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Action video game experience affects oculomotor performance

Greg L. West *, Naseem Al-Aidroos, Jay Pratt

University of Toronto, Canada

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A B S T R A C T

Action video games have been show to affect a variety of visual and cognitive processes. There is, however, little evidence of whether playing video games can also affect motor action. To investigate the potential link between experience playing action video games and changes in oculomotor action, we tested habitual action video game players (VGPs) and non-video game players (NVGPs) in a saccadic trajectory deviation task. We demonstrate that spatial curvature of a saccadic trajectory towards or away from distractor is profoundly different between VGPs and NVGPs. In addition, task performance accuracy improved over time only in VGPs. Results are discussed in the context of the competing interplay between stimulus-driven motor programming and top–down inhibition during oculomotor execution.

1. Introduction

There is a rapidly growing literature suggesting that playing certain types of video games can have considerable effects on various cognitive processes. In a landmark paper, Green and Bavelier (2003) found that people that had extensive exposure to action video games (video game players or VGPs) tend to outperform non-video games players (NVGPs) on tasks measuring the spatial and temporal distribution of attention (such as subitizing, useful field of view, and attentional blink tasks). Moreover, they found similar effects when NVGPs were given training on action video games. Following this paper, the playing of action video games has been found to affect a wide range of cognitive and perceptual tasks, including task switching (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010), mental rotation (Feng, Spence, & Pratt, 2007), change detection (Clark, Fleck, & Mitroff, 2011), spatial resolution (Green & Bavelier, 2007), flanker (Green & Bavelier, 2006), and probabilistic inference (Green, Pouget, & Bavelier, 2010) tasks. In the present study we investigated whether these effects of action video game playing also extend to the production of motor responses; specifically, to attentional control within the oculomotor system during the production of saccadic eye movements.

The effective guidance of oculomotor movements relies on a mix of bottom–up and top–down control mechanisms, and the interplay of these mechanisms can be inferred from the trajectories of saccadic eye movements that are made in the presence of distracting information (McSorley, Haggard, & Walker, 2006; Walker, McSorley, & Haggard, 2006). When saccades are initiated very quickly (i.e., soon after the appearance of a visual target and distractor), the bottom–up signals produced by the target and distractor will have converged on spatial maps within the oculomotor system (typically ascribed to the superior colliculus; SC) where they compete through mutual inhibition for saccadic response. Due to neural averaging on the SC, saccades initiated at this time are directed to an intermediate location between the two visual stimuli. Thus, the trajectories of short latency saccades tend to initially curve toward the distractor before correcting back toward the target. To help resolve the competition between the target and distractor, the oculomotor system also employs top–down inhibition of the distractor-related activity. If distractor related activity is inhibited below baseline levels, the concomitant saccade will initially deviate away from the distractor. Because the contribution of top–down inhibition to saccadic programming occurs more slowly than that of the bottom–up signals, a time course of saccadic trajectory deviations can be observed (Campbell, Al-Aidroos, Pratt, & Hasher, 2009; McSorley et al., 2006; West et al., 2011). The curvature of saccadic trajectories tends to transition linearly as a function of latency from curving towards distractors (as the saccade is determined primarily by stimulus-driven signals) to curving away from distractors (when top–down inhibition dictates saccadic programming). If inhibition is not sustained,

* Corresponding author at: University of Toronto, Department of Psychology, 100 St. George Street, Toronto, ON, Canada M5S 3G3. Tel.: +1 416 978 6587; fax: +1 416 978 4811.

E-mail address: greg.west@utoronto.ca (G.L. West).

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curvature will then diminish back to zero at very long latencies (McSorely, Haggard, & Walker, 2009). Because the time course of saccadic trajectory deviations provides a measure of the interplay between top–down and bottom–up contributions to saccadic programming, we used this time course to assess changes in oculomotor functioning as a result of action videogame playing.

While no study to date has examined the effect of action video game experience on saccadic motor functioning, several studies in the literature regarding underlying attentional capture and inhibition, based on reaction time (RT) data, cannot conclusively demonstrate if VGPs and NVGPs show differences in these bottom–up and top–down processes. In the first study to examine these processes, Castel, Pratt, and Drummond (2005) used a version of a Posner cueing task that had SOAs ranging from 50 to 1200 ms. They found no differences between VGPs and NVGPs in attentional capture at the short SOAs or the inhibition of return of attention at the long SOAs. Using temporal order judgments, however, West, Stevens, Pun, and Pratt (2008) found that VGPs had larger visual prior entry effects than NVGPs, suggesting playing action video games increases reflexive attentional capture. Counter to this finding, Chisholm, Hickey, Theeuwes, and Kingstone (2010) used a distractor interference task and found that VGPs show reduced attentional capture. Thus, from the RT-based experiments, no clear pattern emerges as to whether or not playing video games affects capture or inhibitory attentional processes.

Turning to a very sensitive measure of oculomotor control may provide some clarity regarding differences in the interplay of bottom–up and top–down processing between VGPs and NVGPs. Specifically, measuring deviations in saccadic trajectories have been found to show differences in saccadic control when none were apparent with temporal (i.e., RT) measures (Al-Aidroos & Pratt, 2010). In addition, saccadic trajectory deviations provide a measure that is dissociable of RT, which is commonly found to differ between VGPs and NVGPs (e.g., Castel et al., 2005; Green & Bavelier, 2003). To investigate if there is a difference in oculomotor control between VGPs and NVGPs, we used a distractor paradigm where participants made saccades towards a target stimulus while trying to ignore a concurrently displayed distractor. Trajectory deviations towards or away from the distractor were measured to detect the presence of any differences in saccadic control between both groups.

2. Method

2.1. Subjects

Twenty-eight males with normal or corrected-to-normal vision were recruited and placed into one of two groups, VGP or NVGP, based on their responses to a questionnaire given prior to the experiment. The criterion used to define a VGP was during the past 6 months the individual engaged in a minimum of 3–4 days a week of action video game usage with a minimum of 2 hours of playing time on each day. An abridged list of action video games reported as played included: Counter-Strike, Call of Duty: Modern Warefare, Medal of Honor, Kill Zone 2, Halo 3, God of War 3, Half-Life 2, Grand Theft Auto 3 and Rainbow Six: Las Vegas. The criterion to be considered a NVGP was little or no exposure to video game usage in the past 6 months. Fourteen males with a mean age of 18.7 were placed in the VGP category, and fourteen males with a mean age of 19.1 were placed into the NVGP category. No reliable difference in age between the two groups was found, $t<1$. Written informed consent was obtained from all participants, who received partial course credit for their participation.

2.2. Apparatus

Saccadic eye movements were recorded by measuring pupil position and corneal reflectance using a camera-based eye tracker (SR Research Eyelink 1000) with a temporal resolution of 1000 Hz and a RMS spatial resolution of 0.01° of visual angle. Gaze position was established using a nine-point calibration and validation scheme. The beginning and end of saccadic eye movements were determined using a 30°/s threshold with the additional criterion that the eye exceeded an acceleration of 8000°/s/s during the movement. Experimental displays were presented on a 19 in. flat CRT at a refresh rate of 85 Hz and a resolution of 1024×768 pixels. A chin rest was used to fix participants' heads 80 cm from the monitor.

2.3. Stimuli and procedure

Each experimental session began with eye-tracker setup during which calibration and validation were performed repeatedly until a minimum average accuracy of 0.5° was attained. Participants then completed one block of 8 practice trials, followed by four blocks of 40 experimental trials. The experimental conditions were distributed evenly across all 168 trials. Between trials, the experimenter could elect to recalibrate the eye tracker if needed. Every trial began with a fixation stimulus (a white ring with an outer diameter of 0.35° and an inner diameter of 0.16°) that was presented in the center of the display on a light-gray background (see Fig. 1 for a typical trial sequence). Once participants moved their gaze to within 1.5° of the fixation stimulus (all reported distances are from the center of a stimulus), they were required to maintain fixation within this region for a randomly determined duration between 800 and 1300 ms. In order to create variability in saccadic reaction times (SRTs) the SOA between the onset of the target and the offset of the fixation stimulus on each trial was randomly chosen to be one of seven possibilities: −200, −100, −50, 0, 50, 100, and 200 ms (Fig. 2).

The target was a white cross and always appeared 8.0° from the fixation stimulus. The distractor, which was always present, was a white circle that could appear 8.0° above, below, to the right, or to the left of the fixation stimulus and equidistant from adjacent target locations. The distractor was always presented in one of the two locations directly adjacent to the target (6.12°, center to center). Both the target and the distractor subtended 1.0° horizontally and vertically, and were drawn with line widths of 0.1°. Once the target was present, participants were required to move their gaze to within 3° of the target stimulus using a single saccade. If participants failed to maintain fixation before the target was presented, a 200 Hz error tone sounded for 100 ms, the display items were extinguished for 750 ms, and then the trial recommenced. If fixation failed three times consecutively, the experimenter could choose to recalibrate the eye tracker. After the target was presented, if participants failed to initiate a saccade within 1000 ms, or failed to move their eyes to the target location first, the error tone sounded and an error was recorded. At the end of a trial, the display items remained on the display for 240 ms and were then removed for an inter-trial interval of 600 ms.

2.4. Measures

Saccadic curvature was used to measure differences in oculomotor capture between VGPs and NVGPs. Saccadic curvature was calculated using the quadratic method put forth by Ludwig and Gilchrist (2002). Namely, the trajectory of each saccade was scaled and translated to travel a common absolute distance, and the best-fitting quadratic polynomial to the trajectory was determined. The coefficient of the

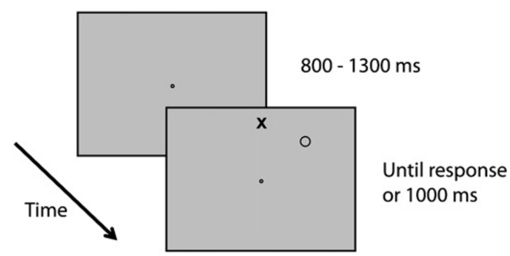

Fig. 1. A typical trial sequence. Participants were instructed to make a saccade towards the 'X' target stimulus while ignoring the 'O' distractor stimulus.

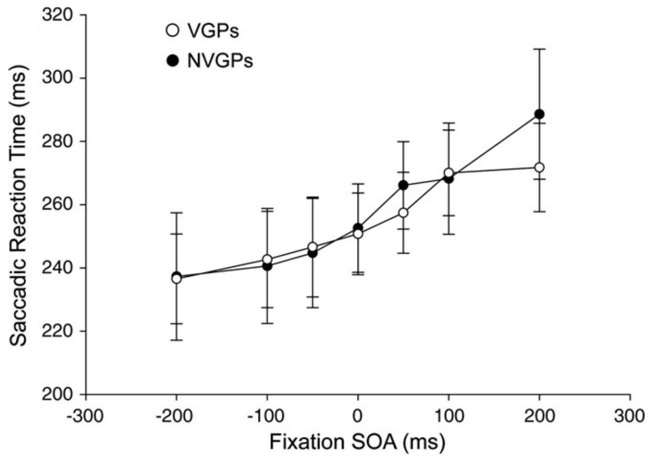

Fig. 2. Saccadic reaction times (SRTs) for video game players (VGPs) and non-video game players (NVGPs) as a function of fixation-target stimulus onset asynchrony (SOA).

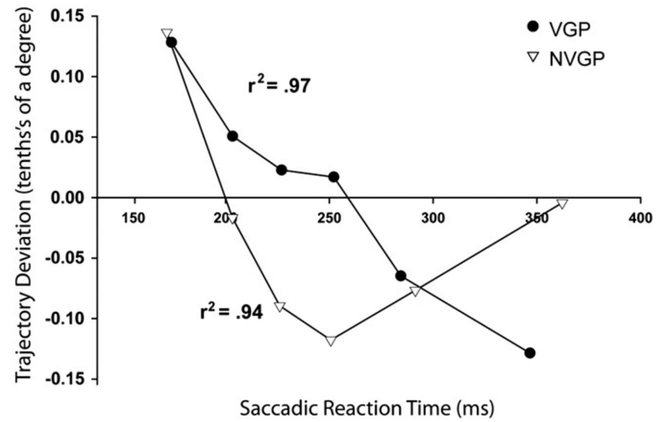

Fig. 3. Saccadic trajectory deviations vincetized by saccadic reaction time shown as a function of group (VGPs and NVGPs). The mean SRT (x-axis) and mean curvature (y-axis) for one bin is reflected in each point. The group-level linear regression line of curvature onto SRT is plotted for VGPs ($r^2=.97$) and the quadratic for NVGPs ($r^2=.94$).

quadratic term of the resulting polynomial provides the measure of the amplitude of curvature, which is reported in tenths of a degree of visual angle. To reveal the time course of saccadic curvature, each participant's SRTs were vincentized into six latency bins (Vincent, 1912), and the mean curvature for the responses in each separate bin was calculated.

3. Results

Error trials for VGPs ($M=21.6$, $SD=7.92$) and NVGPs ($M=26.2$, $SD=10.78$) were excluded from the reported analyses of saccadic trajectories. As well, trials were trimmed from each participant's data set using a three standard-deviation threshold, first based on SRT and then curvature (VGPs = 1.6%; NVGPs = 1.8%). We first assessed whether SRT differed between VGPs and NVGPs. A 2 (Group: VGP vs. NVGP) × 6 (Bin) ANOVA comparing SRTs across the six vincentized bins, revealed the obvious main effect of bin ($F(5, 130)=153.96$, $p<.001$), but no effect of group, and no group by bin interaction ($Fs<1$). A similar 2 (Group: VGP vs. NVGP) × 7 (SOA: −200, −100, −50, 0, 50, 100, 200 ms) ANOVA assessing the effect of fixation-offset timing, revealed an equivalent pattern: an obvious effect of SOA ($F(6,156)=24.62$, $p<.001$), but no effect of group and no group by SOA interaction ($Fs<1$). Thus, there were no reliable differences between VGPs and NVGPs in the distribution of SRTs, nor in the effect of fixation-offset timing on SRT.

Of main interest was to examine the effect of experience playing action video games on oculomotor control by looking at saccadic curvature. Fig. 3 plots the time course of saccadic curvature for both groups. Qualitatively, whereas VGPs show a slower trend from early curvature towards the distractor to late curvature away, NVGPs show a more rapid transition to curvature away, which then diminishes at later latency bins. To assess this pattern, we performed a 2 (Group: VGP vs. NVGP) × 6 (Bin) ANOVA on saccadic trajectory curvature revealing a main effect of bin ($F(5, 130)=5.46$, $p<.001$) and a moderate group by bin interaction ($F(5, 130)=1.90$, $p=.099$); the main effect of group was not significant ($F<1$). Importantly, this analysis also revealed a significant group by bin interaction of the within-subject quadratic contrast. Following up this interaction with separate ANOVAs for each group, the time course of saccadic curvature was best characterized by a linear trend for VGPs ($F(1, 13)=19.30$, $p=.001$), and a quadratic trend for NVGPs ($F(1, 13)=5.36$, $p=.038$). Whereas curvature for VGPs changed monotonically from towards the distractor to away, the time course for NVGPs changed direction at longer latencies, eventually returning to zero curvature.

To further characterize the group differences in curvature, we performed statistical tests on three discreet portions of the saccadic curvature time course. As can be seen in Fig. 3, at the shortest SRT bin (SRTs ~ 175 ms), saccadic curvature was captured almost equally towards the distractor stimulus for both VGPs ($M=0.12$, $SD=0.19$) and NVGPs, ($M=0.13$, $SD=0.11$; two-tailed independent-samples $t(26)=0.20$, $p=.84$). Differences begin to emerge across the first three latency bins, however. While deviations trend towards curvature away from the distractor for both groups, this transition appears to occur more rapidly for NVGPs. To evaluate the significance of this difference, a linear regression comparing curvature onto SRT was conducted on each participant using the vincentized means, with the produced mean slope of these lines being compared between VGPs and NVGPs. The mean slope (in tenths of a degree per ms) of the first three bins was significantly steeper for NVGPs ($M=-0.001$, $SD=0.005$) than VGPs ($M=-0.007$, $SD=0.01$), as revealed by a two-tailed independent samples *t*-test ($t(26)=2.16$, $p<.05$), confirming that the transition to curvature away occurred more quickly for NVGPs than VGPs. Across the final three bins, the direction of the slopes (rather than the steepness) differed between the two groups. For the VGPs, curvature continues to grow more negative. The opposite is true in NVGPs, as curvature away from the distractor was reduced across the final three bins. This difference in direction was confirmed again by measuring the slope produced by each participant over the final three bins. The mean slope for VGPs ($M=-0.001$, $SD=0.003$) was significantly different from that of NVGPs ($M=-0.002$, $SD=0.003$; $t(26)=2.58$, $p<.05$). Overall, while VGPs and NVGPs show equivalent curvature at the earliest latencies, marked differences emerge across the remaining time course of saccadic curvature. NVGPs show a rapid transition to curvature away from the distractor, but curvature away diminishes at longer latencies. In contrast, VGPs show a relatively slower change from curvature towards to curvature away, but curvature away is sustained at even the longest latencies.

Given the marked differences in saccadic trajectory deviations observed in the present study, and prior demonstrations that playing action videogames improves performance on many visual tasks, it is surprising that VGPs and NVGPs did not differ in overall task performance (i.e., the ability to make a saccade to the target stimulus). In particular, it is surprising that the observed differences in the ability to overcome distractor-related activity did not affect the percentage of saccades that were erroneously directed to the distractor. Looking at the percentage of saccades that landed on the distractor, VGPs ($M=15.85$, $SD=6.94$) were not significantly better at ignoring distractors than NVGPs ($M=19.24$, $SD=10.17$); one-tailed *t*-test, $t(26)=1.40$, $p=.087$. Based on the recent suggestion that the effects associated

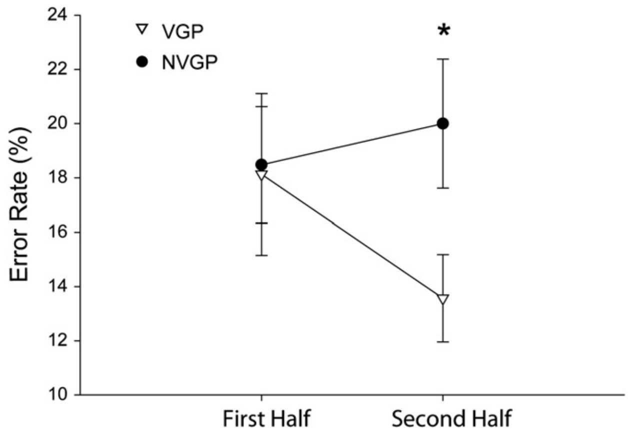

Fig. 4. Error rates (%) for both VGPs and NVGPs divided into the first and second half of experimental trials.

with action video game playing are related to improving people's ability to more efficiently learn (Green et al., 2010), we tested whether differences in task performance were stronger at the end of experimental sessions than at the beginning. Comparing the proportion of saccades to distractors through a 2 (Video Game Experience: VGP vs. NVGP) × 2 (Time: first half vs. second half of trials) ANOVA, revealed a significant interaction between video game experience and time, $F(1, 26) = 6.28$, $p = .019$. While NVGPs performance did not improve over time, $t(13) = 1.18$, $p = .259$, VGPs performance did, $t(13) = 2.20$, $p = .046$, with the result that by the second half of the experiment, VGPs were significantly better than NVGPs at ignoring the distractor, one-tailed $t(26) = 1.90$, $p = .035$ (see Fig. 4). This change in accuracy did not change the course of the saccadic deviations. Examining the contrasts for a 2 (Group: VGP vs. NVGP) × 2 (Time: first half vs. second half) × 6 (Bins) ANOVA revealed the expected linear (Bin; $p < .001$) and quadratic (Group X Bin; $p < .020$) trends, but no interactions with Time ($ps > .50$). Thus, although the effect of expertise on accuracy was limited to the second half of the study, the differences in saccadic trajectories between VGPs and NVGPs in the present study were associated with better overall task performance.

4. Discussion

The present study investigated whether experience playing action video games can affect the interplay between the stimulus-driven and top–down processes that guide saccadic eye movements by measuring trajectory deviations towards or away from a distractor stimulus. At the very shortest SRT bin, both VGPs and NVGPs showed nearly identical amounts curvature toward the distractor. Differences in curvature between the two groups did, however, occur across the subsequent SRT bins. For the NVGPs, the saccadic trajectories curved away from the distractor by the third SRT bin and this repulsive effect began to dissipate by the fifth SRT bin. In contrast, the saccadic trajectories for the VGPs exhibited a slower change to curve away from the distractor (not until the fifth SRT bin) and this repulsive effect continued to increase across all the SRT bins. It is worth noting that these differences in saccadic trajectories occurred despite no differences in SRTs between the two groups.

The present results indicate that playing action video games does indeed affect oculomotor control and the underlying interplay between stimulus-driven and top–down attentional processes. In terms of stimulus-driven oculomotor capture, there appears to be no difference of consequence between VGPs and NVGPs as the groups had nearly identical curvatures toward the distractors at the shortest SRT bin. This is consistent with the findings of Castel et al. (2005), who found that action video game experience did not alter attentional cueing effects measured with manual reaction times (RTs). It is worth noting that other studies that have either found more (West et al., 2008) or less (Chisholm et al., 2010) attentional capture have used various temporal measures of capture. Given the we have previously used saccadic trajectories to find differences not picked up by manual RTs (Al-Aidroos & Pratt, 2010), the nearly identical performance of the two groups at the shortest SRT is compelling evidence that action video game playing does not affect oculomotor capture.

Different patterns of top–down oculomotor control did, however, emerge between VGPs and NVGPs from the second SRT bin onward, possibly reflecting differences in FEF functioning associated with frontal inhibition. While NVGPs initially showed greater distractor inhibition, they were not able to maintain this inhibition over time, while VGPs showed more inhibition as SRTs increased. This could be due to delays in disengagement in VGPs, thus slowing the time course of curvature away from the distractor. Castel et al. (2005), however, failed to find any effect of video game playing on the onset of IOR, which is thought to be a good measurement of disengagement (e.g., Klein et al., 2006). A more likely explanation is that VGPs have more residual attention to encode distractor stimuli compared to NVGPs (Green & Bavelier, 2003, 2006), that could result in sustained distractor capture effects that outweigh frontal inhibition from the FEF (McSorley et al., 2006).

Interestingly, NVGPs showed less inhibition at the longest SRTs bins, suggesting that the time course of frontal contribution to oculomotor control also differs between the two groups. This is especially pertinent when considering the results of Campbell et al. (2009), who found that trajectory deviations in older adults showed no oculomotor inhibition at later SRTs where ample time was allowed for frontal mechanisms to modulate oculomotor control. Similarly, NVGPs show decreased inhibition when more time was allowed for frontal structures to affect eye movements compared to VGPs who show strong inhibition when enough time is allowed to override initial capture effects. This suggests that experience with action video games could modulate cortically generated inhibition via projections from frontal structures that is well known to decline with age (e.g., Colcombe, Kramer, Erickson, & Scalf, 2005).

Although accuracy measures were not the main focus of our study, we nonetheless found a difference in error rates between VGPs and NVGPs, but only in later trials when participants had the ability to learn how to optimize their task performance. This link between action video games and learning was recently made by Green et al. (2010), who argue that experience with games help people “learn to learn”. The pattern of performance observed in the present study supports this view that VGPs were more able to learn how to optimally perform on the task over time compared to NVGPs.

Overall, our results suggest that experience playing action video games can have profound effects on oculomotor output. We nevertheless need to point out that in the current study we compared those who self-identified as VGPs and NVGPs. It is therefore a possibility that these results are due to a population bias. This is, however, unlikely as a multitude of training studies have demonstrated that effects associated with video game playing are not due to participant self-selection but actual experience dependent changes in cognitive function (Green & Bavelier, 2003, 2006). Thus, the present study shows that effects associated with action video game have the ability to modulate the interplay between stimulus-driven and top–down processes that directly determine the control of saccadic eye movements.

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References

Al-Aidroos, N., & Pratt, J. (2010). Top–down control in time and space: evidence from saccadic latencies and trajectories. *Visual Cognition*, *18*(1), 26–49.

Campbell, K. L., Al-Aidroos, N., Pratt, J., & Hasher, L. (2009). Repelling the young and attracting the old: examining age-related differences in saccade trajectory deviations. *Psychology and Aging*, *24*, 163–168.

Castel, A., Pratt, J., & Drummond, E. (2005). The effect of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica*, *119*, 217–230.

Chisholm, J. D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception, & Psychophysics*, *72*, 667–671.

Clark, K., Fleck, M. S., & Mitroff, S. R. (2011). Enhanced change detection performance reveals improved strategy use in avid action video game players. *Acta Psychologica*, *136*, 67–72.

Colzato, L. S., van Leeuwen, P. J., van den Wildenberg, W. P., & Hommel, B. (2010). DOOM'd to switch: superior cognitive flexibility in players of first person shooter games. *Frontiers in Psychology*, *1*. doi:10.3389/fpsyg.2010.00008.

Colcombe, S. J., Kramer, A. F., Erickson, K. I., & Scalf, P. (2005). The implications of cortical recruitment and brain morphology for individual differences in inhibitory functioning in aging humans. *Psychology and Aging*, *20*, 363–375.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science*, 850–855.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, *423*, 534–537.

Green, C. S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological Science*, *18*, 88–94.

Green, C. S., & Bavelier, D. (2006). Enumeration versus multiple object tracking: the case of action video game players. *Cognition*, *101*, 217–245.

Green, C. S., Pouget, A., & Bavelier, D. (2010). Improved probabilistic inference as a general learning mechanism with action video games. *Current Biology*, *20*, 1573–1579.

Klein, Castel, & Pratt (2006).

Ludwig, C. J. H., & Gilchrist, I. D. (2002). Measuring saccade curvature: a curve-fitting approach. *Behavior Research Methods, Instruments, & Computers*, *34*(4), 618–624.

McSorley, E., Haggard, P., & Walker, R. (2006). Time course of oculomotor inhibition revealed by saccade trajectory modulation. *Journal of Neurophysiology*, *96*, 1420–1424.

McSorely, E., Haggard, P., & Walker, R. (2009). The spatial and temporal shape of oculomotor inhibition. *Vision Research*, *49*, 608–614.

Vincent, S. B. (1912). The function of vibrissae in the behavior of the white rat. *Behavior Monographs*, *1*(5).

Walker, R., McSorley, E., & Haggard, P. (2006). The control of saccade trajectories: direction of curvature depends on prior knowledge of target location and saccade latency. *Perception & Psychophysics*, *68*, 129–138.

West, G. L., Al-Aidroos, N., Susskind, J., & Pratt, J. (2011). Emotion and Action: The effect of fear on saccadic performance. *Experimental Brain Research*, *209*(1), 153–158.

West, G. L., Stevens, S., Pun, C., & Pratt, J. (2008). Visuospatial experience modulates attentional capture: evidence from action video game players. *Journal of Vision*, *8*(16), 13.1–13.9.