REDUCED ATTENTIONAL CAPTURE IN ACTION VIDEO GAME PLAYERS

by

JOSEPH DONALD CHISHOLM

B.Sc. H., St. Francis Xavier University, 2005

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES
(Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA
(Vancouver)

June 2009

© Joseph Donald Chisholm, 2009
ABSTRACT

Over the past 30 years, video games have become a more accepted and increasingly popular form of entertainment. Due to this increase in public interest as well as the increasing complexity of modern video games, researchers have begun to study whether extensive video game experience can affect cognitive and perceptual skills. Of particular interest is whether video game experience affects aspects of visual attention. Recent studies indicate that playing action video games improves performance on a number of visual attention-based tasks. However, it remains unclear whether action video game experience primarily affects endogenous or exogenous forms of spatial orienting. To examine this issue, action video game players and non-action video game players performed an attentional capture task. Results showed that action video game players responded quicker than non-action video game players both when a target appeared in isolation and when a salient, task-irrelevant distractor was present in the display. Action video game players additionally showed a smaller capture effect than non-action video game players. When coupled with the findings of previous studies, the collective evidence indicates that extensive experience with action video games may enhance players’ top-down attentional control which in turn can modulate the negative effects of bottom-up attentional capture. Collectively, this work also adds to the literature suggesting that video games can provide a novel form of rehabilitation for individuals living with various cognitive or visual deficits.
TABLE OF CONTENTS

Abstract .................................................................................................................................................. ii
Table of Contents ................................................................................................................................... iii
List of Figures ......................................................................................................................................... iv
Acknowledgements ............................................................................................................................... v
Co-Authorship Statement ......................................................................................................................... vi

CHAPTER 1: INTRODUCTION ................................................................................................................... 1

References ............................................................................................................................................. 24

CHAPTER 2: EXPERIMENT ...................................................................................................................... 29

Methods.................................................................................................................................................. 34

Participants ........................................................................................................................................... 34

Apparatus & Stimuli ................................................................................................................................. 34

Procedure ............................................................................................................................................. 35

Results................................................................................................................................................... 37

Discussion............................................................................................................................................ 39

References............................................................................................................................................. 42

CHAPTER 3: CONCLUSION ....................................................................................................................... 46

References ............................................................................................................................................. 58

APPENDIX: Copy of UBC Research Ethics Board Certificate of Approval.............................................. 62
LIST OF FIGURES

Figure 2.1 - Predicted results if action video game experience affects exogenous attention ......33

Figure 2.2 - Predicted results if action video game experience affects endogenous attention .....33

Figure 2.3 – Example of trial displays ..................................................................................35

Figure 2.4 - Group reaction time results as a function of distractor presence ......................38

Figure 2.5 - Group accuracy results as a function of distractor presence ..............................39
ACKNOWLEDGMENTS

First and foremost, I would like to thank my supervisor, Dr. Alan Kingstone for his guidance, patience, and personal and academic support. Next, I would like to thank my MA Committee members, Dr. Jim Enns and Dr. Todd Handy, and my collaborators Dr. Jan Theeuwes and Clayton Hickey, for challenging me, while at the same time offering advice and encouragement. Thank you to members of the BAR lab for all their help along the way and a very special thank you to my family and friends for the support they’ve provided over the years.

This work was supported by the University of British Columbia, the Natural Sciences and Engineering Research Council of Canada, and the Michael Smith Foundation for Health Research.
CO-AUTHORSHIP STATEMENT

I am the primary author on all of the MA work presented in this thesis, including experimental design, implementation, data analyses, and manuscript preparation. The work benefited from discussions with my supervisor, Dr. Alan Kingstone and collaborators Dr. Jan Theeuwes and Clayton Hickey.
CHAPTER 1

Introduction

The origin of video games dates back to the 1950s; however, it was not until the release of the Atari 2600 home video game console in 1977, followed by the Nintendo Entertainment System in 1985, that video games became a widely popular form of entertainment in North America. Playing video games has now become an almost ubiquitous past time in modern society. More people than ever, children and adults alike, spend a significant amount of their time playing a wide variety of interactive games. According to the Entertainment Software Association, 68% of households in the United States now own a video game console. This increase in the popularity of video games is also reflected in recent data showing that the video game industry earned over 10 billion dollars in hardware and software sales in North America in 2008 alone (Entertainment Software Association, 2009). In addition, video games have evolved into an increasingly sophisticated, visually impressive, cognitively and behaviourally demanding form of entertainment. In light of the complex nature of modern video games as well as the recent surge in public interest, researchers have begun to investigate how extensive experience with these games may affect individuals’ cognitive and perceptual abilities.

Greenfield (1984) was one of the first to voice that, due to the spatial and sensory-motor skills required as well as the associated cognitive complexity, video games presented an interesting area of research for the scientific community. She used the term ‘cognitive socialization’ (Greenfield, 1989) to refer to the effect cultural tools, such as video games and personal computers, had on individuals’ ability to process and subsequently communicate information. Video games were designed to entertain opposed to educate; however, as a popular cultural tool, they presented a potentially powerful source of informal education. Greenfield
voiced that informal education via the content of video games was less important, and it was instead the form of the medium in terms of design features such as interactivity and dynamic visual scenes which presented interesting possibilities for the unintentional acquisition of cognitive skills (Greenfield 1984).

Early work comparing video game players (VGPs) and non-video game players (NVGPs) investigated differences in hand-eye coordination (e.g. Drew & Waters, 1986; Griffith, Voloschin, Gibb, & Bailey, 1983), reaction time (RT; Orosy-Fildes & Allan, 1989; Clark, Lanphear, & Riddick, 1987) as well as general spatial skills (e.g. Subrahmanyam & Greenfield, 1994; McClurg & Chaille, 1987; Dorval & Pepin, 1986; Gagnon, 1985; Lowery & Knirk, 1982). In the majority of situations, experience with video games yielded benefits in performance in both young and elderly samples. In addition to leading to improved hand-eye coordination and speeded RT, video game experience also improved individuals’ spatial abilities, especially for those who initially possessed poor spatial skills. For example, females represent a group that tends to perform worst on spatial tasks than males and these earlier studies have suggested that video game experience could reduce the performance gap between males and females on spatial tasks. Recent results from Feng, Pratt, and Spence (2007) further support the differential effects video game experience has on gender.

Feng et al. compared male and female performance on a mental rotation task similar to that used by Vanderburg and Kuse (1978). Twenty undergraduate students, who reported no video game experience during the past four years, were recruited to participate in the experiment (10 males and 10 females). Participants were split into two groups, one which received training on a visually intense action video game (Medal of Honor: Pacific Assault) and the other received training on a non-action puzzle game (Balance). The mental rotation task consisted of 24 items
where participants were shown a target object and four additional objects rotated in 3-dimensional space. The task was to identify which two of the four rotated objects matched the target object. Accuracy was used as the dependent measure and participants were given three minutes to complete as many items as possible. Testing participants prior to video game training revealed that males initially demonstrated better performance on the mental rotation task compared to females. This finding is consistent with past work on gender differences in spatial skills.

Both groups then received 10 hours of video game training before being retested on the mental rotation task. Post training results revealed two important findings. First, those trained on the action video game showed significant improvement in performance on the task whereas the control group (i.e. non-action game) showed no significant change in pretest to posttest performance. Second, females demonstrated the greatest increase in performance in the action video game group. Female’s post training performance in the control group was also equal to male’s performance in the control group. Therefore, providing females with video game experience, particularly action video game experience, can reduce the size of gender differences in spatial tasks.

Recently, there has been growing interest in whether video games affect aspects of visuospatial attention. Research on this topic to date has solely investigated performance differences in tasks that involve covert shifts of attention. Based on a series of introspective observations by Helmholtz in 1894, we have come to accept that visual attention can be controlled and moved from one location in space to another location in space covertly, that is, without moving the eyes. In more recent years, this conclusion has been confirmed using a variety of experimental techniques. For example, Eriksen and Hoffman (1973) employed a
paradigm based on Sperling's (1960) partial report cueing technique, and demonstrated improved
target identification following priming by a spatial cue. Participants were required to fixate on a
cross positioned in the centre of an otherwise blank field. Then, a target letter, A, H, M, or U,
appeared 1 deg of visual angle from fixation. The letter could appear in any one of the 12 clock
positions of an imaginary clock face. Preceding the target letter was a bar marker which
indicated the location of the target stimulus. Without moving their eyes from fixation,
participants were to shift their attention to the cued location. If the letter target was a member of
the set A-U, participants moved a lever in one direction, and in the opposite direction if the letter
was a member of the set H-M. Results showed that response time improved steadily with
increasing delay between the location cue and the target stimulus, reaching asymptote about 300
ms after location cue presentation. Appropriate control conditions showed this response time
improvement to be 'location specific' and not an artifact of the more general alerting effects
which accompany a temporal warning signal.

Sperling and Reeves (1980), and Reeves and Sperling (1986), have employed a 'rapid
serial visual presentation' (RSVP) technique to demonstrate that 'people can look fixedly at one
thing while paying attention to another'. Participants were instructed to maintain steady eye
fixation on a dot positioned in the middle of a screen. About .9 deg of visual angle to the left of
fixation a stream of letters appeared at a rate of 4.6 characters/second. The same distance to the
right of fixation a stream of numbers appeared at a rate of 4.6 characters/second, or faster.
Maintaining fixation on the centre dot, participants attended to the letter stream for a pre-defined
target, the detection of which was the signal to switch attention (but not the eyes) to the number
stream and report the first digit processed. Participants seldom reported the number which
occurred simultaneously with the letter target. They reported a digit that occurred later. This
result agrees with Helmholtz's observation that attention shifts may be independent of gaze, and these shifts will take some time to occur.

Electrophysiological studies (e.g., Eason, 1981; van Voorhis, & Hillyard, 1977; Eason, Harter, & White, 1969) have revealed a clear and consistent enhancement of the visual evoked response potential (ERP) in response to stimuli at attended locations in space. For example, if a participant is told to fixate on a black dot in the middle of a screen, and then circular flashes of light are presented 1 deg to the left and right of fixation, specific ERP components show reciprocal increases and decreases in amplitude to flashes in either the left or right location when attention is switched between them. Behavioural and electrophysiological evidence thus converges on the conclusion that attention can be moved between locations in space, covertly, that is, without any shift in gaze.

Probably the most extensive work on covert shifts of spatial attention, or covert orienting, as it is more commonly known, has been conducted by Posner and his co-workers (e.g., Posner, 1980; Posner, Snyder, & Davidson, 1980; Posner, Nissen, & Ogden, 1978). In their first study (Posner et al., 1978) the critical question was whether responses to a simple luminance change would occur more quickly when participants knew in advance where the stimulus was likely to occur than when they did not know where the stimulus was likely to occur. There was extant evidence that knowledge of spatial location would improve identification performance of letters and numbers (e.g., Eriksen & Hoffman, 1973; Sperling, 1960), but for reasons outlined in the previous section, Posner's interests were, at least initially, in tasks in which the stimulus input was as simple as possible.

The dependent variable was simple response time (a single key press) to the onset of a 'suprathreshold luminance increment', i.e, a "flash" of light. The target flash could appear either
to the left or to the right of a central fixation point. One second before the target appeared, the participant was provided with a central location cue which was either an arrow pointing to the left of fixation, or an arrow pointing to the right of fixation, or a neutral plus sign (+). If the cue was an arrow, the target flash occurred at the cued location on 80% of the trials, and at the uncued location on 20% of the trials. In other words, the probability of the arrow being valid was .80, and the probability of the location cue being invalid was .20. The plus sign was a neutral warning signal, indicating that a target was just as likely to appear to the left of fixation as to the right of fixation (p=.50). Participants were informed of the predictive value of the location cues. Results showed that response time was about 25 ms faster on valid than neutral location cue trials, and about 40 ms slower on invalid than neutral location cue trials. Thus, relative to the neutral condition, Posner et al. demonstrated both a response time benefit in processing when target onset occurred at the expected location, and a response time cost when target onset occurred at the unexpected location. They were able to discount two possible explanations for these results. First, the monitoring of eye movements during the task showed that only 4% of all the trials produced movements, and their subsequent detection showed that changes in response speed for targets appearing at expected and unexpected locations were not associated with preparatory eye movements toward the cued target position. Second, because a simple response time task was used, the results could not be mediated by selective motor preparation.

The results were interpreted as being due to selective visual attention of limited capacity. Thus, attending to one location requires the commitment of attentional resources to that location, which, since resources are limited, entails a reduction in resources at other locations. Attention facilitates performance by improving the processing efficiency, that is, the pick-up of information, in the cued position. Therefore focusing attentional resources on a particular spatial
location produces a localised change in perceptual sensitivity in the visual field: Information processing is enhanced at the attended location, at the expense of reduced processing efficiency at unattended positions.

An abundance of recent neuroimaging data has also added to our general understanding of how covert spatial attention is allocated. Based on the collective results from non-human animal studies as well as patient studies, Posner and Peterson (1990) have outlined the involvement of the parietal lobe, midbrain structures, specifically the superior colliculus, and the pulvinar nucleus in covert orienting. Damage to any of these areas will result in general attentional deficits; however, each region appears to have a specific function in covert orienting. Superior colliculus damage leads to deficits in shifting attention from one spatial location to another. Posterior parietal lobe damage yields deficits in disengaging attention from its current spatial location (Posner, Walker, Friedrich, & Rafal, 1984). Research has also demonstrated changes in covert attentional performance following lesions or chemical injection of gamma-aminobutyric acid (GABA) agonists or antagonists into the pulvinar nucleus of the thalamus (Peterson, Robinson, and Morris, 1987).

It is now well established that attending to a spatial location, whether overtly or covertly, improves the processing of information at that location. Video games present players with an abundance of information occurring simultaneously across an entire display. Much like in everyday life, in these virtual environments players must deal with far more information than they can hope to process at any given time. Therefore, players are in an almost constant state of orienting and engaging spatial attention in very fast paced and visually complex environments. This has led some to address the question of whether extensive video game experience affects
aspects of visuospatial attention. Greenfield and colleagues were one of the first to address this question.

Using RT and accuracy measures to behaviourally index attention, Greenfield, deWinstanley, Kilpatrick, and Kaye (1994) investigated the effect of video game experience on ones’ ability to effectively divide visual attention across a display. In their first experiment, 34 male undergraduate students were recruited to participate. Each participant initially played two sessions of a video game (Robot Battle) to assess video game experience. Those who earned a high score in the video game were considered experts and those who scored quite low were considered novices. Sixteen of the 34 participants (Eight experts and eight novices) met the inclusion criteria and were subsequently tested in the attention task.

A luminance detection task was used, where participants were required to report whether a target item (an asterisk) appeared on the left or right side of a computer display or whether two targets appeared simultaneously. Two conditions were used to manipulate the probabilities associated with the target location. In the first condition, a target appeared at one location in 80% of trials (likely location), the opposite location in 10% of trials (unlikely location), and simultaneously in 10% of trials. In the second condition, a target was equally likely ($p = 0.45$) to appear on the left or right of the display (neutral condition). Again, two targets appeared simultaneously in 10% of trials. Results indicated that both “expert” and “novice” players demonstrated a benefit in RT when a target appeared at the likely location compared to the neutral condition. Consistent with previous findings (e.g. Posner et al., 1980), novices demonstrated a cost in RT when the target appeared at the unlikely location compared to the neutral condition. Critically, unlike novices, experts did not show any RT cost associated with a target appearing at the unlikely location. Greenfield et al. interpreted these results to suggest that,
as a result of extensive experience with displays that often require attention to be divided, when focusing attention on a particular location, VGPs may be capable of maintaining peripheral resolution.

To ensure that their result was not due to a self-selection bias, the authors conducted a second experiment. Forty participants were recruited to participate in experiment 2 and were randomly assigned into either an experimental or control group. Within each group, participants were further divided into experts and novices, again based on initial video game scores. The experimental group was then given five hours of video game practice whereas the control group received no additional exposure to the game. Participants conducted the same attentional task as described above for experiment 1. Results indicated that, although the training did not eliminate the RT cost associated with a target appearing in the unlikely location, trained novices did reduce the relative cost of such events. These results provided evidence suggesting that the video game experience played a causal role in improving performance. Specifically, Greenfield et al. claimed that extensive video game experience could alter the strategies players use to deploy visuospatial attention.

More recently, Green and Bavelier have contributed a great deal of research highlighting differences between VGPs and NVGPs. In their first article, Green and Bavelier (2003) reported differences between action video game players (AVGPs; those who predominantly play action video games) and NVGPs in a modified flanker/perceptual load task, a useful field-of-view (UFOV) task, an enumeration task, and an attentional blink task. In all tasks, only male participants were tested and were divided into AVGP and NVGP groups. AVGPs were those who reported playing action video games four days a week (one hour per day minimum) over the
previous six months. NVGPs were those who reported little to no video game use over the same six month period.

In the modified flanker/load task participants were asked to report whether a square or diamond (target) appeared at one of six possible locations on an imaginary circle. On each trial, an additional item was placed in the periphery (i.e. outside the imaginary circle) and was either compatible or incompatible with the target shape. By determining the RT difference between compatible and incompatible trials, one measures what is called a compatibility effect which is believed to index the amount of attentional resources available to the individual. Green and Bavelier also manipulated task difficulty by adding one, three, or five additional non-target items at the other locations within the display. Results showed that NVGPs’ compatibility effect decreased as task difficulty increased. This is consistent with the idea that when task difficulty is low, attentional resources can ‘spill over’ and process information outside the scope of the primary task. As task difficulty increases, the primary task requires more attentional resources which then prevents attention from attending to ‘secondary’ or irrelevant information. AVGPs also demonstrated a significant compatibility effect when task difficulty was low; however, in contrast to NVGPs, this compatibility effect remained even at the highest task difficulty. This result was interpreted as indicating that AVGPs possess increased attentional resource capacity relative to NVGPs.

Green and Bavelier (2003) provided supporting evidence for this interpretation by comparing AVGP and NVGP performance in an enumeration task. In this task, participants were briefly presented with displays consisting of one to 12 white squares. Displays were only presented for 50 ms and participants were required to accurately indicate the number of squares present in each display. Accuracy of correctly identifying the number of squares present was the
dependent measure. This task provides a measure of the number of items one can attend at a given time, also referred to as a subitizing range, and is also considered a measure of attentional resource capacity. NVGPs were able to report up to three squares with little error (< 10%); however, from four items and up, error increased in a linear fashion with the addition of each additional square. In contrast, AVGPs were able to report up to five squares with little error (< 10%). AVGPs’ error rates also increased linearly when six or more squares were present in the display; however, AVGPs were consistently more accurate than NVGPs at all set sizes beyond the NVGPs’ subitizing range.

Intrigued by these findings, Green and Bavelier (2003) wished to investigate whether the observed attentional improvements would extend to regions outside what they referred to as a video game training zone. Thus, they tested AVGPs and NVGPs in a UFOV task which provides a measure of how visuospatial attention is distributed. Participants were required to accurately report the spoke that a target (triangle within a circle) appeared along. The distribution of visual attention was tested across groups at three eccentricities, one well with the typical training zone of AVGPs (10°), one at the boundary of AVGPs’ training zone (20°), and one well outside the training zone (30°). To ensure equal difficulty across eccentricities, different presentation times were used. The display was presented for only 6 ms when the target was located at 10°. On trials where the target was located at 20° or 30°, the display was presented for 12 ms. Results revealed that AVGPs were far more accurate at reporting the location of the target compared to NVGPs. Critically, this advantage did extend to the 30° condition leading Green and Bavelier to suggest that the improvements in visuospatial attention are not limited specifically to trained locations.

This work was later replicated (Green & Bavelier, 2006a) demonstrating similar results in slightly modified flanker/load and UFOV tasks as well as the enumeration task (Green &
Bavelier, 2006b). In their most recent work Green & Bavelier (2007) also demonstrated that AVGPs possess improved visuospatial resolution, consistent with Greenfield et al.’s (1994) account of their divided attention data. Green and Bavelier compared AVGPs and NVGPs in a crowding task to assess whether extensive action video game experience alters the spatial resolution of visual attention. Crowding refers to the difficulty one experiences in identifying a target when it is surrounded by nearby distractors compared to the relative ease of identifying the target when it appears in isolation (Intriligator & Cavanagh, 2001).

Twenty male participants, classified as either an AVGP or NVGP, completed the crowding task. Those who reported playing a minimum of five hours of action video games per week over the previous six months were considered AVGPs. NVGPs were those who reported 0 hours per week of action video game experience over the previous six months. Participants were presented with displays that consisted of three “T” shapes that were randomly oriented right-side up or inverted. Each trial began with an auditory tone, followed by an inter-stimulus interval of 150 ms. The display was then presented for 100 ms. The task required participants to indicate the orientation of the T shape that resided between the other two T shapes. Shapes were presented at three eccentricities, 0°, 10°, and 25° and were separated by 30, 400, and 600 min of arc (MOA), respectively. The size of the T shapes at each eccentricity was dependent on an initial threshold measurement of identifying a T when presented in isolation. Results revealed that AVGPs demonstrated less interference due to crowding compared to NVGPs at all eccentricities. An additional finding also indicated that AVGPs were capable of discriminating significantly smaller Ts than NVGPs. These results were interpreted as evidence that AVGPs not only possess improved spatial resolution of visual attention, but that they may also possess better visual acuity than NVGPs.
A study by Castel, Pratt, and Drummond (2005) further addressed possible changes in attentional processing between AVGP and NVGPs, in visual search and inhibition of return (IOR) tasks. Forty participants, split into AVGP and NVGP groups, completed the IOR task. Similar to the criteria used by Green and Bavelier (2003), those who reported playing action video games for four days a week with a minimum of one hour per day over the previous six months was considered an AVGP. NVGPs were those who reported little to no video game experience of the same six month period. Participants were initially presented with a display consisting of a central fixation point and two boxes, one on either side of fixation. This initial display remained for 1000 ms and was followed by a 50 ms cue, illuminating one of the two boxes. Following the cue, the target appeared at one of six randomly determined stimulus onset asynchronies (SOAs; 100, 200, 400, 600, 800, or 1000 ms). Participants were informed that the cue provided no information regarding the location of the target and they were to respond with a key press when they noticed the appearance of a target (circle). A target appeared in 80% of trials and the remaining 20% of trials were catch trials. The cue and target were also equally likely to appear at either box location. Results showed that AVGPs and NVGPs alike demonstrated faster RT at cued locations when the cue-target SOA was short (less than 200 ms), and slower RT at cued locations when the SOA was long. This finding replicates previous IOR findings (e.g. Klein, 2000; Posner & Cohen, 1984). Although both groups showed a similar pattern of results, AVGPs demonstrated an overall RT advantage compared to NVGPs.

Similar results were found in the visual search task. Ten AVGPs and 10 NVGPs, who previously participated in the IOR task, completed the visual search task. Participants were presented with either easy or hard search displays with set sizes of four, 10, 18, or 26 items. The task required participants to search the display and report, as quickly as possible, whether the
letter “b” or “d” was present. On easy trials, all the distractor items were the letter “k” and on hard trials, the distractors consisted of a random assortment of the letters h, j, g, y, l, and p. Results showed that both groups demonstrated efficient search patterns when distractors were homogenous (i.e. no increase in RT as a function of set size) and inefficient search patterns when distractors were heterogeneous (i.e. RT increased with set size). The only apparent difference between AVGPs and NVGPs in either task was, again, that RT performance in the AVGP group was consistently shorter than that in the NVGP group. An interaction was found between set size and group in the visual search task but this was reported to be an artifact of a floor effect at the smaller set sizes. Castel et al. interpreted these results to indicate that AVGPs and NVGPs engage similar attentional mechanisms and that AVGP’s observed RT advantage simply reflects improved stimulus-response mapping allowing AVGPs to execute motor responses more quickly.

Despite Castel et al.’s (2005) claims, results from Green and Bavelier (2007, 2006a, 2006b, 2003) as well as Greenfield et al. (1994) and Feng, et al. (2007), who also replicated Green and Bavelier’s UFOV findings, appear to provide undeniable evidence that the differences between AVGPs and NVGPs are at least partly due to changes in attentional processing. Results from a recent study by West, Stevens, Pun, and Pratt (2008) also support this view. West et al. compared AVGP and NVGP performance on a temporal order judgement (TOJ) task and a simulated lifeguard search task. Results showed that AVGPs were more sensitive to an exogenous cue in the TOJ task, and were also better at detecting a target in their search task compared to NVGPs. Whereas previous findings suggest that action video game experience affects the later stages of attention, these findings suggest that action video game experience also affects early sensory processing. In addition, West et al. did not use RT measures; therefore,
there was no confound of the result being due to video game players merely being faster at pressing buttons. In summary, the research to date presents very compelling evidence that action video game experience does affect processes associated with visual attention.

A primary concern associated with this area of research has been to determine whether action video game experience produces the observed attentional effects or whether improved attentional skills simply covaries with video game experience. It has been suggested that instead of video game experience causing the observed benefits, it is possible that those who possess greater than normal attentional abilities are drawn to the fast paced world of action video games. With work done by many of those mentioned above, this concern can largely be put aside. As described earlier in Greenfield et al.’s (1994) and Feng et al.’s (2007) studies, training NVGPs on action games yields reliable improvements in performance. Early work by Orosy-Fildes and Allan (1989) showed that even very little exposure to video games could improve performance on a simple reaction time task. They demonstrated that participants who received only 15 minutes of video game experience subsequently improved their performance by 50 ms on the RT task. No such improvement was observed in the control group who received no video game experience. Improvements in general spatial skills have also been observed following video game training (e.g. Subrahmanyam & Greenfield, 1994; McClurg & Chaille, 1987; Dorval & Pepin, 1986; Gagnon, 1985).

Returning to visuospatial attention, Green and Bavelier are once again responsible for providing a wealth of research highlighting the role action video game experience plays in improving attentional performance. In all of their investigations (Green & Bavelier, 2007, 2006a, 2006b, 2003), they have conducted a training study to confirm that action video game experience played a causal role in the findings from their self-selected samples. Green and Bavelier
recruited NVGPs and split them into two groups, an experimental group assigned to train on an action video game and a control group, assigned to train on a non-action video game. Comparing performance on any of the previously described attentional tasks (e.g. flanker/load compatibility, UFOV, enumeration, crowding) pre and post video game training consistently revealed the same result. Those who received training on the action video game reliably improved in performance post training relative to pre training. This effect was not observed in those who trained on the non-action game.

In addition to supporting the causative role played by action video game experience in benefiting visuospatial abilities, it must be noted that the type of game being played is also very important. Almost all previous training studies have compared performance between those trained on some form of fast paced or visually complex video game (consistently referred throughout as an “action” video game) and those trained on less visually demanding control games. Control games have typically been of the puzzle variety or Tetris. As previously mentioned, the benefits associated with video game training have been specific to action video games. This presents an interesting question of whether different types of games produce benefits in different cognitive areas or whether the sole benefits that can be acquired are those due to fast paced action video games. A recent study by Basak, Boot, Voss, and Kramer (2008) has shed some light on this issue.

Basak et al. recruited an elderly sample of 40 participants who reported no video game experience over the last two years. As is now typical with video game training studies, participants were divided into experimental and control groups. The experimental group received, in total, 23.5 hours of training on a real-time strategy (RTS) video game (Rise of Nations) and the control group received no video game training. Participants were tested three
times (pre, during, and post training) in six tasks aimed at measuring the effect of video game experience on executive function and four tasks aimed at measuring the effects on visuospatial attention. Results indicated that training on a RTS video game improved performance on tasks indexing executive function but not on tasks of visuospatial attention. Those who received the video game training showed improvements on measures of task switching, working memory, visual short term memory, and reasoning. No improvements, aside from general practice effects, were observed in the control group. In addition, the experimental and control group performance did not differ on any task related to visuospatial attention. This study presents two important findings. First, it indicates that executive functions in an elderly sample can be improved with video game experience. Second, it reveals that different types of video games may yield effects at different levels of our cognitive system.

It is worth noting that not all training studies have reported significant improvements as a result of video game training. For example, Sims and Mayer (2002) gave 12 hours of Tetris training to non-Tetris players and compared pre and post training performance on a standard mental rotation task. Results showed that 12 hours of Tetris training failed to improve performance on the mental rotation task. Performance was equal to the control group who received no Tetris training. However, as suggested by Greenfield (1984), although the content of Tetris involves rotating objects in 2-dimensional space, this type of game may not possess any particular form or design characteristics which promote any changes in our cognitive systems.

A recent study by Boot et al. (2008) also failed to demonstrate significant differences in self-reported AVGPs and NVGPs in addition to showing little effect of action video game training on a number of tasks. Boot et al. examined performance of AVGPs and NVGPs, as well as NVGPs trained on an action video game, NVGPs trained on a real-time strategy video game,
and NVGPs trained on a control video game. Contrary to earlier findings, AVGPs failed to show a significant advantage on the UFOV task as well as the enumeration task. However, improvements were documented on multiple object tracking, visual short term memory, task switching, and mental rotation tasks. In addition, despite receiving 21.5 hours of training, results failed to demonstrate a significant effect of training in any group (action, strategy, or control) on any of the host of tasks used by Boot et al.

These studies notwithstanding, there still exists a relatively great deal of research supporting the causative role action video game experience plays in improving visuospatial skills. Video games can thus provide a novel tool to investigate cognitive and perceptual systems and how they can be affected by experience. However, although previous work has identified situations where AVGPs and NVGPs differ in visuospatial attention, further study is required to uncover the attentional mechanisms underlying the observed differences. A key and heretofore unanswered question is whether there is a fundamental difference in the spatial orienting of attention between AVGPs and NVGPs. As AVGPs spend a significant amount of time in very fast paced and visually complex environments, it is possible that such experience could alter how objects are selected from displays.

The guidance of visuospatial attention is commonly held to be influenced by two functionally independent and often competing processes (e.g. Jonides, 1981, Posner 1980), i.e. a rapid preattentive (exogenous) process and a slower attentive (endogenous) process. During early preattentive/exogenous processing, attention is pulled in the direction of salient stimuli in a bottom-up manner independent of attentional resources. In contrast, slower attentive/endogenous processing orients attention in a top-down controlled manner dependent on the goals and expectancies of the individual, and it is resource limited. Neuroimaging data has also provided
supporting evidence for the distinction between exogenous and endogenous attention (e.g. Corbetta & Shulman, 2002, Hopfinger, Buonocore, & Mangun; 2000, Posner & Peterson, 1990; however, see Peelen, Heslenfield, & Theeuwes, 2004 for inconsistent findings). Results indicate that exogenous attention activates the ventral frontal cortex and the temperoparietal junction. In contrast, endogenous attention engages the posterior parietal lobe and frontal eye field regions.

When presented with a display that consists of an item unique in some feature dimension (e.g. colour, shape), one is very quickly able to detect this item with little to no effort. Such elements that “pop-out” from the display are often referred to as singletons. In situations where a singleton is task-irrelevant yet still receives priority independent of the observer's goals or beliefs, one refers to attentional capture. Therefore, consistent with West et al.'s (2008) findings, the difference between AVGP and NVGP could be due to AVGP's greater sensitivity to salient display items, resulting in attention being captured more quickly in a bottom-up/exogenous manner by the unique target item. However, such an explanation presents two problems. First, as pointed out by Yantis and Egeth (1999), it is incorrect to refer to bottom-up attentional capture when the target is the most salient item in the display as individuals may employ top-down/endogenous strategies to locate the item they have been instructed to find. One can only speak of attentional capture in a purely bottom-up manner when the salient singleton is known to be task-irrelevant so there is no incentive to attend to it. Second, whether a difference in performance exists between AVGP and NVGP on a visual search task which consists of a highly salient task-irrelevant distractor has yet to be investigated.

To study attentional capture, Theeuwes (1991, 1992) developed the additional singleton paradigm. In an additional singleton task, participants are asked to covertly search a display and locate a unique target singleton. On some trials a highly salient task-irrelevant singleton is also
present in the display. Attentional capture is then measured by comparing performance on trials where the distractor singleton is present relative to trials where it is absent. The typical finding is that RT is slower on trials where a distractor singleton is present.

Theeuwes (1991, Experiment 2) recruited 16 participants to assess whether visual search can occur in parallel but also be selective even in the presence of a distractor singleton. Each display presented to participants consisted of five, seven, or nine shapes arranged on an imaginary circle. The shapes were either diamonds or circles and the display items were also coloured either red or green. Line segments, oriented 22.5° off of the vertical or horizontal plane, were placed within each shape. However, within a target singleton, defined in either the form or colour dimension, the line segment was perfectly vertical or horizontal. Participants were required to locate the target and respond to the orientation of the line segment within the target.

Participants were split into two groups. For one group, the target singleton was unique in the form dimension (e.g. a circle amongst a display of diamonds). For the other group the target was unique in the colour dimension (e.g. a green item amongst a display of red items). On half the trials a task-irrelevant singleton was added to the display in the dimension opposite to that of the target. For example, if the target singleton was unique in the form dimension, the irrelevant singleton would be unique in the colour dimension. Theeuwes presented the displays in a mixed fashion. In either condition, although participants knew that a target singleton would be present, they only knew the unique dimension they were told to search for (i.e. colour or form); however, the exact target was never known in advance. For example, if searching for a unique form, it was unknown whether that form would be a circle or diamond. Similarly, target location, line orientation, and distractor location (when present) was randomly determined from one trial to the next.
Results revealed that search was efficient across all set sizes. Critically, there was an effect of distractor type on RT performance. When searching for a unique colour, an irrelevant form singleton did not significantly interfere with search. In contrast, searching for a unique form was significantly affected by the presence of an irrelevant colour singleton. Compared to when the target form singleton was presented in isolation, RT was slowed by approximately 100 ms when an irrelevant colour singleton was present in the display. One possible explanation for these results suggested that colour information becomes available before form information. As Theeuwes suggested that attention is captured by the first available feature, attention would be automatically drawn to the colour singleton regardless of whether it is the target or irrelevant singleton. In other words, attention is first drawn to the most salient item in a display relative to surrounding items.

To test this notion, Theeuwes (1991) conducted a third experiment. This experiment was identical to experiment 2 except for changing the relative salience of the irrelevant singletons. In the condition where participants searched for a form singleton, the irrelevant colour singleton was made relatively less salient. When participants searched for a colour singleton, the relative salience of the irrelevant form singleton was increased. Results again revealed that search slopes were approximately flat across set sizes. Critically, a reversal of the findings from experiment 2 was observed. Search for a colour singleton was slowed by the presence of a more salient but task-irrelevant form singleton. In contrast, search for a form singleton was not affected by the presence of a colour singleton of lower salience. Therefore, these results are consistent with the notion that attention is automatically captured as a function of visual salience.

Theeuwes (1992) conducted a series of follow-up studies to further investigate the capture of attention by salient singletons. The task paradigm used was the same as in Theeuwes
Sixteen participants were again split into two groups. For both groups, the target line segment was always located within a green circle. For one group; however, no-distractor trials presented the green circle amongst red circles. In the distractor present trials, one of the items became a red diamond. For the second group, no-distractor trials presented the green circle amongst green diamonds. In distractor present trials, one display items became a red diamond.

Results revealed that search was again efficient across all set sizes. Critically, when searching for a green circle surrounded by green diamonds (form singleton), the presence of a red diamond (colour singleton) interferes with search performance. In contrast, when searching for a green circle surrounded by red circles (colour singleton), the presence of a red diamond (form singleton) did not affect search performance. These finding were identical to the results in Theeuwes (1991, Experiment 2). In addition; however, this study revealed that having advance knowledge of target and distractor features did not prevent attentional capture. Therefore, such foreknowledge did not result in capture being overridden by top-down attentional processes. Theeuwes suggested that attention is first captured by the most salient item in a display (e.g. colour singleton) and is then subsequently captured by the second most salient item in the display (e.g. form singleton).

Theeuwes (1992, Experiment 1B) conducted a second experiment to investigate whether practice would allow top-down control to eventually override attentional capture. The procedure and conditions were exactly the same as experiment 1A described above; however, only the condition of searching for a form singleton was used. Participants completed 288 practice trials followed by a staggering 1,728 experimental trials. RT was divided into three training sections and performance on distractor present and absent trials was compared across each. Results indicated that practice did not interact with any other factor. In other words, extensive practice
had no effect in preventing the capture of attention by a salient singleton even if such an item is
known to be task-irrelevant. At all practice sections, search performance was consistently
affected by the presence of an irrelevant colour singleton when searching for a form singleton.
Collectively, these results have led Theeuwes to make two fundamental statements regarding the
capture of attention. First, attention is automatically captured by the most visually salient
singleton present in a display. Second, it is not possible for top-down control processes to
prevent the capture of attention.

The following chapter presents a study that used Theeuwes (1991, 1992) additional
singleton paradigm to investigate whether AVGPs and NVGPs differ in an attentional capture
task. By comparing AVGPs and NVGPs in the additional singleton task, the aim of the present
study hoped not only to identify another situation where AVGPs and NVGPs differ in
performance, but to shed some light on the attentional mechanisms underlying the observed
attentional differences. Of interest was whether action video game experience exerts its effect
primarily on exogenous or endogenous attentional processes. Additionally, as all previous work
has shown performance benefits as a result of video game experience, in the attentional capture
task used, it was of interest whether this would present a situation where AVGPs would
demonstrate worst performance than NVGPs, reflected as showing a greater degree of
interference by the task-irrelevant singleton.
References


evoked cortical potentials and reaction time in man. *Physiology and Behavior, 4*(3), 283- 
289.

facts about the computer and video game industry. Retrieved August 10, 2009 from 


visuospatial attention. *Journal of Experimental Psychology, 32*(6), 1465-1478.


Green, C.S. & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of 


Sperling, G. (1960). The information available in brief visual presentations. Psychological
Monographs: General and Applied, 74(11), 1-29.


Subrahmanyam, K. & Greenfield, P.M. (1994). Effect of video game practice on spatial skills in

50(2), 184-193.

51(6), 599-606.

points in space. Perception & Psychophysics, 22, 54-62.


attentional capture. Journal of Experimental Psychology: Human Perception &
Performance 25 661-676.
CHAPTER 2

Experiment

The amount of information available to the visual system is much greater than what we can fully process at any given time. It is therefore important that we select relevant information from the environment and ignore information that is irrelevant, particularly when this information may disrupt our actions. It has been suggested that visual selection is determined through an interplay of top-down and bottom-up processes such that bottom-up (exogenous) processes play a role in early vision while top-down (endogenous) processes are more important later in processing (e.g., Theeuwes & Van der Burg, 2007; van Zoest, Donk & Theeuwes, 2004; Hickey, van Zoest, & Theeuwes, under review). According to this idea, attention is pulled in the direction of salient stimuli in a bottom-up manner independent of attentional resources during the early exogenous stage. Later in time, limited-capacity endogenous processes orient attention in a controlled manner dependent on personal goals and expectations.

The need for fast and efficient selection when playing video games is particularly great because video games typically involve demanding visual input that requires fast hand-eye coordination, quick reflexes, and precision timing. It is crucial for successful video game performance that players rapidly select relevant information and ignore irrelevant information. Video game players often play for many hours over extensive periods, raising the possibility that this visuospatial training may lead to changes in the way objects are selected from the environment. Consistent with this, research investigating differences between video game players (VGPs) and non-video game players (NVGPs) has reported a whole host of performance

1 A version of this chapter has been accepted for publication, pending revisions. Chisholm, J., Hickey, C., Theeuwes, J., & Kingstone, A. (2009). Reduced attentional capture in action video game players. Attention, Perception, & Psychophysics.
differences. For example, VGPs possess quicker reaction times (RTs; Castel et al., 2005; Clark et al., 1987; Goldstein et al., 1997), improved hand-eye coordination (Griffith, et al., 1983), enhanced spatial abilities (e.g. McClurg & Chaille, 1987; Gagnon, 1985), and improved target detection (West, et al., 2008; Feng, et al., 2007; Green & Bavelier, 2006a). Many of these findings are observed specifically as a result of experience with action video games, which typically place players in a first-person perspective and often involve fast-moving, salient objects that require immediate action. Although the differences between action video game players (AVGPs) and NVGPs are impressive both in terms of breadth and number, whether action video game experience translates into a fundamental change in exogenous or endogenous attentional systems remains unclear.

Results from Green and Bavelier (2003, 2006a) have been suggested as evidence of better endogenous control of attention in AVGPs. These authors demonstrated differences between AVGPs and NVGPs on a useful-field-of-view (UFOV) and flanker compatibility task. The UFOV provides a measure of the visual field area across which an individual is capable of processing rapidly presented stimuli. It is commonly measured by having participants localize a target that can be presented at a number of peripheral eccentricities either alone or in the presence of distractors (Ball & Owsley, 1992). Green and Bavelier (2003, 2006a) found that AVGPs reported the location of the target more accurately at all target eccentricities, suggesting that these individuals were better able to control the location and focus of attention. In a modified flanker compatibility task, AVGPs and NVGPs were presented with a flanker item either centrally or in the periphery. Both groups demonstrated a compatibility effect in a low perceptual load condition, but, critically, only AVGPs showed a compatibility effect in the high load condition. The authors interpreted these findings as indicating that AVGPs possess an
increase in available attentional resources compared to NVGPs because AVGPs could apparently attend to the distractors in all conditions. AVGPs’ compatibility effect did not differ from low to high load trials; however, a load X flanker location (periphery or central) interaction indicated that AVGPs dynamically altered how attention was allocated depending on task demands. Attention was more peripherally biased in the low load trials but more centrally biased in the high load conditions. Collectively, these findings suggest that extensive action video game playing may improve the ability of players to control how attention is spatially allocated.

A recent study by West et al. (2008) demonstrated that action video game experience also modulates early sensory processing. AVGP and NVGP performance was compared on temporal order judgment (TOJ) and signal detection tasks. For the TOJ task, participants were required to determine which of two lines, one horizontal and one vertical, was presented first. Prior to the onset of the stimuli an exogenous cue was presented at one of the two target locations. Consistent with prior work, West et al. found that a target at the uncued location had to precede the cued target by a substantial time period in order to be perceived as occurring earlier. This is consistent with the idea that attention was deployed to the location of the exogenous cue. Critically, AVGPs required a longer period between the presentations of target stimuli in order to correctly identify the temporal order. This finding suggests that AVGPs possess a greater sensitivity to the capturing effect of an exogenous cue. In the signal detection task, participants were asked to detect an abrupt change in motion. The display consisted of an aerial view of “swimmers” moving in straight lines and on half the trials a target was presented in the form of a “swimmer” that stopped its motion and increased arm oscillations. The target was presented at varying eccentricities and amongst high and low load conditions. Overall, AVGPs demonstrated greater sensitivity ($d'$) in detecting the target compared to NVGPs. Together these findings
suggest that the observed attentional benefits in AVGPs could be a result of increased sensitivity to exogenous stimuli.

Research thus indicates that some performance differences between AVGPs and NVGPs result from changes in attentional processing. However, whether the effect of action video game experience acts primarily on endogenous or exogenous attentional control remains unclear. The goal of the present study is to further investigate the attentional mechanisms underlying the observed attentional benefits gained from action video game experience. To this end, NVGPs and AVGPs completed a task based on the additional singleton paradigm of Theeuwes (1991). In the additional singleton paradigm participants are presented with visual search displays that contain a target that differs in shape from a number of surrounding distractors. Sometimes the target is the only unique item in the display, but more often one of the distractors has unique color. The presence of this color singleton increases RT and error rates (Theeuwes 1991, 1992; though see Folk, Remington, & Johnston, 1992, for inconsistent results), a pattern that has been demonstrated as resulting from the capture of attention (Hickey, McDonald, & Theeuwes, 2006, though see Leber & Egeth, 2006; for reviews of the capture literature see Burnham, 2007; Corbetta & Shulman, 2002; Rauschenberger, 2003; Ruz & Lupiáñez, 2002, Theeuwes & Godijn, 2001).

It was expected that action video game experience would have an impact on RT across all experimental conditions. AVGPs are trained to respond quickly to visual stimuli and this presumably has an impact on multiple cognitive stages, including but not limited to attentional processing (e.g. stimulus-response mapping may also be affected by video game experience, as suggested by Castel et al. 2005, or alternatively, AVGPs could simply process information more quickly). The primary interest lay in the specific effect of action video game experience on the
capture of attention. Experimentation was approached with the idea that results could follow one of two patterns. If action video game experience affects exogenous attention - resulting in increased saliency sensitivity - then AVGPs should show increased attentional capture (Figure 1.1). In contrast, if video game experience has an impact on endogenous control one should expect reduced capture (Figure 1.2).

**Figure 2.1 - Predicted results if action video game experience affects exogenous attention**

![Graph A](image)

**Figure 2.2 - Predicted results if action video game experience affects endogenous attention**

![Graph B](image)
Method

Participants

Thirty male participants recruited from the University of British Columbia provided written informed consent before participating for course credit or monetary compensation (18 – 38 years, mean: 21.5 years). All participants had normal or corrected-to-normal vision. Participants were categorized as either AVGPs or NVGPs based on self-reported video game playing habits. An AVGP was defined as someone who played a minimum of 3 hours per week of action video games over the last 6 months. Those participants classified as AVGPs played action video games from 3 to 15 hours per week (average of 7 hrs per week) and reported playing similar action titles (e.g. Counter-Strike, Left 4 Dead, Call of Duty 4: Modern Warfare, Halo 3, Crysis, Call of Duty: World at War, Resident Evil 5, Far Cry 2). A NVGP was defined as someone who reported playing little to no action video games over the past 6 months. Three of the participants classified as NVGPs reported playing strategic video games but not action video games. These three participants on average played 5 hours per week. The sample of 12 NVGPs excluding these three participants played on average 10 minutes per week of either strategic or action video games.

Apparatus & Stimuli

A standard IBM computer (AMD 1800+ processor) and 17” VGA monitor was used to present the stimuli to participants. Participants were seated in a chair and a chin rest was used to stabilize participants’ heads 57 cm in front of the monitor. Manual responses were made using the right and left buttons on a standard mouse.
The task was very similar to that of Theeuwes (1991). The visual display consisted of 10 shapes equally spaced around a fixation point on an imaginary circle with a radius of 11°. The displayed items were circles or diamonds coloured either red or green. Circle items were 3.5° in diameter and diamond items were 4.5° of visual angle each with a 1.5° x 0.2° inner line segment. Line segments within non-target display elements were tilted 22.5° to the left or right of the horizontal or vertical plane. The line segment within the target element was oriented either horizontally or vertically (Figure 2.1).

**Figure 2.3 – Example of trial displays**

A. Distractor absent condition with a circle target and horizontal response. B. Distractor present condition with a diamond target, horizontal response, and differently coloured (dotted) circle distractor.

*Procedure*

Following the completion of a questionnaire regarding video game habits participants were seated in front of a computer in a dimly lit testing room. Before beginning the experiment, participants were given both an oral and written explanation of the task. Each display consisted of one unique shape (target element) and nine non-target items of a different shape. Participants were told to respond to the orientation of the line within the unique shape and were encouraged
to respond quickly but to maintain an accuracy of approximately 90%. Participants were also explicitly told to ignore any colour information and solely focus on identifying the orientation of the line within the target element. Responses were made using the left and right mouse buttons to indicate whether the line was oriented vertically or horizontally, respectively.

At the beginning of each trial, a fixation dot (0.5°) was presented at the center of the visual field. The onset of the display occurred randomly between 600 – 1600 ms after the onset of the fixation dot. The display remained on-screen until a response was made. An auditory tone was produced for any incorrect response. Eye movements were not recorded but participants were strongly encouraged and given regular reminders to maintain fixation. Participants initially completed a practice block followed by 15 experimental blocks. Each block consisted of 40 trials, 20 distractor present and 20 distractor absent, for a total of 40 practice trials and 600 experimental trials. In the distractor absent condition, the unique target and all non-target items were the same colour (either red or green) and in the distractor present condition, one non-target item was coloured opposite to the other items in the display. The display was presented in a mixed fashion. The location, shape, and colour of the target switched randomly from one trial to the next. The orientation of the target line segment was also randomly assigned from trial to trial. When present, the location of the distractor was pseudo-randomly assigned\(^2\), with the constraint that the shape and colour of the distractor singleton was always opposite to that of the target (e.g. green circle target, red diamond distractor or vice versa). A distractor singleton was presented in

\(^2\) In distractor present trials, the location of the distractor was assigned such that the distractor was 50% likely to be presented to one of the two locations on the vertical meridian of the display and 50% likely to be presented at any other location. Bias towards presentation of the salient distractor on the vertical meridian was included in the experimental design in order to test a hypothesis regarding distractor suppression at locations likely to contain salient irrelevant stimuli. This manipulation had no significant effect on the data and is not discussed further.
50% of trials. At the end of each block, feedback was provided regarding average reaction time and accuracy.

Results

Fifteen participants met the AVGP criteria. Trials with an incorrect response were excluded from analysis resulting in the removal of 7.0% of all trials. Mean RT was calculated for distractor present and distractor absent conditions and the Van Selst and Joliceour (1994) recursive outlier trimming procedure was used, resulting in a loss of an additional 3.3% of trials. A repeated measures analysis of variance (ANOVA) was conducted with distractor presence (present/absent) and video game experience (AVGP/NVGP) as factors. The analysis revealed a significant main effect of distractor presence with participants responding slower when a distractor was present in the display ($F_{(1,28)}=147.61, p<0.001$, $\eta^2_p = 0.84$, Power =1.0). A significant main effect of video game experience was also identified, with AVGVs responding faster than NVGVs ($F_{(1,28)}=11.72, p<0.01$, $\eta^2_p =0.19$, Power =0.91). Distractor presence and video game experience also interacted such that the effect of distractor presence was larger in the NVGP group ($F_{(1,28)}=6.63, p<0.05$, $\eta^2_p =0.30$, Power =0.70, Fig. 3). AVGVs showed a 93 ms capture effect whereas the NVGP capture effect was 143 ms.
Figure 2.4 - *Group reaction time results as a function of distractor presence*

Graphical representation of reaction times and accuracy for AVGPs and NVGPs on distractor present and absent trials (error bars indicate standard error of the mean). AVGPs demonstrated overall faster RTs (p<0.01) and were less affected by the presence of a task-irrelevant distractor (p<0.05).

Accuracy data was also analyzed with a repeated measures ANOVA with distractor presence and video game experience as factors. A main effect of distractor presence was identified, with errors increasing in frequency when the distractor was present ($F_{(1,28)}=11.26, p<0.01$, $\eta^2_p = 0.29$, Power =0.90; $M_{\text{absent}}=6.5\%$ error; $M_{\text{present}}=7.8\%$ error). No other effects were significant (Video game experience: $F_{(1,28)}<1$; Video game experience x Condition: $F_{(1,28)}<1$). RT increased with errors indicating no speed-accuracy tradeoff.
Figure 2.5 - *Group accuracy results as a function of distractor presence*

Accuracy did not differ between groups for either distractor present or absent conditions ($F < 1$).

**Discussion**

As expected, AVGPs were significantly faster in all conditions. Critically, the presence of a salient, task-irrelevant distractor singleton was found to interfere with search to a greater degree in NVGPs than in AVGPs. Experimentation was approached with the idea that AVGPs would show increased capture if they were more sensitive to visual salience, whereas they would show reduced capture if they had better endogenous control of attention. The results are clearly in line with the latter hypothesis.

The fact that AVGPs demonstrated less capture suggests that they are able to employ an endogenous strategy to reduce the effect of the task-irrelevant distractor. There are two possibilities here: AVGPs might be able to inhibit the distractor (i.e. avoid orienting attention to the irrelevant singleton) or might alternatively be better able to recover from capture once it occurs. Improved inhibition of task-irrelevant information could occur if AVGPs possess greater
attentional resources, as proposed by Green and Bavelier (2006a), as the availability of attentional resources (or working memory capacity) has been implicated in reducing the effect of distractors (e.g. Lavie & de Fockert, 2005; Engle, Conway, Tuholski, & Shisler, 1995).

However, it appears more likely that AVGPs have better ability to recover from capture. This hypothesis is preferred for three reasons. First, it would be consistent with the substantial literature showing that capture is insensitive to endogenous attentional set (Theeuwes, 1991, 1992, 1996; Hickey, et al., 2006). Second, it is in line with results from Green and Bavelier (2003, 2006a) demonstrating that AVGPs attended an irrelevant flanking distractor, which resulted in a compatibility effect on target processing. Finally, the ability to rapidly assess the task relevance of visual stimuli and reorient attention away from irrelevant stimuli would benefit performance during action video games. In contrast, a decreased sensitivity to exogenous input would appear to be counter-adaptive in the context of video games.

The results leave open the possibility that game playing affects both endogenous and exogenous attention, in that the endogenous effect identified in the present study may act to drown out a smaller exogenous effect. This limitation is also apparent in earlier studies of video game training. For example, the UFOV task used by Green and Bavelier (2006a) and the “swimmer” task used by West et al. (2008) have both endogenous and exogenous components, and results from these studies do not make it clear if video game playing affects one of these control processes discretely or has an impact on both. In any case, the current results demonstrate that the greatest impact of video game training on behaviour in the capture task comes from improved endogenous control, not increased sensitivity to visual salience.

A second caveat needs to be attached to the present study. The sample of AVGPs and NVGPs was entirely self-selected, and as such leaves open the possibility that a propensity to
play video games correlates with reduced attentional capture without causing it. However, a number of studies have now demonstrated causal links between video game training and changes in attentional processing (e.g. Feng et al., 2007; Green & Bavelier, 2007, 2006a, 2006b, 2003; however see Boot et al., 2008 for notable exceptions); therefore, it seems reasonable to believe that a similar relationship underlies the present results. Only further research will determine if this is actually the case.

The goal of the present study was to further investigate the attentional mechanisms affected by action video game playing. Some research has suggested that AVGPs have better endogenous control of attention, whereas other studies have suggested that AVGPs are more sensitive to salience. AVGPs took part in an attentional capture task and found that they showed less evidence of attentional capture, consistent with the idea that they have better attentional control. AVGPs are likely not less sensitive to salience than NVGPs, rather they are better able to rapidly discard irrelevant stimuli following selection.
References


Hickey, C., van Zoest, W., & Theeuwes, J. (under review). The time course of exogenous and endogenous control of covert attention. *Experimental Brain Research.*


CHAPTER 3

Conclusion

Results from the study outlined in Chapter 2 provide several findings worth noting. First, consistent with the findings outlined in Chapter 1, this work provides additional evidence supporting the view that AVGPs and NVGPs differ in attentional processing. Although, the observed main effect of RT could simply reflect improved stimulus-response mapping in AVGPs (Castel et al., 2005), such an explanation cannot account for the observed interaction between distractor presence and video game experience. Second, this study provides evidence indicating that AVGPs are less affected by the presence of a task-irrelevant singleton compared to NVGPs. Not only does this identify another task where AVGP and NVGP performance differs but, according to the hypothesized predictions, it provides evidence that action video game experience exerts its effects primarily on endogenous attentional processes. Thus, action video game experience appears to provide players with improved control over top-down attentional processes compared to non-players. Third, consistent with the claims of Theeuwes (1991, 1992) the findings from the present study indicate that although the interfering effects of a distractor can be reduced, irrelevant salient singletons still capture attention in a purely bottom-up fashion even for those who possess improved top-down attentional control.

The observation of a RT advantage for AVGPs has been a consistent finding in the video game literature (e.g. Castel et al., 2005; Goldstein et al., 1999; Orosy-Fildes & Allan, 1989). The most intuitive explanation for this observation has been proposed by Castel et al. (2005) – AVGPs may simply be trained to make manual responses more quickly in response to visual stimuli. AVGPs spend a significant amount of time rapidly pressing buttons in response to on-screen cues. Therefore, in concert with the reported improvement in hand-eye coordination (e.g.
Griffith et al. 1983), the observed improvement in response times could be due to AVGPs being particularly skilled at fast button pressing. Although this explanation has yet to be fully refuted, as outlined in Chapter 1, evidence has been provided that implicates that action video games provide players with more than simply an improved ability to press buttons more quickly. Since a change in attentional processing has been proposed, and empirically demonstrated, between AVGPs and NVGPs, an alternate explanation seems required.

Prior research has indicated that AVGPs are more accurate and quicker to locate targets within visual scenes. This has been suggested to be the result of an improved ability to allocate spatial attention in visual space (Feng et al., 2007; Green and Bavelier, 2006a, 2003) as well as demonstrating greater sensitivity to visually salient items (West et al., 2008). Consistent with the findings demonstrated in the previous chapter, the former research indicates that action video game experience provides players with improved control over the allocation of spatial attention. Although West et al.’s (2008) findings suggest that action video game experience affects early sensory processing, the most salient item in their search task was the target. Therefore, one cannot rule out the possibility that participants employed some top-down strategy to locate the target. If AVGPs are capable of orienting attention to the location of the target more efficiently than NVGPs, this could lead to the differences typically observed in measures of RT. Although the present study argues that action video game experience affects endogenous control processes, it remains a possibility that such experience affects multiple levels of cognitive skills and these all interact to produce the observed benefits. It is also possible that the observed improvement in visuospatial resolution (Green & Bavelier, 2007; Greenfield et al., 1994) could play a role in the RT differences; however, further research is required to fully understand the factors giving rise to this behavioural effect.
In Chapter 2, the claim was made that the reduced capture effect observed in AVGPs is likely due to a decrease in the dwell time on the distractor singleton once capture has occurred. However, it should be acknowledged that the competing hypothesis – that perhaps AVGPs were simply better at inhibiting the singleton and preventing capture altogether – remains a viable alternative. This other account is consistent with work conducted by Folk and Remington (1998) who provided an alternative explanation to Theeuwes (1991, 1992) findings. Folk and Remington suggested that the increase in RT observed when a task-irrelevant singleton was present in a display reflected filtering costs. This notion suggests that the deployment of attention is slowed due to an increase in the time needed to conduct deliberate filtering operations. This view posits that attention is deployed in a top-down manner and orients toward the target item; however, such an operation requires more time to complete when a second singleton (i.e., a distractor singleton along with the target) is added to the display. Folk and Remington (1998) thus argue that attention is not oriented to the spatial location of the distracting singleton, but instead it simply takes longer to inhibit the singleton prior to orienting to the target. If the attentional capture effect does reflect filtering costs, it could be argued that the key findings of the present study are the result of AVGPs demonstrating less costs associated with the presence of a distractor singleton.

It is worth noting that Theeuwes (1996) has presented contrasting evidence to the Folk and Remington hypothesis, showing that attention does orient to the spatial location of the distractor singleton. Again using the additional singleton paradigm, participants were asked to respond to a letter within a target singleton. Theeuwes manipulated the congruency of the letter within the target shape with the letter within the distractor singleton shape. What Theeuwes found was a clear congruency effect which provided compelling evidence that attention was
oriented to the spatial location of the distractor singleton. This result reinforces the assumption that both AVGPs and NVGPs covertly orient to the spatial location of the distractor singleton prior to disengaging and re-orienting toward the target singleton.

A study by Goldstein et al. (1997) also provides evidence against the proposed inhibition hypothesis. These authors recruited an elderly sample and tested performance on a reaction time task and on a Stroop Effect task. Twenty-two participants were split into two conditions. Those in the experimental group received a minimum of five hours of video game experience (Super Tetris) per week over five weeks. The control group received no video game training. Pre and post training analysis revealed that those who received the video game training showed improvement in the reaction time measure whereas the control group showed no improvement. The Stroop Effect is believed to be a measure of inhibitory executive control processes. In order to perform well in this task, one must be capable of inhibiting the irrelevant information (i.e. word presented) in order to quickly identify the colour of the text. Critically, video game experience had no effect on improving performance on the Stroop Effect task. One caveat is that the game used to train participants was Tetris, which has been previously shown to have little effect on any cognitive or attentional task. Nevertheless, the results provide, albeit weak, evidence suggesting that video game experience does not improve inhibitory control in an elderly sample. These results, coupled with Theeuwes’ (1996) findings and the reasons outlined in Chapter 2, supports the view that it appears more likely that AVGPs are better at recovering from attentional capture, once it has occurred, opposed to demonstrating smaller filtering costs or improved inhibitory control. However, this has yet to be demonstrated empirically.

In yet another study, Theeuwes, Atchley, and Kramer (2000) specifically investigated the time needed to disengage from a task-irrelevant but highly salient singleton. Using the additional
singleton paradigm, participants again searched for a form singleton and an irrelevant colour singleton was occasionally present in display. A premask where all display items were gray was initially presented for 700 ms. At an SOA of either 50, 100, 150, 200, 250, and 300 ms prior to the presentation of the search display, one of the items changed from gray to red (irrelevant colour singleton). Results revealed that the irrelevant colour singleton only affected RT performance when it appeared temporally near to the target singleton. RT was significantly slower when the irrelevant singleton appeared 50 or 100 ms prior to the search display; however, at SOAs of 150 ms or greater, search performance was not affected by the irrelevant singleton. Therefore, Theeuwes et al. claimed that individuals required approximately 150 ms to disengage attention from the capturing stimulus. If follow-up studies confirm that the findings highlighted in Chapter 2 are in fact due to quicker recovery from capture, of interest is whether AVGPs show a smaller window of where an irrelevant singleton can capture attention in this task. For example, perhaps AVGPs only require 100 ms to disengage attention and would therefore only demonstrate a capture effect at the shortest SOA (50ms).

Although previously mentioned in Chapters 1 and 2, it is again worth noting the primary limitation associated with present work. Since the recruited sample was entirely self-selected, one cannot draw any causal conclusions between the reduced capture effect and action video game experience. However, once again, based on previous training studies (e.g. Basak et al., 2008; Green & Bavelier, 2007, 2006a, 2006b, 2003; Feng et al., 2007; Greenfield et al., 1994), it appears safe to assume that a similar pattern of results would occur if a training study was conducted. A number of variables were in fact measured in the questionnaire that participants completed prior to experimental participation in an effort to index possible covariates.
Unfortunately, responses to these questions rarely showed enough variability for any meaningful covariate analyses. Currently, the questionnaire is being refined for use in further research.

The aim of future research is to carry this work into other areas of cognitive psychology in order to further our understanding of the effects video game experience has on cognitive processes. Additional investigation into the mechanisms of how video game experience leads to observable differences in performance is still required and remains a primary interest. It also remains of interest to identify other areas of performance that video game experience may benefit. A number of projects with these goals in mind are currently being prepared.

First, a follow-up experiment to the study presented in Chapter 2 is currently in progress. In order to demonstrate whether AVGPS are better able to inhibit the distractor singleton or better able to recover once captured, a more explicit measure is required. To that end AVGP and NVGP performance is currently being compared in an oculomotor capture task. Although this task presents a different paradigm than the additional singleton paradigm, it is conceptually very similar. Participants must make an eye movement to a target singleton, and on half the trials an abrupt onset appears in the form of an additional item in the display. By measuring eye movements, one can examine whether attention is captured by the abrupt onset, i.e., an eye movement in the direction of the onset stimulus indicates capture. The failure of an abrupt onset to capture attention would result in the eyes moving directly to the target. Also, examining fixation durations will provide an explicit measure of how long participants dwell on the distractor stimulus (assuming that this occurs) prior to reorienting attention to the target. Thus, this project will not only shed new light on the mechanisms underlying the differences between AVGPS and NVGPs but it will also be the first investigation to compare overt orienting of attention in AVGPS and NVGPs. It is commonly accepted that there exists a strong connection
between covert and overt shifts of attention. Covert shifts of attention have been discovered to precede eye movements, suggesting that covert orienting plays a role in guiding eye movements (e.g. Fischer & Breitmeyer, 1987). However, to date all previous studies investigating the effect of video game experience on visuospatial attention has employed covert orienting tasks. Therefore, it will be of great interest to the field to determine whether the observed attentional effects are specific to covert orienting of attention or whether they also extend to overt orienting.

Second, the original goal of the work presented in Chapter 2 was to gain insight into the attentional mechanisms that could be affected by action video game experience. It was claimed that action video game experience exerts its effects primarily on endogenous attentional mechanisms. However, results did not provide a definitive answer of whether such experience affects only endogenous process or whether other attentional processes are affected as well. Therefore, to further investigate the effect action video game experience has on attentional orienting mechanisms, future work hopes to use electrophysiological measures to compare AVGPs and NVGP performance. By investigating ERP components that index attentional orienting mechanisms, a more clear understanding of the effects action video game experience has on either exogenous or endogenous processes is possible. ERPs will be measured while AVGPs and NVGPs perform a simple cueing task (e.g. Posner, 1980) where participants will be required to respond to the appearance of a target preceded by either exogenous or endogenous cues. Additional work also hopes to investigate ERPs of AVGPs and NVGPs while participating in the additional singleton paradigm. Such an analysis will add to the present findings as well as the oculomotor results by examining the attentional mechanisms involved as well as the time-course of covertly orienting attention to a target in the presence of a highly salient but task-irrelevant singleton.
Third, of great interest is whether skills learned through video game experience can transfer to everyday activities such as reading. Research has indicated the role of visuospatial attention in reading skills (e.g. Brannan & Williams, 1987), and action video game experience improves aspects of visuospatial attention. Therefore, one is led to question whether video game experience can affect performance on reading tasks. Deficits in reading ability associated with dyslexia have also recently been associated with attentional function (Valdois, Bosse, & Tainturier, 2004). In addition, dyslexics appear to be particularly sensitive to crowding (e.g. Spinelli, De Luca, Judica, & Zoccolotti, 2002). Currently, AVGP and NVGP performance in a crowding task using single words of various inter-letter spacing is being compared. In addition, eye tracking measures are also being used to examine differences in AVGP’s and NVGP’s reading ability when presented with full sentences and entire paragraphs. These tasks are particularly interesting as they present situations that are far more relevant to everyday life compared to the typical lab-based paradigms that use simple visual stimuli. Using vocal reaction time responses as the dependent measure, preliminary results from the crowding task indicates that AVGPs are less affected by smaller inter-letter spacing than NVGPs. This result is consistent with Green and Bavelier’s (2007) crowding study; however, the project is still ongoing.

Finally, future work also aims to conduct training studies similar to those previously reported in the literature. By training NVGPs on an action video game, the goal of this work aims to further establish the causal role played by video game experience in improving cognitive and attentional performance. In addition, much like the work done by Basak et al. (2008) and Boot et al. (2008) there is also a great interest in whether different types of video games provide benefits at different levels of cognitive processing. To date, research indicates that action video
games primarily affect performance on visuospatial tasks (e.g. Green & Bavelier, 2007, 2006a, 2006b, 2003) whereas real-time strategy games appear to affect higher level executive functions (Basak et al., 2008). Also, in conducting training studies, it will be important to determine how long-lasting the attentional and cognitive effects are. Strikingly, Feng et al. (2007) demonstrated that the improvements observed in the mental rotation and UFOV task persisted when participants were re-tested five months post training. What made this finding particularly interesting is that after the final post-test measurement, none of the participants received any additional video game experience over the five month period leading up to the follow-up assessment. One can expect that further research in this topic area will continue to shed light on the mechanisms that underlie the differences between AVGPs and NVGPs. With a better understanding of how video game experience affects visuospatial attention, as well as other levels of cognitive processing, it raises the possibility of creating novel rehabilitation treatments aimed at helping those suffering from cognitive, attentional, or visual deficits.

As much of the literature investigating the effects of video games has demonstrated improvements following some form of training, this has raised the question of whether video games could be used as a rehabilitative tool. A recent review by Achtman, Green, and Bavelier (2008) has outlined the areas where video game experience improves performance and has highlighted populations that could potentially benefit from video game experience. The greatest amount of work in this area has focused on the effects video games have on elderly individuals. Research to date has provided numerous situations where elderly samples demonstrated cognitive benefits or simple improvements in RT measures as a result of video game experience (e.g. Basak et al., 2008; Goldstein et al., 1997; Dustman, Emmerson, Steinhaus, Shearer, & Dustman, 1992; Clark et al., 1987).
Depending on whether the results from Chapter 2 are indicative of improved inhibitory processes or quicker disengagement provides practical implications for a number of special populations. For instance, if action video game playing helps individuals inhibit distracting events, then frontal-lobe lesion patients that have deficits in this form of control would be likely to benefit from video game playing. Conversely, if action video game playing is found to enhance one's ability to disengage attention from objects in the environment, then parietal lobe lesion patients that have attentional disengage deficits could be targeted to benefit from video game playing. However, as the disengagement hypothesis is only favoured, confirming this view has applications for individuals with autism as well as attention deficit hyperactivity disorder (ADHD). Recent research has demonstrated that individuals with autism (Landry & Bryson, 2004; Wainwright-Sharp & Bryson, 1993; Casey, Gordon, Mannheim, & Rumsey, 1993) or ADHD (Wood et al., 1999) show deficits in disengaging visuospatial attention. Research has yet to investigate the effect of video game experience on these populations; however, the present results suggest that these groups could benefit from action video game experience. Finally, aside from a general RT difference, younger adults and elderly individuals demonstrate equal performance in an attentional capture task (Kramer, Hahn, Irwin, & Theeuwes, 1999). Therefore, although the present results suggest that elderly individuals could improve their overall RT performance, action video game experience is unlikely to affect the capture of attention seen in an elderly sample.

As a final note, it is worth mentioning situations where video game experience has led to performance differences in everyday tasks. In the early 1980s the United States military began to investigate the effects video games had on a performance test battery. For example, Jones, Kennedy, and Bittner Jr, (1981) assessed performance after training Navy enlisted men on the
Atari video game Air Combat Manoeuvring (ACM). This game was chosen due to its similarity to radar and sonar displays used by military personnel. Results indicated that the ACM task was beneficial for the performance test battery and should perhaps be included in the training of military personnel. Reports also indicate that video game experience can benefit health care practitioners. Rosenberg, Landsittel, and Averch (2005) recruited participants to a perform number of laparoscopic surgery tasks. Performance on the task significantly correlated with video game skill, measured as performance scores on three different three video games. Rosser et al. (2008) reported similar findings, demonstrating that surgeons who played video games performed laparoscopic surgery with 32% fewer errors and 24% faster than surgeons who did not play video games. Therefore, not only does video games have the potential of improving visuospatial attention when measured in a laboratory setting, results indicate that the skills acquired through video game experience may also transfer into everyday activities.

In conclusion, while the origin of video games dates back to the 1950s, it was not until the early to mid-1980s, that video game playing became a popular form of entertainment in North America. Since that time, in less than 25 years, playing video games has become an almost ubiquitous past time in modern society. Moreover, with the recent growth in portable video game devices both in dedicated game-playing hardware (e.g., the Nintendo DS and Playstation Portable) and multipurpose hardware (e.g., the iPhone) the opportunity and time committed to playing video games continues to increase. And with this, increase in the amount of dollars committed to video game playing also continues to rise. In addition, video games have evolved into an increasingly sophisticated, visually impressive, cognitively and behaviourally demanding form of entertainment. In light of the complex nature of modern video games as well as the recent surge in public interest, it is a small wonder that research studies, such as the work in the
present thesis, have become more and more interested in the cognitive aspects of video game playing – ranging from the effect that video game playing has on human perception and performance, to the neural systems that are affected by video games. Researchers have thus begun to investigate how extensive experience with these games may affect individuals’ cognitive and perceptual abilities. The work presented in this thesis has shown that video game playing can have a profound and positive influence on individuals’ cognitive and perceptual abilities. The goal for researchers, the video game industry, and consumers alike is to see the way forward so that these positive impacts can be applied in meaningful ways.
References


CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR: Alan Kingstone
DEPARTMENT: UBC Arts/Psychology, Department of
UBC BREV NUMBER: H04-80767

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>UBC</td>
<td>Vancouver (excludes UBC Hospital)</td>
</tr>
</tbody>
</table>

Other locations where the research will be conducted: N/A

CO-INVESTIGATOR(S):
Thomas Foulsham
Kirsten Dalrymple
Joseph Chisholm
Evan Risko
Michael R. Maclsaac
Kaitlin Laidlaw

SPONSORING AGENCIES:
Natural Sciences and Engineering Research Council of Canada (NSERC) - "Research in Cognitive Ethology" - "Components of Human Selective Attention"

PROJECT TITLE:
Research in Cognitive Ethology

EXPIRY DATE OF THIS APPROVAL: July 3, 2010

APPROVAL DATE: July 3, 2009

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Anita Ho, Associate Chair