours), and with no possibility of monetary compensation, it would have been extremely difficult to find enough participants if I were to limit them by gender. Second, while female participants are generally not included when recruiting expert VGPs, they have been used in experiments involving a training condition, as done here (see Feng et al., 2007).

4.2. Experiment 4: Training – Visual TOJ

4.2.1. Methods

Participants for experiments 4-6[4]

The participants were recruited using the same method and from the same sample as Experiment 1. A total of twenty-five (n=25) undergraduate student participants were recruited from the University of Hawaiʻi at Mānoa in exchange for course credit. The participants were split into two groups, an experimental group

[4] The SOA of 45 ms was still used in the endogenous condition, as it led to significant cueing effects despite seminal research suggesting that a larger SOA would be optimal. This enabled an exact replication of experimental conditions in Experiments 1-3.

trained with the action video game *Call of Duty 4: Modern Warfare* (n=12, average age of 22, 10 females) and a control group trained with the non-action video game *Pinball Hall of Fame* (n=13, average age of 23, 10 females). All participants were categorized as non-video game players, self-reporting no video game experience within the last 6 months and no history of regular video game play prior to the previous six months. These participants underwent Experiments 4, 5, and 6 (order counterbalanced).

Stimuli and apparatus

The experimentation was identical to Experiments 1-3. For the video game intervention, a Playstation 3 (PS3) and a 42" LCD display was used for the presentation of both the action (*Call of Duty 4: Modern Warfare*) and non-action (*Pinball Hall of Fame)* video games. During training, participants sat approximately 150 cm from the display. A standard wireless PS3 controller was used as the input device.

Overall procedure

A pre-test for all Experiments (4-6), identical to that used in Experiments 1-3, was given. Both groups then underwent a two-week video game training regimen (see below for details). Following the two-week video game training period, participants were presented with a post-test that was identical to the pre-test.

Video Game Training

Each participant completed 10 hours of video game training within a two-week period (in each session they played between 1 and 3 hours). Video game training consisted of playing either *Call of Duty 4: Modern Warfare* (action game) or

Pinball Hall of Fame (non-action game). All video game training was completed in the Sinnett Perception and Attention Research Laboratory at the University of Hawaiʻi at Mānoa (Krauss Hall Room 14).

4.2.2. Results

The average PSS was calculated in an identical manner as in the previous experiments. In each of the experiments, a repeated measures ANOVA with Test (pre and post) as a within subjects factor and Game type (action vs. non-action) as a between subjects factor was conducted.

Experiment 4a (Endogenous cues): The endogenous visual cue successfully directed attention for both action and non-action game groups in both the pre-test (action: 46 ms; $t(11) = 6.79$, $p < .001$; non-action: 73 ms; $t(12) = 5.06$, $p < .001$) and the post-test (action: 56 ms; $t(11) = 4.14$, $p = .002$; non-action: 53 ms; $t(12) = 6.64$, $p < .001$).

The main effect of Test did not approach significance ($F[1, 23] = .22$; $p = .639$), nor was there a main effect of Game type ($F[1,23] = 1.09$; $p=.307$). Lastly, there was also no interaction between video game type and test ($F[1,23] = 1.92$; $p = .179$). Despite this lack of significance, planned t-tests were carried out in order to directly compare pre to post tests for the action and non-action conditions. No significant differences were observed when comparing pre to post-test PSS scores for action game (*Call of Duty*) players (See Figure 18; 46 ms vs. 56 ms respectively; $t (11) = .393$, $p = .543$) or non-action game (*Pinball*) players (73 ms vs. 53 ms; $t (12) = 1.83$, $p = .201$).

Experiment 4b (Exogenous cues): The exogenous visual cue successfully directed attention for both action and non-action game groups in both the pre-test (action: 66 ms; $t(11) = 6.90$, $p < .001$; non-action: 89 ms; $t(12) = 9.56$, $p < .001$) and the post-test (action: 101 ms; $t(11) = 4.66$, $= .001$; non-action: 82 ms; $t(12) = 10.54$, $p < .001$).

The main effect of Test did not approach significance ($F[1, 23] = 1.54$; $p = .226$), nor was there a main effect of Game type ($F[1,23] = .017$; $p = .898$). The interaction between video game type and test was marginally significant ($F[1,23] = 3.469$; $p = .075$). Again, the planned t-tests comparing pre to post-tests failed to demonstrate any significant differences for either the action game players (see Figure 19; 66 ms vs. 101 ms respectively; $t (11) = 2.59$, $p = .136$) or the non-action game players (89 ms vs. 82 ms; $t (12) = .725$, $p = .411$).

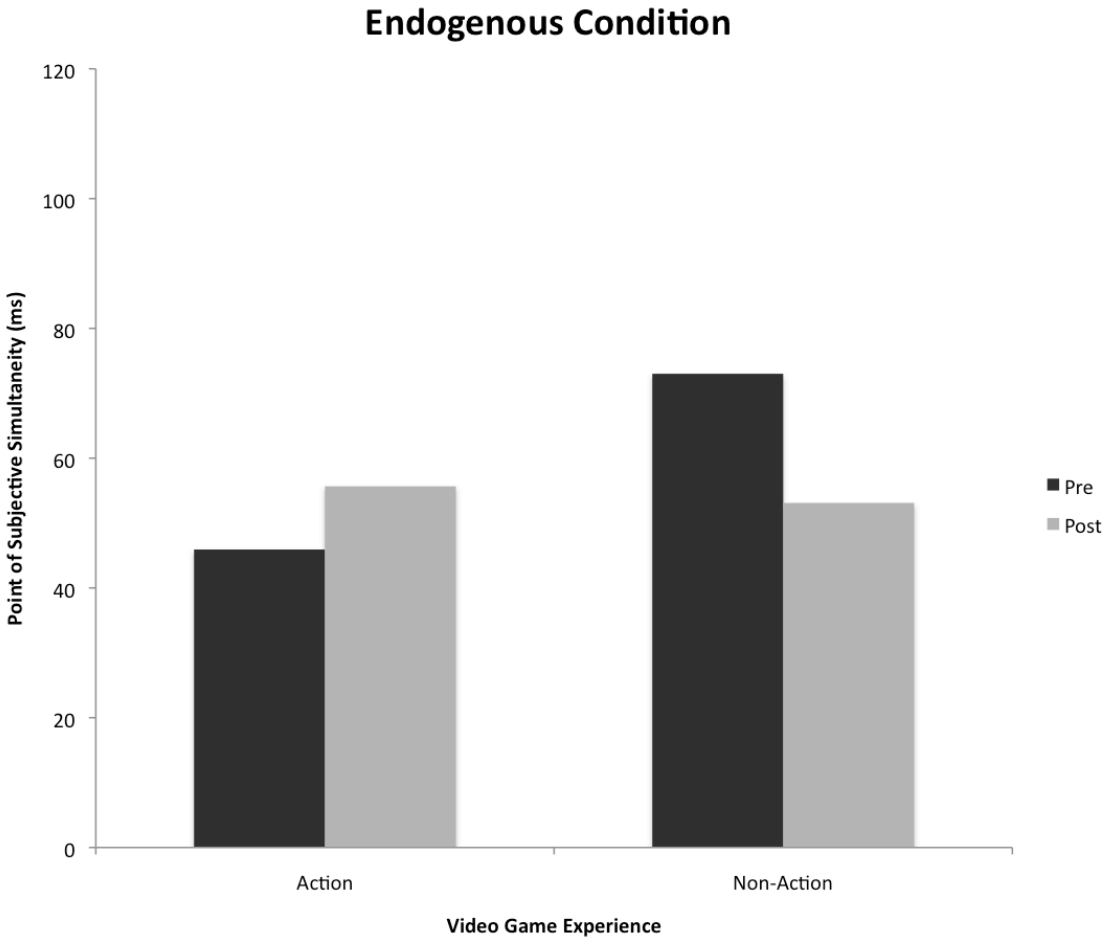


Figure 18. The average PSS in the endogenous TOJ task for *Call of Duty* and *Pinball* players pre and post-training.

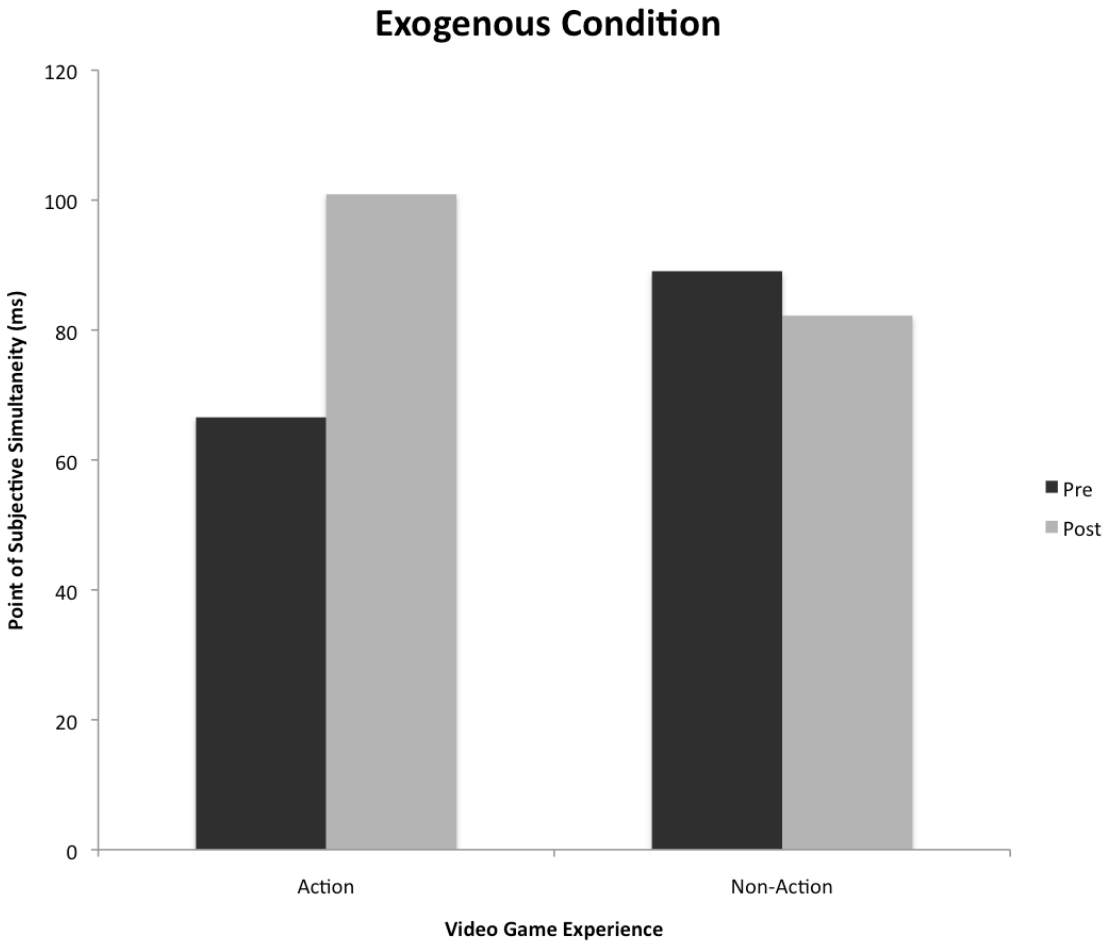


Figure 19. The average PSS in the exogenous TOJ task for *Call of Duty* and *Pinball* players pre and post-training.

4.2.3. Discussion

There are a number of important points that merit discussion. Based on the results of West et al. (2008), it was predicted a priori that pre and post-test differences would be seen in NVGPs trained with the action video game while NVGPs that were trained with the control non-action game would not yield different results. However, the analogous planned comparison did not yield any significant differences between the groups. The failure to produce any results is troublesome, considering the significant findings reported by West et al. The question then

remains, why, when using a nearly identical paradigm are results not replicated. Recall that in Experiment 1 a similar null result was found, therefore, regardless of whether VGPs were recruited or if NVGPs were trained with an action game, the paradigm failed to produce any group differences.

If the notion that video game play experience can modulate spatial attention can be accepted, especially given the varying paradigms that have led to such effects (see Chisholm et al., 2010; West et al., 2008), then a last possibility to explain the lack of results could lie with the selected participants in Experiment 1 and a problem with the training paradigm used here. It is possible that the chosen non-action game (*Pinball*) might actually include some components of an action game, although, this would not explain any lack of differences between pre to post tests in the action or non-action conditions. Regardless, it is apparent that much of the video game literature dealing with attention focuses on the use of action video games, specifically, first person or third person shooters, as the main experimental game type. However, the selection of control games has been less standardized. Puzzle games, such as *Tetris,* have been used, but so have simulation games like *The Sims*.

4.3. Experiment 5 – Auditory TOJ

Based on the results of West et al. (2008) and recent evidence suggesting that video game playing leads to enhancements in other sensory modalities, it was again hypothesized that differences would be seen in NVGPs trained with the action video game when compared with those trained with the control game. This would support the claim for a supramodal attentional system (see Section 1.3.4). However,

this hypothesis must be made with care, considering the lack of a significant result in Experiment 2.

4.3.1. Results

The auditory cue successfully directed attention for both action and non-action game groups in both the pre-test (action: 80 ms; $t(11) = 6.13$, $p < .001$; non-action: 104 ms; $t(12) = 5.12$, $p < .001$) and the post-test (action: 68 ms; $t(11) = 4.71$, $p = .001$; non-action: 91 ms; $t(12) = 4.43$, $p = .001$).

The main effect of Test failed to reach significance ($F[1, 23] = .983$; $p = .332$), nor did the main effect of Game type ($F[1,23] = 1.2$; $p = .286$). There was also no interaction between video game type and test ($F[1,23] < .001$; $p = .998$). Planned t-tests revealed no significant differences when comparing pre to post-test PSS scores for the action game (see Figure 20; 80 ms vs. 68 ms; $t (11) = .621$, $p = .447$) or the non-action game (104 ms vs. 91 ms; $t (12) = .421$, $p = .529$).

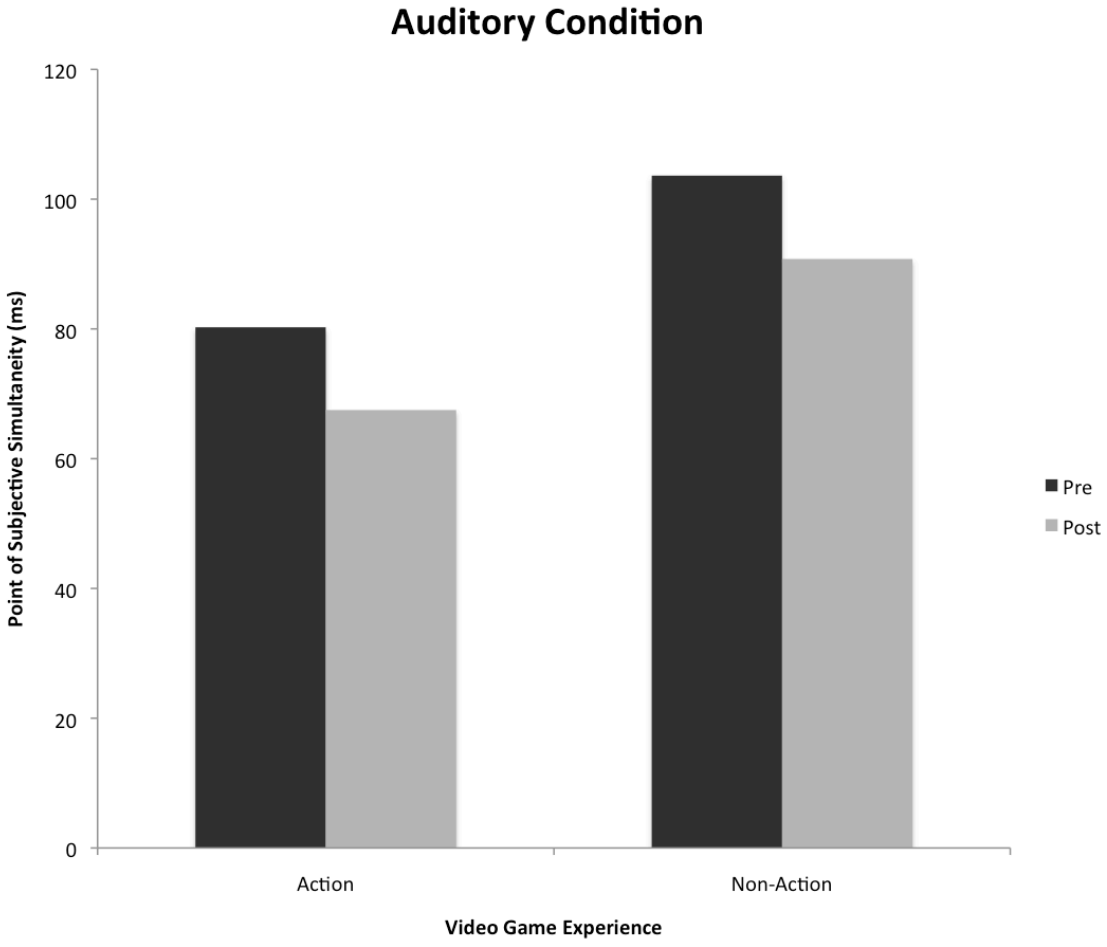


Figure 20. The average PSS in the auditory TOJ task for *Call of Duty* and *Pinball* players pre and post-training.

4.3.2. Discussion

Although Donohue et al. (2010) recently utilized a TOJ task that used a combination of visual and auditory targets (discussed below, see section 4.4.2), no study has exclusively used auditory cues and targets in a TOJ task examining the effects of action video games. When doing exactly this, no significant differences were observed. This coincides with the findings observed in the visual domain (see Experiment 4), in which those trained with either the action or non-action video game also failed to demonstrate a significant difference between pre and post-tests.

While interpreting a null result is difficult at best, these findings could nevertheless indicate two things. First, as no auditory findings were observed after training with an action game, it is possible that attentional resources are governed by a segregated system. That is, any observed visual enhancements would not extend to the auditory modality. Second, although a direct comparison between experiments is difficult, it is worth noting that there were no differences in PSS scores when comparing the exogenous visual and auditory experiments (all p's > .2). This suggests that the distracting qualities of the cues are equal for both the visual and auditory modalities.

4.4. Experiment 6 – Crossmodal (Visual and Auditory) TOJ

It was predicted that the outcome of Experiment 6 would be similar to the results of the previous crossmodal experiment (see Experiment 3). Thus, it was hypothesized that differences would be seen after training with the action video game when compared with the control game. Specifically, the action game group was expected to have a significantly smaller PSS value than the control group.

4.4.1. Results

The cue successfully directed attention for both action and non-action game groups in both the pre-test (action: 52 ms; $t(11) = 4.94$, $p < .001$; non-action: 42 ms; $t(12) = 7.82$, $p < .001$) and the post-test (action: 46 ms; $t(11) = 8.95$, $p < .001$; non-action: 43 ms; $t(12) = 8.18$, $p < .001$).

The average PSS was calculated in an identical manner as in the previous experiments. The main effect of Test failed to reach significance ($F[1, 23] = .162$; p

= .691), nor did the main effect of Game type (F[1,23] = 1.021; p = .323). There was also no interaction between video game type and test (F[1,23 = .211; p = .650). Planned t-tests failed to reveal any significant differences when comparing pre to post-test PSS scores for the action game (see Figure 21; 52 ms vs. 46 ms; t (11) = .228, p = .643), or the non-action game (42 ms vs. 43 ms; t (12) = .004, p = .953).

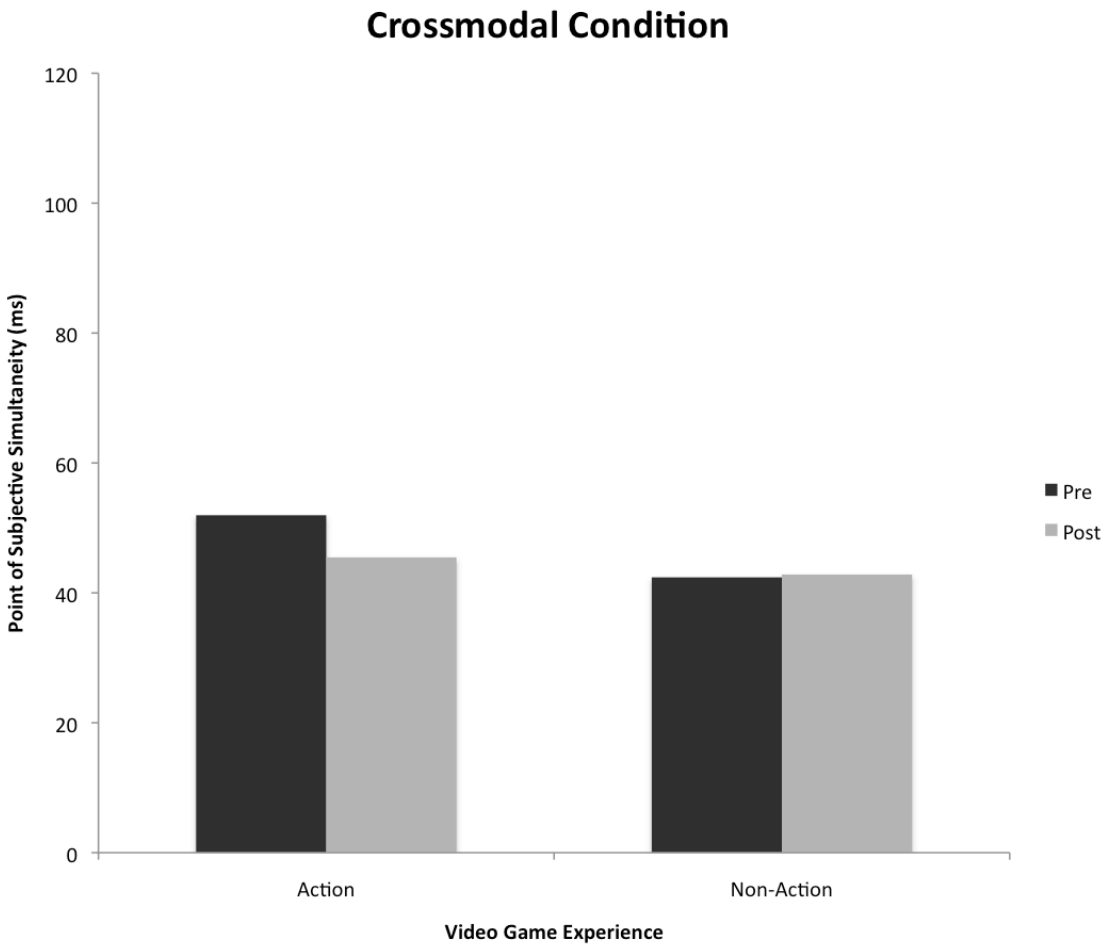


Figure 21. The average PSS in the crossmodal TOJ task for *Call of Duty* and *Pinball* players pre and post-training.

4.4.2. Discussion

The results of the crossmodal task failed to correspond with the findings from Experiment 3. In Experiment 3, VGPs had significantly smaller PSS values in

the crossmodal TOJ task as compared to NVGPs. Here, we see that despite a trend in the same direction, participants trained with the action video game did not demonstrate this same effect post training. It is possible that here, and for all of the experiments in this chapter, the 10 hour video game intervention simply was not sufficiently long enough (note Li, et al., 2009 used 50 hour training periods, but see Green & Bavelier 2003 for an example using 10 hours of training).

Although the findings in this experiment were not significant, it is not the first time that auditory stimuli have been used in a TOJ task with video game players. In a recent study, Donohue et al. (2010) used a similar crossmodal TOJ task as employed here, and a separate adaptation in which participants were asked to judge whether the presentation of two stimuli were simultaneous or not (instead of determining temporal order). Using these two tasks, Donohue et al. demonstrated that VGPs were able to distinguish multisensory stimuli as being temporally distinct at closer intervals than were NVGPs, much like the findings from Experiments 3 here. However, it should be noted that Donohue et al. did not replicate these effects in a group of NVGPs that were trained on video games. This does leave open the possibility that the effects seen in the Donohue et al. (2010) study were due to a priori attentional enhancements present in habitual VGPs.

4.5. Chapter Discussion

Given the lack of significant differences in Experiment 4-6, one might question whether the TOJ paradigm itself is adequate to measure any differences between VGPs and NVGPs. I would argue that it is adequate for three specific

reasons. First, the visual exogenous paradigm has worked in previous work, showing longer PSS scores for VGPs when compared with NVGPs (see West et al., 2008). Second, significant findings were indeed found in the crossmodal experiment in this dissertation (Experiment 3). And lastly, the cues themselves did lead to significant shifts in PSS scores, showing that the paradigm itself was able to modulate attention in each group.

Looking at the big picture of the results, it is important to note that the non-action game (*Pinball*) did not lead to significant PSS differences when compared with the action game (*Call of* Duty). It is possible that there are similarities between these games that perhaps contributed to the non-significant findings. While acknowledging that the action game did not lead to any post-test differences, it is still possible that the non-action game was incorrectly chosen for this experiment. It may be the case that *Pinball* should not have been categorized as a non-action video game. In order to better understand this, a seventh experiment that was similar in all aspects to Experiments 4-6 was conducted but without the video game training regimen.

The inclusion of a no-intervention group enables one to better understand if the TOJ task might indeed be flawed. That is, requiring participants to return after two weeks and do the experiment again can measure if there is any sort of practice effect, or if there simply is too much variability in the design of this task. Thus, an additional group of participants (n=12, average age of 21, 8 females) was presented with the same TOJ tasks as participants in Experiments 1-3 (endogenous, exogenous, auditory, and crossmodal), and then returned two weeks later without having had

any video game intervention. The analyses were conducted in an identical manner to those above (Experiments 4-6), and there were no significant effects seen in any of the conditions (all $p > .19$).

Despite the no-intervention condition failing to yield significant results, it still remains difficult to speculate why null results were observed in these experiments. The issue of the incorrectly chosen control (non-action) game could be a contributing factor. Indeed, upon closer inspection, the game of *Pinball* appears to be far more advanced than what has traditionally been used in similar training studies. For instance, the game involves rapid eye and hand coordination in a fashion similar to that of a first or third-person shooter, in addition to numerous peripheral elements that must be monitored. Throughout the game, the player must orient very quickly to a rapidly moving ball that is constantly moving in and out of their peripheral vision. It should be noted that a final experiment is currently being conducted in the laboratory using a more commonly used non-action control game. Although there is no single control game that is used in the literature, it is often the case that researchers will utilize *Tetris* or a similar type of puzzle game. Since *Tetris* was not available for the PS3 at the time that testing for the original experiments commenced, *Pinball* was chosen. To date, only four NVGPs have been trained with *Tetris* and preliminary analyses comparing their results to that of the training data from Experiments 4-6 suggest that there are no differences in performance post training.

There are other potential possibilities that could help to understand why null results were found. For instance, although female participants have been used in

other training experiments (see Feng et al., 2007), the majority of research involving video game players has involved an exclusively male sample. Future research should consider adopting this approach. A separate possibility involves the training itself. The ten hours of play might have been insufficient. Furthermore, there was no incentive to perform well in the video games themselves. Thus, it is possible that a participant might simply arrive and fail to put any effort into the game.

Chapter 5:

General Discussion

Chapter 5: General Discussion

5.1. Chapter Overview

The research described in this dissertation attempted to address the effects of habitual video game play on attention, specifically the effects of various types of distracting cues, both within and across multiple sensory modalities. A separate question that was investigated was how possible enhancements in spatial attention in one sense can lead to enhancements in other senses. Experimentally, this dissertation was divided into two sections. The first section (Chapter 3, Experiments 1-3) addressed the first three major aims of this dissertation investigating potential modulations of attention as a result of habitual action video game play. The second section (Chapter 4, Experiments 4-6) addressed the fourth major aim of this dissertation, which was to see whether any performance modulations observed in Experiments 1-3 (specifically crossmodal), could be extended to a group of non-video game playing participants trained with an action video game. In order to better facilitate the discussion of this large data set, each of the specific aims mentioned in Chapter 1 are listed below, and how they were addressed is discussed.

Specific Aim 1: Assess the effects of habitual video game play on visual spatial attention using a TOJ task coupled with endogenous and exogenous cues.

Experiment 1 explored the effects of habitual action video game play on visual spatial attention. Recall that performance between VGPs and NVGPs in a TOJ task combined with endogenous and exogenous cues was assessed. As no significant

differences between groups were found, it is rather difficult to draw any precise conclusions. Interestingly, West et al. (2008) did demonstrate larger PSS scores for VGPs in a similar experiment using only exogenous cues. It is possible that the null effect here is in fact more in line with other research showing that capture effects are in fact reduced in a sample of expert VGPs (see Chisholm et al., 2010). However, it must be acknowledged that this conclusion is difficult to confirm given the current data set.

Corresponding to the exogenous findings, a central (endogenous) cue also failed to produce differences between VGPs and NVGPs. This was, to the best of my knowledge, the first example of an endogenous cuing TOJ task using VGPs as a sample. It is also difficult to speculate why a significant result was not observed. It is possible that the short SOA (cue to target interval) played a role, as traditionally endogenous cuing tasks required longer intervals. However, the fact that the cue worked for both NVGPs and VGPs suggests that this was not the underlying reason.

Specific Aim 2: Assess the possibility of enhanced attentional processing in separate modalities by expanding the TOJ paradigm to the auditory modality.

Although Experiment 1 provided null results, the literature overwhelmingly supports the notion that habitual action video game play leads to enhancements in various aspects of visual attention (i.e., capacity, temporal processing, and spatial processing). However, very little has been done in regards to the potential enhancements in other sensory modalities (but see Donohue et al., 2010; Green et

al., 2010). Thus, it was pertinent to continue the exploration of the effects of distracting cues in the auditory modality.

The results of Experiment 2 also yielded null effects. This finding seemingly suggests that attentional resources are not shared as originally theorized by Wickens (1984). Instead, a segregated attentional system might be more adequate in helping to explain this finding (see Sinnett et al., 2007). This would assume that each sensory modalities' attentional resources would be individualized, leading to a dissociation between performance modulations observed in one modality and not in another. Although compelling, it is difficult to say for certain that attentional resources across modalities are segregated based on the findings of Experiments 1 and 2 alone, as both yielded null effects.

Specific Aim 3: Assess crossmodal interactions by expanding the TOJ task to include a combination of visual cues and auditory targets.

Experiment 3 provided the most interesting set of findings. This is because despite a lack of significant differences in either the visual (Experiment 1) or auditory (Experiment 2) modalities, under crossmodal conditions there were significant differences between VGPs and NVGPs. Specifically, the PSS scores for VGPs were much smaller when compared with NVGPs. This would suggest that they were less likely to be distracted by the visual cue (peripheral flashing box) when responding to auditory targets.

The findings from the crossmodal experiment are important in that they provide initial evidence to the question of whether or not experience in one

modality can affect other separate modalities. To date, there have only been two investigations to show this. Donohue et al. (2010) used a TOJ task with visual and auditory targets to demonstrate that VGPs had an enhanced ability to determine the temporal sequence of the multisensory stimuli when compared with NVGPs. Similarly, Green et al. (2010) utilized a novel auditory perceptual decision making task to demonstrate that action video game experience results in improved probabilistic inference. Together with the findings of Donohue et al. (2010), Green et al. (2010), and the results of Experiment 3, there is evidence to suggest that action video game experience results in benefits that extend beyond the visual modality and can impact multimodal processing.

Specific Aim 4: Determine whether the attentional enhancements seen in VGPs can also be seen in NVGPs who are trained with action video games, as measured by the TOJ task within and across sensory modalities.

A potential concern with Experiments 1-3 is the possibility that any difference is driven by some pre-existing difference between groups rather than the degree of video game experience. That is, it is possible that individuals who are drawn to video games have some already existing talent. Thus, Experiments 4-6 were necessary in order to investigate whether the effects seen in Experiments 1-3 could be replicated in a group of participants with no video game history, but were instead trained with an action video game for a modest amount of time. This also enabled a greater degree of control in regards to what kinds of video games were played and for how long.

Interestingly, none of the analyses carried out for Experiment 4 revealed any significant performance modulations. It was expected that action video game training would result in a modulation of PSS scores (i.e., perhaps be more distracted by the cues) under both endogenous and exogenous cueing conditions. However, much like Experiment 1, this was not the case. Thus, these findings are contrary to West et al.'s (2008), who demonstrated larger PSS scores for a group of expert VGPs.

In the auditory condition in Experiment 5, those trained with the action video game once again failed to demonstrate significant performance differences post-training. This would be supportive of a segregated attentional system (see Sinnett et al., 2007), as any performance modulation that is observable in the visual modality is not expressed in the auditory modality. However, this conclusion is extremely speculative since significant findings in Experiments 1 or 4 were not observed.

Lastly, Experiment 6 failed to find with VGPs, enhanced multimodal processing as was seen in Experiment 3. Interestingly, it should be noted that Donahue et al. (2010) also failed to show training effects in a non-video game playing sample, despite finding significant differences between expert VGPs and NVGPs in a separate condition using a similar paradigm to that used here. In light of their findings, it is possible that video game play might lead to modulations in attentional processing, specifically related to multisensory processing. Furthermore, this provides additional support to the notion that a supramodal attentional system operates in humans, with modulations in one sensory modality having effects on separate modalities (Driver & Spence, 1998; McDonald et., 2000; Spence et al.,

1998). Again, this conclusion must be held as very preliminary, as it is impossible to circumvent the lack of significant findings in the other experiments presented in this dissertation. Therefore, a clear picture of how video game play can modulate spatial attention still eludes researchers.

5.2. The Impact of Action Video Games on Attention

Although the reported findings are numerous and seemingly contradictory at times, they nevertheless partly support the idea that action video games have the ability to modulate attentional mechanisms. This is based exclusively on the findings from Experiment 3. Previous training studies demonstrated that non-video game players trained with an action video game can show improvement in temporal and spatial processing and increase overall attentional capacity (Feng et al., 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Li et al, 2007; Li et al., 2009). This dissertation attempted to discern the impact that action video games might have on the processing of different types of distracting cues. Overall, the findings failed to demonstrate that the ability to directly control the video game experience (i.e., via training) can have an impact on spatial attention across sensory domains, both unimodally (Experiments 4 and 5) and multimodally (Experiments 6). Interestingly, without training, the only performance gains were seen crossmodally.

5.3. Supramodal or Segregated System of Attention?

Based on the findings presented in this dissertation, it is difficult to ascertain with certainty whether the human attentional system operates in a segregated manner or instead in a supramodal manner. The null findings of Experiments 1, 2, and 4-6 make speculation difficult. However, it is possible to suggest that the null findings are indicative of a segregated system. Although, this speculation might be premature, as the results of Experiment 3 would suggest otherwise. That is, a sample of expert VGPs had significantly smaller PSS scores under crossmodal conditions.

5.4. Limitations of the Present Study

Given the unexpected results, there are a number of limitations that need to be discussed. Methodologically, a few factors may have resulted in the null results of Experiments 1 and 2. First, despite a precedent (Feng et al., 2007) for female participants in action video game research, they have not traditionally been used in groups composed of expert VGPs. That is, females are not normally integrated into the training experiments. Future work should consider using exclusively male participants. Secondly, the relatively short SOA used for the endogenous cue may have been the cause for the null effects of Experiment 1a. Although, it should be noted that the short interval nevertheless resulted in significant cueing effects. Regardless, future researchers might consider using a longer SOA to better coincide with other studies in the literature (i.e., 405 ms, see Shore et al., 2001). Finally, it

should be noted that a relatively modest amount of training time (i.e., 10 hours) was utilized in Experiments 4-6. Although differences have been observed with this small amount (see Feng et al., 2007; Green & Bavelier, 2003, 2006b), it nevertheless might not have been long enough in the present experiment. Indeed, others have incorporated training sessions that last upwards of 50 hours (see Li et al., 2007, 2009).

5.5. Theoretical Contributions of Research

Nearly a decade has passed since Green and Bavelier (2003) first published their paper demonstrating that action video game play can modify visual attention. Since then, these researchers, and several others, have further explored this particular area and have robustly demonstrated that action video game play enhances performance on a variety of visual perceptual tasks. Despite this, all research prior to this dissertation focused on the visual domain with the exception of two recently published investigations (see Donohue et al., 2010; Green et al., 2010). The experimentation presented in this dissertation was intended to address this shortcoming by moving beyond the visual domain and into the auditory domain, while also exploring interactions across senses. Furthermore, the training experiments were designed to increase the basic understanding of how video games modulate attention through training. Finally, by examining how video games affect attentional mechanisms across multiple modalities, it was possible to provide insight as to whether the human attentional system operates under a supramodal (Buchtel & Butter, 1988; Driver & Spence, 1998; Frassinetti et al., 2002; Spence &

Driver, 1994, 1997) or segregated (Duncan et al., 1997; Sinnett, Costa, Soto-Faraco, 2006, Sinnett et al., 2007; Wickens, 1984) manner.

Only one finding presented in this dissertation adds to the literature surrounding the effects of action video games on attention. Specifically, it was first shown here that habitual action video game play leads to a modulation of crossmodal processing in a TOJ task with visual cues and auditory targets (Experiment 3). Unfortunately, this finding was not supported by the results of the crossmodal training study (Experiment 6). This could be indicative of a selection bias when recruiting expert video game players. That is, it is possible that they simply have some sort of inherent skill set that draws them towards video games to begin with.

A pertinent question regarding these findings, and others involving video game players, is what theoretical advantage might video game play offer? The task used here involves the correct identification of order, while at the same time requires participants to inhibit the distracting effects of the cues. In a certain manner the findings support a late selection theory of attention (Deutsch & Deutsch, 1963), as even though the cues are ignored, they nevertheless are processed. In line with the perceptual load theory, it is possible that an increase in PSS (as seen by West et al., 2008) is associated with an increased ability to process distracting information. This would lead to greater effects for the cues, as they would be more easily processed by the VGPs. However, the decrease in PSS scores (Experiment 3) is more difficult to fit with perceptual load theory. The executive component of the ANT (see Fan & Posner, 2004) is perhaps what has been modified here, as decreased

PSS scores would indicate an improved ability to inhibit distracting information. The resolution of this question will be investigated in future research

5.6. Practical Contribution of Research

Practically, the implications of enhancing mechanisms of attention by video game training could lead to helping to improve the skills of individuals in specialized settings. For instance, pilots, surgeons and military personnel have all been shown to benefit from video game training in terms of improving occupational performance (Jones, Kennedy, & Bittner, 1981; Kennedy, Bittner, & Jones, 1981; Gopher, Weil, & Bareket, 1994; Bell & Waag, 1998; Rosser, Lynch, Cuddihy, Gentile, Klonsky, & Merrill, 2007). In addition to providing a training mechanism to enhance performance in a practical setting, the findings presented here could aid in developing new therapeutic approaches to improving cognitive functioning. For example, populations suffering from deficits in perceptual capabilities, such as the elderly or the disabled, might benefit from cognitive training on a video game system (Clark, Lanphear, & Riddick, 1987; Drew & Waters, 1986). That is, it may be possible that by simply playing video games one could ameliorate the effects of age-related cognitive dementia. There are a number of studies that have demonstrated processing modifications of the adult visual system when repeatedly exposed to visual stimuli (Ball & Sekuler, 1987; Fahle & Poggio, 2002; Seitz & Watanabe, 2003, 2005; Watanabe, Náñez, & Sasaki, 2001), thereby demonstrating the potential to use video games for the purpose of cognitive rehabilitation (Lange, Requejo, Flynn, Rizzo, Valero-Cuevas, Baker, & Winstein, 2010). Indeed, video games have already

been shown to improve the motor capabilities of stroke patients who participated in a study that involved video game training with a Nintendo Wii (Saposnik, Teasell, Mamdani, Hall, McIlroy, Cheung, Thorpe, Cohen, & Bayley, 2010). An increased understanding of how video game training can improve basic attentional mechanisms may help to aid in the development of non-invasive and cost effective rehabilitation therapies for the elderly and disabled.

5.7. Future Considerations

Given the less than consistent overall picture of the findings, future experimentation should further explore the concept of attentional capture in habitual video game players. Although the research presented here represents a good start for exploring crossmodal attentional enhancements in VGPs, there are many ways in which this line of research could be expanded upon. Offered below are a few examples of potential follow-up experiments:

1. In order to strictly examine temporal differences between VGPs and NVGPs, a TOJ task should be conducted without the presence of spatial cues (exogenous or endogenous), across modalities and crossmodally. Furthermore, such an experiment should be expanded to include a training component similar to the one used in Experiments 4-6.
2. A separate experiment identical to Experiment 1a should be conducted but with a longer SOA. If the short SOA used for the

endogenous cue in Experiment 1a was the cause for the null results then this modification should clarify the issue.

3. Endogenous cueing effects in VGPs should be explored in auditory and crossmodal TOJ tasks. The present study was limited to the investigation of the effects of exogenous cueing effects in the crossmodal TOJ task. This can be achieved by using a central cue that displays (or speaks) either the word LEFT or RIGHT. Such an experiment would help to clarify the potential differences in the way that exogenous and endogenous cues are processed crossmodally. Again, such experiments should first consider differences between VGPs and NVGPs and then see whether similar effects can be trained.

4. In order to truly assess the crossmodal effects of action video game training, video game training sessions should be varied in terms of modality. Therefore, there should be training conditions in which participants are exposed to only one sensory modality at a time (i.e., visual presentation only or audio presentation only).

5. Many games now incorporate tactile stimulation along with game play. Not only are console game controllers built with vibration capabilities, but hand held gaming devices now offer tactile feedback during game play. By exploring the effects of tactile stimulation, one would be able to explore a third sensory modality.

6. It may be of interest to explore effects not just across sensory modalities, but also across various game types. Furthermore, much of the literature has focused on solely using action video games. However, to date there has been no empirical study that has explored attentional differences across more than two game types. It may be the case that different game types offer differing attentional enhancements while others offer no enhancements. Thus, there is potential to explore differences between action games (i.e. *Call of Duty, Halo,* etc.), massive multiplayer online role-playing games or MMORPG's (i.e., *Myst, Final Fantasy, World of Warcraft,* etc.), music focused games (i.e. *Rock Band, Guitar Hero,* etc.), puzzle games (i.e. *Tetris, Minesweeper,* etc.), and even life simulation games (i.e. *The Sims, Sim City,* etc).
7. Eye-tracking software should be utilized in order to confirm that participants are indeed shifting their gaze to the different cues used in the TOJ task. Implementation of such software would be beneficial in determining the direction of eye movements in response to target locations.
8. The final consideration does not specifically suggest an experimental change, rather, it address a fundamental limitation of the current study. The main problem with these training studies is that it is very time consuming. For some reason, females were more inclined to participate in the training experiments compared to

males. Future training studies should provide improved incentives (other than extra credit) in order to increase participation of males. Such an incentive could, for example, be the inclusion of subject payments as reimbursement for time spent in the laboratory.

5.8. Final Thoughts

This doctoral dissertation has addressed the aims that were outlined in Chapter 1. First, it is clearly demonstrated in Experiment 1 that the results of West et al. (2008) are not conclusive. That is, neither Experiment 1 or 4 supported West et al., as overall the exogenous visual cues produced inconclusive effects in VGPs and in NVGPs. Although, it must be fully acknowledged that the null findings reported here would be met with much scrutiny if they were presented as concrete evidence against West et al. (2008).

Despite null results in Experiment 2 when exogenous cues were presented in the auditory modality, exogenous visual cues were shown to modulate performance when the exogenous cues were presented multimodally. Unfortunately, Experiments 4-6 failed to show any significant differences after participants had been trained with a very modest amount of action video game training. Thus, it is possible that further enhancements can potentially be seen with a greater amount of video game training. The crossmodal results of Experiment 3 provided the most intriguing results. Although the null results of Experiments 1-2 make it difficult to discern whether attention functions in a supramodal or segregated manner, the

results of Experiment 3 seems to provide support for a supramodal system of attention.

An additional point worth mentioning is that this dissertation provides insight into the basic methodologies employed in studies of attention in video game players. For instance, by highlighting the significance of using certain game types, future researchers can be more cognizant in choosing certain video games as control games. Also, future studies exploring endogenous cueing effects should consider lengthening the SOA of the endogenous cue since this might impact the effectiveness of the cue and the amount attentional capture that occurs.

This doctoral dissertation provides a theoretical account of the effectiveness of action video games in modulating attentional abilities. These findings have a direct impact on the interpretation of past and present research regarding basic mechanisms of attention. The real world applications of such research are numerous and there is the potential to solve many attention based problems in various professions. It is, however, important that this line of research continue in order to further elucidate the effectiveness of video games as a tool to improve attention at the theoretical and practical level. Although this dissertation provides a good basis for the beginning of a much larger research program in understanding the role that action video games might have on modulating attentional capture, a potential next step would be to determine the effects of endogenous cues in the auditory modality and crossmodally. Finally, an exploration into the effectiveness of the various game types and not just action video games should be examined. Needless to say, video games offer a unique experience that has the potential to

reshape and enhance the capability of the human attentional and perceptual systems.

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Appendix A

Informed Consent Form

The UNIVERSITY OF HAWAII AT MANOA
Department of Psychology
University of Hawaii
Phone: 808.956.6272

Consent Form
Cognitive deficits in post-concussive syndrome

Principal Investigator: Dr. Scott Sinnett, Department of Psychology, University of Hawaii at Manoa. Phone: (808) 956-6272, Email: ssinnett@hawaii.edu.

Introduction and Purpose
Previous investigations have demonstrated that humans' ability to perceive their environment may be enhanced when utilizing more than one sensory modality, which theoretically increases the amount of attentional resources available to the organism. A common belief in this research is grounded in the idea that a decreased amount of attentional resources will lead to decreased amounts of perception (e.g., a difficult secondary task will lead to lower perception levels). However, recent research has shown that our perception may be intrinsically tied to other environmentally important events that simultaneously occur. These experiments have shown that perception for unattended events is higher if these events are presented at, or around, the same time as an attended event. The purpose of this experiment is to explore these recent claims in a unimodal and multimodal setting.

Study Procedures
If you agree to participate, the experiment will take about 30-60 minutes of your time. You will spend most of this time seated in front of a computer monitor. There will be a varying number of blocks (no more than 5) where you will be presented a stream of objects originating from the screen and/or speakers placed beside the screen. You will be required to respond, by pressing different keys on the keyboard, or a foot pedal under your foot, to specific targets that occur in the stream of objects. Before beginning the experiment, you will receive ample instruction and training on the task. If you are not sure about any instructions, or wish to have more practice, do not hesitate to ask. There are no risks associated with participating in this experiment.

Confidentiality
Your identity will be kept strictly confidential. All documents will be identified only by a subject code number and kept in a locked filing cabinet. You will not be identified by name in any reports of the completed study. Data that will be kept on a computer hard disk will also be identified only by your subject code number and will be password protected so that only the principle investigator, Dr. Scott Sinnett, his graduate students, and research assistants will have access to it. Following the completion of the study, the data will be transferred to a CD and stored in a locked filing cabinet. Note, the results of this study will be used to write a scientific report.

Contact for information about the study
This study is being conducted by Dr. Sinnett, the principal investigator. Please call him if you have any questions about this study. Dr. Sinnett may be reached at (808) 956-6272 or ssinnett@hawaii.edu.

The UNIVERSITY OF HAWAII AT MANOA
Department of Psychology
University of Hawaii
Phone: 808.956.6272

Contact for concerns about the rights of research subjects

If you have any concerns about your treatment or rights as a research subject, you may contact the IRB Committee on Human Studies at (808) 956-5007.

Consent
Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy to your class standing.

Please feel free to ask the experimenter any additional questions you may have about the study.

Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study.

_____
Subject Signature Date

_____
Printed Name of the Subject

Appendix B

Video Game Questionnaire

Subject # _____

Date: _____

Video Game Questionnaire

1. What is your gender?

☐ Male ☐ Female

2. How old are you? _____

3. Are you:

☐ Right-handed ☐ Left-handed

4. What is your major? _____

5. How long have you been a video game player? _____

Please answer questions 5 and 6 based on your video game experiences in the past 6 months.

5. Per week, how many days would you estimate that you play video games? _____

6 Per day, how many hours would you estimate that you play video games? _____

7. In the last two weeks (14 days), how many days do you estimate to have played video games? _____

1

Subject # _____

Date: _____

8. Do you prefer to play video games on a game console (i.e. Xbox, Playstation, Wii) or on the computer?

☐ Video game console ☐ Computer

9. Do you own any of the video game consoles below?

Please check all that apply.

☐ Xbox 360

☐ Playstation 3

☐ Playstation Portable (PSP)

☐ Nintendo Wii

☐ Nintendo DS

☐ Other, please list: _____

10. Please list the video games that you have played in the past 6 months.

---------- (Thank You! Please turn in your questionnaire) ----------

Administrator:

Order of Experiment:

Notes:

2

Appendix C

Experimenter Scripts (Experiments 1-6)

Endogenous and Exogenous TOJ Task (Experiments 1a, 1b, 4a, and 4b)

Instructions presented prior to the practice trials (instructions appeared on the computer screen):

Did you see the vertical or horizontal line first?
Press the Z key for horizontal and the / key for vertical
Press the SPACEBAR for practice trials

Instructions presented immediately following the practice trials (instructions appeared on the computer screen):

Are you ready to begin?
Press Z to begin the experiment or press / to practice again
Note: the thickening of the box is non-predictive (does not predict which side will appear first)
Also, accuracy should be the aim, not speed

Auditory and Crossmodal TOJ Task (Experiments 2, 3, 5, and 6)

Instructions presented prior to the practice trials (instructions appeared on the computer screen):

Welcome to the experiment.
In this experiment you will hear two sounds, a crow and a dog
Your task is to simply say if you heard the crow or the dog first?
Press the D key for dog and the C key for crow
Press the SPACEBAR for practice trials

Instructions presented immediately following the practice trials (instructions appeared on the computer screen):

Are you ready to begin?
Press D to begin the experiment or press C to practice again
Try to be as accurate as possible