Influence of Video Game Playing on Change Detection

An Eye Tracking Study

Christopher Havery

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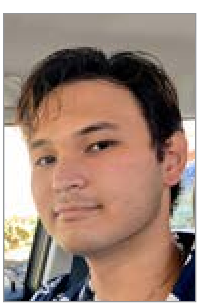
Mentor: Dr. Scott Sinnett

Extensive video gameplay has been associated with enhanced cognitive abilities, specifically with respect to mechanisms of perception and attention. However, it is unclear if these enhancements are specific to video games, or if instead can be applied broadly. Furthermore, the underlying reasons for these effects are unclear. The present experiment focused on determining; (1) if video game players (VGPs) outperform non-video game players (NVGPs) in a non-video game based task (i.e., change detection), and (2) if superior oculomotor behavior is present in VGPs by assessing their number of fixations, fixation latencies, and response initiation after target fixation to determine if eye-movement patterns might be a possible reason for the associated behavioral enhancements. To that end, 36 participants (9 VGPs and 27 NVGPs) were recruited from the University of Hawai'i at Mānoa with the VGP criterion as someone who plays four or more hours of video games per week. Participants were presented with a stream of visual events where one target item changes in the scene while having their oculomotor movements tracked by a web-based eye-tracker. Participants were tasked with detecting the changing target item as quickly and accurately as possible. Results failed to show a significant difference between VGPs and NVGPs for change detection performance and oculomotor measurements. Limitations and future extensions will be discussed in context with the notion that video game experience associated differences could modulate spatial awareness and visual search strategies, as well as oculomotor behavior.

The technology industry is rapidly evolving to meet the demands of consumers. New devices are put forth to cater to the needs and whims of people across the globe, and the video game industry is no exception to this trend, a result of which can be seen by the current population of gamers. As of last year, there were estimated to be 3.24 billion gamers worldwide (Clement, 2021b), which can be attributed to the increased service and satisfaction that video games provide. Another indication is the heightened prevalence of female gamers, as the ratio of female to male gamers shifted from approximately 1:2 to 4:5



I attended Pearl City High School during my adolescence, though I attended Leeward Community College as a full-time student during my senior year of high school. After graduating PCHS as a valedictorian in 2018, I transferred to the University of Hawai'i at Mānoa, which is where I finally felt I could express myself and pursue my interest in psychology. That said, I have learned that one often learns more by doing rather than observing, and this experiment was the perfect opportunity to get research experience in the psychological sciences outside of my studies. I am particularly interested in cognition and how our internal mechanisms influence cognition and vice versa. This experiment examined both relations, as I got the chance to observe both the potential cognitive effects of video games on our basic perceptual processes as well as the effects of differing visual search strategies on spatial attention tasks.

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(Clement, 2021a). The current global trend shows that more of the world's populace is being exposed to video games.

Regarding the level of engagement, video games have been found to be particularly potent in recent years. An investigation by Barr & Copeland-Stewart (2022) found that video game engagement has increased from most players reporting that they played games several times a week to several times in a single day in 2020, though this may also be in part due to the recent pandemic that has swept the world, motivating people to stay indoors. However, even before the beginning of the COVID-19 pandemic, excessive video game engagement was a concern among many countries, with some even going as far as to label it an addiction (Irmak & Erdogan, 2016). Given the stark difference in the prevalence of video games as well as the level of engagement in recent years, the need for more literature on how video game playing can influence our brains and cognition is more crucial than ever. Many studies conducted in the past have found various links between video games and their effect on mental processes and behaviors, though whether video games are detrimental or beneficial to the brain remains a topic of debate.

The question becomes more complicated when considering some of the potential advantages that video game play can elicit. Hodge et al. (2019) demonstrated both the possibility of stunted moral development as well as the growth of moral development amongst adolescents and young adults, with the outcome depending heavily on the genre of the video game being played. Thus, the genre is an important factor to consider in video game studies, though most benefit appears to draw from action video games specifically.

When studied in a laboratory setting, avid players of action video games have displayed seemingly enhanced visual processing abilities, including contrast sensitivity, spatial resolution, visual attentional range, enumeration, multiple object tracking, visuomotor coordination, and visual working memory (Blacker et al., 2014; Clark et al., 2010; Green & Bavelier, 2003; Spence & Feng, 2010). These aspects are all core to the experience of playing video games, many of which coincide with terms and features well known by those who frequently play. To illustrate with some examples, video games often ask the player to adjust the brightness of their screen until a symbol becomes visible, which tests their contrast sensitivity. Another example would be using a map to keep track of your and your enemies' locations in an action game, which involves multiple object tracking. Some tasks in action games may even involve two or more aspects of visual processing, such as keeping track of the number of bullets you have remaining in a first-person shooter while trying to move around the field (which utilizes both visuomotor coordination and visual working memory). At present, many researchers are wondering what effect this has on avid video game players (or VGPs) in comparison to people who do not play video games (non-VGPs), which has led to several inquiries designed to test these potential ramifications.

The effects of video game playing on an individual are theorized to be within the realm of cognition. Green and Bavelier (2003) attributed differences in performance on flanker tasks, enumeration, spatial attention tasks, and attentional blink tasks between VGPs and non-VGPs to be a result of differences in attentional and perceptual capabilities due to extensive training with video games. In this sense, extensive video game play may influence our visual cognitive processes, a conclusion supported by other researchers including Spence and Feng (2010), who found that VGPs outperformed non-VGPs in mental rotation tasks, and Blacket et al. (2014), who reported that VGPs displayed improvements in visual working memory when compared to non-VGPs.

However, video game influence on perception and cognition may not be the only viable explanation for these enhancements, as pointed out by Boot et al. (2011). After putting numerous studies on video games under scrutiny, they reported that many such experiments seemed to share the same set of pitfalls, being the lack of clandestine recruitment regarding their status as a VGP or non-VGP (potentially cueing participants to the goal of the research or even the expected results, thereby unintentionally creating bias or increased effort on the part of the VGPs), a lack of specification regarding the method by which researchers recruited participants, of control for third-variable influences as a result of a cross-sectional experiment design, of any means to compare the tasks being performed in the laboratory to the types of activities that may be encountered in a video game, and finally, a lack of fool-proofing to account for the possibility of a placebo effect. These deficiencies hinder the experimental validity of many studies conducted at the time that utilized avid video game players as their participants, which unfortunately called their conclusions into question.

Additionally, there remains much uncertainty about the degree to which any video-game related improvement in attention and perception might extend to contexts beyond the video game itself. For example, could people who play video games display improved performance on distracted driving emulations, where the average person is more error-prone when distracted (e.g., by talking on a phone) despite their eye movements remaining unchanged (i.e., their attention was reduced rather than simply not looking; see Strayer, Drews, & Johnston, 2003). Similar logic could be applied to air trafficking or military operations, which are high-stress situations in which attention to detail is key for success and a single mistake could potentially cost dozens of lives. But before questions such as these can be answered, a definitive connection between video game playing and attention and perception must first be identified.

To evaluate the perceptual and attentional difference modulated by video game experience, Clark et al. (2010) tasked VPG and non-VGP participants to undergo a change blindness paradigm in which they were to detect a single changing object in a series of two seemingly identical images interrupted momentarily by a gray flickering display. The object in each trial either appeared or disappeared from the visual sequence, and the change could occur in one of the four quadrants of the image–being top-left, top-right, bottom-left, and bottom-right. In their results, the researchers reported that the VGPs were able to detect the changing target while requiring less exposure to the series of images than their non-VGPs counterparts. They interpreted these findings to suggest that VGPs may deploy improved search strategies that could lead to enhancements in their spatial attention that were not present in non-VGPs, thus exercising enhanced top-down (or anticipatory) control. This theory is in direct contrast to other studies that concluded that VGPs have enhanced bottom-up (sensory) control as a result of the effects that video games had on their cognitive abilities.

The research conducted in this project extends upon the aforementioned study by Clark et al. (2010) with the implementation of oculomotor measurement. Such additional measurement of eye-movement patterns would allow for additional nuances of spatial attention differences between the VGPs and non-VGPs by assessing the saccadic (or eye-movement) patterns, the number of fixations, and their average latency. As such, this project will explore whether extensive video game playing leads to a change in eye-movement behavior—specifically the frequency of eye fixations and their durations—or if instead the enhancement is based solely on improved cognitive (perceptual and attentional) capabilities. Examining the number of saccadic eye movements and the duration of each eye fixation simultaneously yields contrasting results. For example, if a participant were to exhibit average fixation durations but faster change detection, it would indicate that they are capable of processing more visual stimuli at once compared to other people (inversely, people with shorter fixation durations or longer fixation durations display an increase or decrease in saccadic eye-movements respectively). Thus, the deciding factor of this experiment would have to be the difference between fixations and durations of VGPs and non-VGPs' eye movements. Keeping that in mind, the main objectives of this investigation are as follows:

1. To evaluate if VGPs exhibit enhanced spatial attention by detecting the changing target faster than non-VGPs.
2. To assess if the functional difference in eye-movement patterns between the two groups measuring:
    a. Average number of fixations
    b. Average latencies of each fixation
    c. Response initiation duration after target fixation.

Methods

Participants

36 participants (9 VGP & 27 NVGP, mean age = 22, SD = 3.12) volunteered to participate in the experiment in exchange for course credit. Contrary to previous studies (Clark et al., 2010; Green & Bavelier, 2003), males (N=13), females (N=22), and non-binary participants (N=1) were represented in this study, and video game experience was assessed with a nine-question survey that was administered post-experiment to avoid unintentional biasing throughout the study. Those who played video games—primarily action games—for 4 or more hours a week were considered to be VGPs, whereas those who played video games for 3 or less hours a week were considered to be NVGPs. All participants had either normal or corrected-to-normal vision, and the study took approximately 30 minutes.

Apparatus & Stimuli

The experiment was conducted in a well-lit room on a 15-inch MacBook Pro (2018) with a 2880 x 1800 pixel resolution. Participants sat about 60 cm away from the computer screen. LabVanced was used for the change blindness flicker paradigm construction and presentation, which featured a webcam-based eye-tracker that utilized facial detection to calibrate and record the number of fixations participants made as well as the duration of each gaze (Finger et al., 2017). Additionally, the time it took participants to click on the target from the time they fixated on it was recorded.

Picture stimuli were created for this experiment using Adobe Photoshop (Adobe Photoshop 22.5.5 Release). Sixty-four photographs of natural scenery and objects seen in day-to-day life were modified to either add or remove a single item from one of four quadrants (8 of the changes were objects added in the upper-right quadrant, 8 were objects removed from the upper-right quadrant, 8 were objects added to the upper-left quadrant, 8 were objects removed from that same quadrant, and so forth for the bottom two quadrants). Photos were carefully selected to not include any people or faces that could influence the results. In addition, the average size of the change was 3.68% of the total area of the photo, ranging from 0.62% to 10.54%, a proportion similar to that of Clark et al. (2010), ranging from 0.43% to 14.46%. The mouse press hitbox was made just big enough to encapsulate the changing target.

Procedure

Participants were given both written and oral instructions prior to the start of the experiment. The study began with LabVanced's eye-tracking calibration using the MacBook Pro's built-in webcam that involved gazing at dots on the screen for a certain duration whilst adjusting head positioning (Finger et al., 2017) as well as three practice trials that were not used in the main experiment.

Trials consisted of 60 frames, with the first image of the pair being presented for 250ms or for 15 frames, a blank grey screen for 250ms or another 15 frames, then the second image for 250ms or 15 frames and finishing off with the same grey screen for 250ms or 15 frames. These four presentations continually looped until participants made the left mouse response to the correct changing target (see Fig. 1).

Participants used a USB computer mouse to locate the change between the two images. Unlike the Clark et al. study (2010) that implemented a max display of fifteen sequences, our display sequence looped until the changing stimulus was detected using the mouse press response. To account for different mouse cursor positionings in each trial, a message with a fixation cross prompted participants to move the cursor at the center of the screen to proceed to the next trial. The 64 trials in the main experiment were completely randomized for each participant. Data was exported immediately after each participant run.

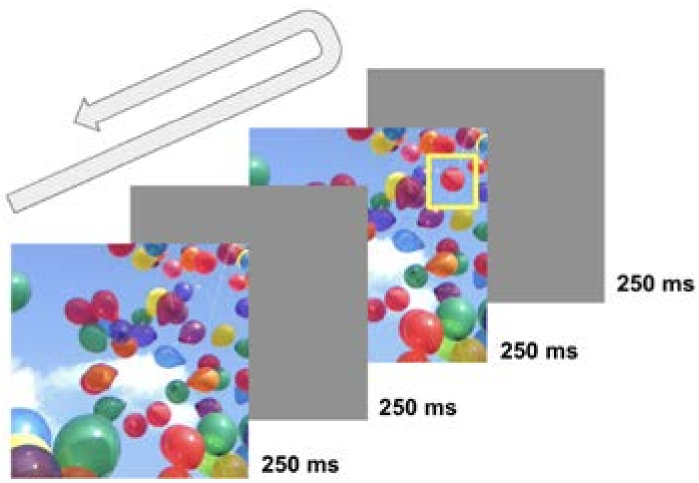

Figure 1. A trial sample of display sequence with the target change in a yellow box. In each trial, the display sequence looped until the participant used the left-mouse response on the changing target.

Results

Reaction Time (RT) Analysis

Response latencies for participants to detect the change were averaged and compared with a two-tailed independent-samples t-test at α=0.05 comparing reaction time in VGPs and NVGPs. On average, VGPs detected a changing target faster (M = 6032ms) than NVGPs (M = 7499ms), but this was not statistically significant, $t(34) = 1.692$, $p = .100$, $d = .651$ (See Fig. 2).

Oculomotor Behavior

A non-directional two-tailed independent-samples t-test at α=0.05 was also conducted on the average number of fixations

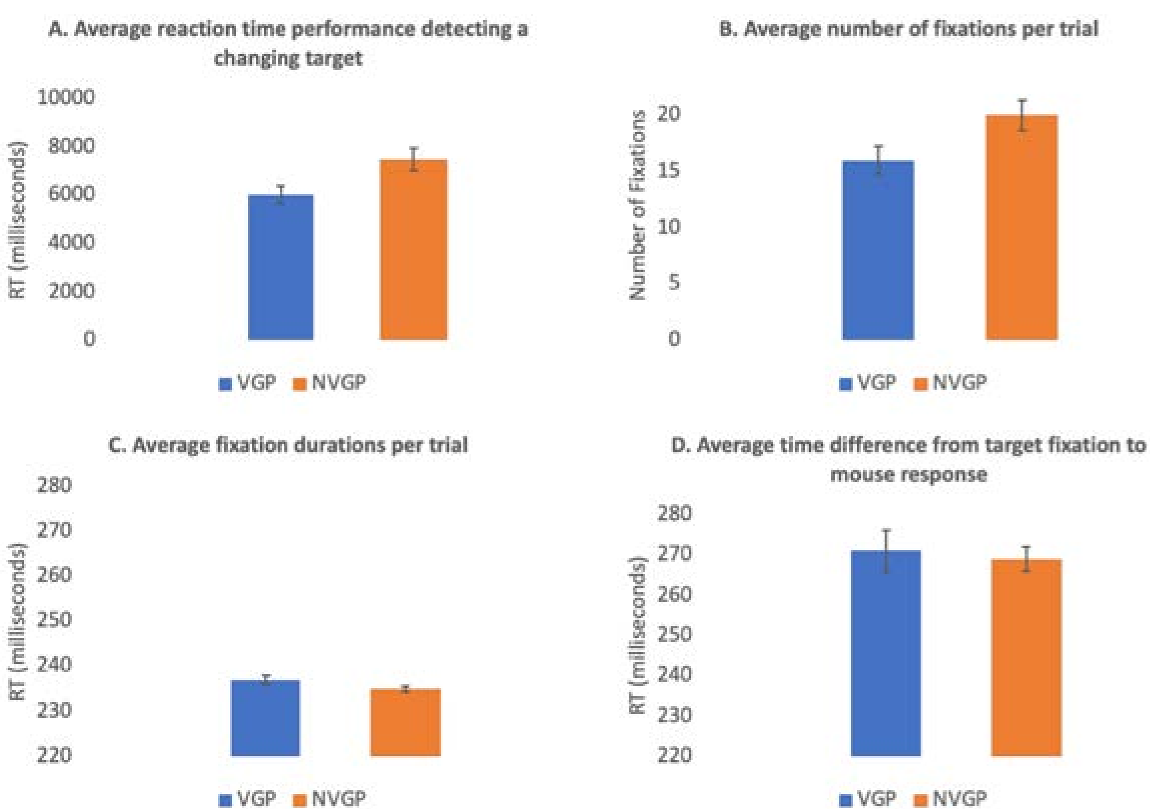

Figure 2. Display reaction time performance with standard error whiskers between VGPs and NVGPs (A), the eye-tracking fixation numbers between VGPs and NVGPs (B), the mean fixation durations of VGPs and NVGPs (C), and the action-initiations of VGPs and NVGPs (D).

pooled from LabVanced's eye-tracking software (Finger et al., 2017) to examine the mean difference of fixation between the VGPs and the NVGPs. On average, the analysis revealed a smaller number of average fixations (16) for VGPs compared to their NVGP counterparts (20), but this was not statistically significant, $t(34) = 1.573$, $p = .125$, $d = .605$ (see Fig. 2).

VGPs were also shown to have a longer fixation duration (237ms per fixation) when compared to NVGPs (235ms), though the results were also insignificant, $t(34) = -1.770$, $p = .086$, $d = -.681$; (see Fig. 2).

Action (Mouse Response) Initiation Post Target Detection Analysis

Regarding the time between the last fixation and the response, based on the t-test analysis, there was no significant difference in action-initiation duration between VGPs (M = 271ms) & NVGPs (M = 269ms); $t(34) = -.412$, $p = .683$, $d = -.159$ (see Fig. 2).

Discussion

Previous literature on video game influence on cognition has shown that VGPs outperform NVGPs on multiple perceptual and attentional tasks. The main objective of this investigation sought to reveal how such perceptual difference takes place, by evaluating both behavioral and oculomotor performance between the two groups. Going beyond behavioral responses provides additional nuance of top-down strategy moderated by the video game experience leading to how VGPs can outperform NVGPs.

Contrary to previous work, however, the initial reaction time assessment revealed a null difference between the VGPs and NVGPs. Despite the VGPs performing 1467ms faster than NVGPs on our change detection task, this failed to reach statistical significance regardless of the medium effect size. Additionally, contrary to the prediction of the oculomotor pattern difference, VGPs and NVGPs did not differ in the average number of fixations nor the average fixation length. This suggests that both groups did not differ in their eye movement patterns to identify the changing target, but the marginal significance and a relative medium to large effect size signal the implication of confounding factors that could have inflated the errors that contributed to our insignificant outcome. That is, in spite of the null differences in our data, the VGPs produced longer fixation latencies while making smaller number fixations, indicating that the top-down control over the visuospatial attention produces fewer shifts of attention but with a greater information processing within those individuals focusing points. Therefore, a further extension of this work is encouraged to examine the theoretical implication of the general principle of human cognition: whether the top-down modulation of video game experience leads to more efficient processing of visuospatial processing.

To that end, there are a number of limitations that are noteworthy to mention. First, our inclusion criterion as a VGP participant is different from that of Clark et al. (2010), who defined VGPs as someone who plays video games for a minimum of 6 hours per week. However, due to the effects of COVID in the middle of our investigation, we have also included responders who play 4 to 5 hours weekly as well, to balance the between-group assignments. In the same light, the criteria for NVGP were also expanded to include people who played video games for 2 to 3 hours rather than solely those who played for 0 to 1 hours—again, being the criteria used to define NVGPs in the study by Clark et al. (2010)—due to a lack of eligible participants. Although participants were recruited so as to not let them onto the research objective—a pitfall in many VGP studies as addressed by Boot et al. (2011)—a future extension of this investigation could benefit from recruiting participants at a more video game venue or tournament-based conferences to obtain a more homogenized sample to allow for a more accurate baseline of video game experience.

Another unexpected limitation was found in trials in which natural scenery was depicted. Such trials included images of plants and foliage, and participants often remarked after the experiment that they faced difficulty finding the changing target in those trials: a sentiment reflected by their performance in which their overall reaction time tended to be extremely high. Conditions which exceeded over three standard deviations above the average (≥ 21028ms) were removed on a case-by-case basis. Trials of this sort may need to be recreated or removed altogether before this experiment is run again.

It is also worth mentioning the counterargument that could be made that we cannot claim with complete certainty that VGPs could outperform NVGPs due to their video game experience. Indeed, the nature of the cross-sectional design in the present investigation hinders establishing such causal inference as some other factor correlated with video game playing could have mediated the observed performance. For example, those who play video games may be inherently more motivated to perform well in computerized tasks leading to inconsistent baseline motivation to the NVGP counterparts. However, it is unlikely that such difference could specifically influence fewer fixations and their latencies for VGPs to outperform NVGPs (e.g., smaller fixation counts, and longer individual latencies). Therefore, it is reasonable that limitations of cross-sectional designs do not necessarily undermine the empirical or theoretical accounts present in this study. Furthermore, previous literature has provided evidence in support of a robust link between video game experience and improvements in multiple visuospatial tasks (Boot et al., 2008; Feng et al., 2007; Green & Bavelier, 2003). Therefore, a collection of evidence to date suggests that video game playing could provide an individual difference measure for the evaluation of top-down modulation of visuospatial attention.

Additionally, from this study arises new considerations, specifically regarding the budding increase in fixation duration exhibited by VGPs. Supplementary experimentation to discover whether this finding was based on happenstance or if there really does exist a minute difference between the length of each fixation made by VGPs and NVGPs could lead to further inquiries as well, for example, whether this difference is applied in everyday life or limited to attentional tasks, or if this difference is permanent or reversible.

As video games become a more profound part of daily life, especially for children and young adults as well as those affected by the global pandemic (Barr & Copeland-Stewart, 2022; Irmak & Erdogan, 2016), it is important to investigate the ramifications that increased video game play will have on both current and future generations. In addition to their effects, a topic of great interest to parents and researchers alike is the differences exhibited by those who play certain genres of video games. Action and FPS video games are both hailed and stigmatized for their potential effects on youths (Boot et al, 2011; Bowman & Rotter, 1983; Clark et al, 2010; Green & Bavelier, 2003; Hodge et al., 2019), hastening the urgency by which the intricacies of these effects are modulated. Certainly, though this current study raises more questions than it answers, these questions are ones worth answering.

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