Improved top-down control reduces oculomotor capture: The case of action video game players

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The last decade has seen an increase in research dedicated to understanding the cognitive effects associated with extensive video game use, highlighting the differences between video game players and non-video-game players (NVGPs). This growing body of work has largely employed paradigms that require the engagement of selective visual attention and has been consistent in demonstrating benefits in task performance associated with video game experience (e.g., Castel, Pratt, & Drummond, 2005; Chisholm, Hickey, Theeuwes, & Kingstone, 2010; Clark, Fleck, & Mitroff, 2011; Dye, Green, & Bavelier, 2009a, 2009b; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994; Mishra, Zinni, Bavelier, & Hillyard, 2011; West, Stevens, Pun, & Pratt, 2008). The beneficial effects of video game experience observed in these attention-based paradigms has been routinely observed in, if not in some cases restricted to, action video game players (AVGPs). Not only has this literature highlighted that AVGPs outperform NVGPs across a variety of attention-based tasks, but training studies have also demonstrated that NVGPs can exhibit similar performance benefits after relatively short periods of training with action video games, as compared with training with control nonaction video games (Feng et al., 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Green, Pouget, & Bavelier, 2010; Greenfield et al., 1994; but see Boot, Kramer, Simons, Fabiani, & Gratton, 2008, for a notable exception). These findings strongly suggest that there exists a causal relationship between action video game experience and improvements in task performance.

In terms of accounting for the advantage demonstrated by AVGPs—specifically, in visual-attention-based paradigms—the literature has collectively pointed to an endogenous mechanism. Indeed, the evidence to date converges on the conclusion that AVGPs' improved performance in attention-based paradigms (i.e., tasks that require the deployment of visuospatial attention) reflects enhanced top-down control over the allocation of selective visual attention (e.g., Chisholm et al., 2010; Clark et al., 2011; Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010; Feng et al., 2007; Green & Bavelier, 2003, 2006a; Karle, Watter, & Shedden, 2010; Mishra et al., 2011; see Hubert-Wallander, Green, & Bavelier, 2010, for a review). Of course, this does not mean that other cognitive mechanisms cannot be positively (or negatively) affected by action video game playing, nor does this mean that the only interpretation of AVGPs' improved performance on attention tasks is that it reflects enhanced endogenous control (see, e.g., Castel et al., 2005; Green et al., 2010). However, both behavioral and neurophysiological evidence has provided support for the top-down control account of AVGPs' performance advantages in visual-attention-based paradigms. For example, AVGPs are quicker to locate and respond to targets presented among distractors (e.g., Chisholm et al., 2010; Feng et al., 2007; Green & Bavelier, 2003, 2006a). Neurophysiological evidence has also demonstrated that AVGPs are better able to suppress (Mishra et al., 2011) or filter (Bavelier, Achtman, Mani, & Focker, 2011) task-irrelevant information. The fact that AVGPs and NVGPs are equally affected by exogenous cues (Castel et al., 2005; Dye et al., 2009a; Hubert-Wallander, Green, Sugarman, & Bavelier, 2011; however, see West et al., 2008) lends further support that the AVGP advantage is specific to an endogenous mechanism. Together, these findings suggest that AVGPs can be viewed as a group that possesses enhanced top-down control over the allocation of visuospatial attention and, thus, makes a noteworthy

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population to sample from as a means of informing key models of attention.

One notable paradigm that brings together competing theories of attention is the attentional/oculomotor capture task (e.g., Bacon & Egeth, 1994; Folk, Remington, & Johnston, 1992; Theeuwes, 1991, 1992; Yantis, 1993; Yantis & Jonides, 1990). In a recent article, Chisholm et al. (2010) reported that the interfering effect of a salient visual distractor was less pronounced for AVGPs than for NVGPs. Working from the theoretical perspective that top-down control in this task is not possible until *after* a salient distractor has captured attention (Theeuwes, 1991, 1992, 2004; Theeuwes & Godijn, 2001), Chisholm et al. suggested that AVGPs were better able than NVGPs to apply top-down attentional control to disengage their attention from the distractor stimulus. However, this interpretation effectively dismissed an equally viable alternative interpretation: that AVGPs' enhanced top-down control was applied *before* visuospatial attention was ever captured by the distractor (Bacon & Egeth, 1994; Folk et al., 1992). In other words, top-down control accentuated the target stimulus or inhibited the distractor stimulus, thereby dampening the ability of a salient distractor to capture attention.

The aim of the present article is to distinguish between these two theories—that is, whether top-down control is applied before or after a distracting stimulus captures attention. To this end, we compared AVGP and NVGP performance in an oculomotor capture task. This paradigm is a conceptual equivalent of the attentional capture paradigm (Hunt, von Muhlenen, & Kingstone, 2007), but now, critically, eye movements (saccades) are recorded while participants search the visual display. In tracking participants' eye movements, one can acquire an overt measure of where attention is allocated.

In our task, participants searched for a unique color target, and, on half the trials, an additional nontarget item appeared in the display as an abrupt onset. Traditionally, individuals will make reflexive saccades toward the abrupt onset even when it is known to be task irrelevant (e.g., Boot, Kramer, & Peterson, 2005; Irwin, Colcombe, Kramer, & Hahn, 2000; Theeuwes, Kramer, Hahn, & Irwin, 1998). The proportion of initial saccades that orient toward the abrupt onset provides a measure of oculomotor capture. On the basis of previous work, we predicted that AVGPs' performance would be negatively affected by the presence of an abrupt onset to a lesser degree than would that of NVGPs. The key question was whether this AVGP top-down advantage would be achieved *after* attention was captured by the distractor stimulus (i.e., by faster disengagement from the distractor) or *before* attention was captured by the distractor stimulus (i.e., a reduced capture by the distractor stimulus).

It is worth noting that all previous studies demonstrating a difference between AVGP and NVGP have employed covert attention paradigms (i.e., restricted eye movements), or, when eye movements were allowed, they were not recorded. Therefore, to the best of our knowledge, this is the first study to record AVGP eye movements. It is thus possible that the benefits seen in covert orienting tasks will not extend to an overt orienting task, since covert and overt attentional systems may be separable when eye movements are withheld and attention is allocated covertly (Hunt & Kingstone, 2003a, 2003b; Klein, 1980). That said, the general consensus is that when eye movements are executed, covert and overt shifts of attention are tightly linked, such that covert shifts precede overt shifts of attention (Hoffman & Subramaniam, 1995; Moore & Fallah, 2001; Van der Stigchel & Theeuwes, 2007). Therefore, it is reasonable to expect that the AVGP covert attention advantage will extend to overt attentional orienting.

Method

Participants

Thirty-six University of British Columbia undergraduate males (17–39 years of age; mean, 21.5) received course credit or monetary compensation. Recruitment involved explicitly asking for AVGPs and NVGPs to participate. Those who reported playing a minimum of 3 h/week of action video games over the last 6 months were defined as AVGPs. The majority of AVGPs reported playing a similar collection of games (e.g., *Counter-Strike*, *Call of Duty*). NVGPs were defined as those who reported little to no action video game playing over the past 6 months. Four participants did not meet either the AVGP or the NVGP criteria and were excluded from analysis. Of the remaining 32 participants, 16 were AVGPs who played action video games approximately 10 h/week. The 16 NVGPs did not report any action video game playing; however, 4 reported playing nonaction games, ranging from 1 to 4 h/week. All participants provided written informed consent and reported normal or corrected-to-normal vision.

Apparatus and stimuli

Visual stimuli were gray and blue circles on a black background, viewed from a chinrest positioned 65 cm before a 17-in. LCD monitor. An Eyelink 1000 (SR Research) tracked and recorded eye movements at 1000 Hz.

The display (see Fig. 1) consisted of six circles evenly spaced around the circumference of a 14.7° imaginary circle. Each circle was 2.35° and consisted of an inner black square (0.3°). An abrupt onset appeared on the imaginary

Fig. 1 Example of the sequence of events for each trial

circle at an angle of 90° or 150° from the target. The onset was identical to the other nontarget items in the display.

Procedure

Participants first answered a questionnaire to assess video game playing experience. Before the computer task was begun, an oral and written (via the computer monitor) description of the task was provided. Participants were told that each display consisted of one target (gray circle) among five nontargets (blue circles) and that they were to make an eye movement to the location of the target circle. Participants were encouraged to respond as quickly and accurately as possible. They were not informed of any possible distractor items.

Each trial began with a central fixation point (0.7°) presented for 150 ms, followed by six gray circles. After 2,500 ms, all but one gray circle changed to blue. The target appeared at each of the possible six positions equally often. On half of the trials, an additional blue circle (abrupt onset) was added to the display at the time the other circles turned blue. After a response was made (or after 2,000 ms, whichever came first), the screen went blank for 150 ms, signaling the trial's end.

Participants received a practice session of 12 trials and were then questioned to confirm that they could identify the target among the nontargets. Participants then completed four blocks of 48 trials (192 test trials). Before each block, a 9-point eye calibration was performed. Initial saccades that landed within a 70° window centered on the target (i.e., 35° either side) were recorded as correct; similarly, initial responses landing within 70° of the onset were capture trials. Other eye movements (excluding blinks) were scored as errors. At the end of each block, participants were presented with their average search time for that block. Participants were asked to read back these times to the experimenter. At the study's end, participants were asked to report what they believed to be the purpose of the study.

Results

Across all analyses, saccades to a target or an abrupt onset with latencies shorter than 100 ms and greater than 500 ms were excluded, resulting in a loss of 6.9% of the trials.

Prior to addressing whether AVGP's advantage occurs before or after capture, it was first necessary to establish that AVGP's and NVGP's performance did, in fact, differ in the task. A 2×2 repeated measures ANOVA with video game experience (AVGP vs. NVGP) and onset presence (absent vs. present) as factors was used to compare search time (i.e., the time taken for the eyes to arrive at the target) across groups.¹ This analysis revealed a main effect of onset presence, $F(1, 30) = 54.39$, $p < .001$, and a main effect of video game experience, $F(1, 30) = 6.59$, $p < .02$, indicating that both groups took longer to reach the target when an abrupt onset appeared in the display; however, AVGP's were able to reach the target faster than NVGP's. A significant interaction between video game experience and onset presence was found, $F(1, 30) = 4.46$, $p < .05$, indicating that AVGP's search time was less affected by the presence of the abrupt onset (Fig. 2a). This finding allows for further analysis to isolate the source of this search time effect.

Quicker to orient attention?

Since AVGP's tend to make faster responses, relative to NVGP's (Dye et al., 2009b), we assessed whether AVGP's and NVGP's differed in the time taken to initiate a saccade (i.e., saccade latency). A 2×3 repeated measures ANOVA was conducted on mean saccade latencies, with video game experience (AVGP vs. NVGP) and trial type (no onset present; onset was present, but the eyes went correctly to the target; and onset was present, and the eyes were captured). The analysis revealed a main effect of trial type, $F(2, 60) = 78.21$, $p < .001$, but no main effect of video game experience, $F(1, 30) = 1.99$, $p > .05$, and no trial type $\times$ video game experience interaction, $F(2, 60) < 1$. Bonferroni-corrected multiple comparisons revealed that both groups produced shorter saccade latencies on capture trials than on either of the accurate trial types ($p < .001$); however, accurate trial types did not differ ($p > .05$). Together, these data and analyses indicate that AVGP's and NVGP's did not differ in time taken to initiate a saccade (Fig. 2b).

¹ Participants were aware that fixating the target offset the display, which led to the start of the next trial. Occasionally (5%), participants made a saccade and incorrectly thought that they had fixated the target. When they discovered that the display had not offset, they made a "refixation" to the target. A conservative cutoff of 800 ms was used to exclude these trials from the analysis.

Fig. 2 Action video game player (AVGP) and non-video-game player (NVGP) performance data. **a** Time AVGPs and NVGPs took to reach the target on onset-absent and onset-present trials. AVGPs experienced less interference from the presence of the abrupt onset, as compared with NVGPs ($p < .05$). **b** AVGP and NVGP saccade latency across trial types. Although a slight AVGP advantage was observed, this effect was not reliable ($p > .05$). **c** Fixation duration on the abrupt onset distractor. Both AVGPs and NVGPs spent an equal amount of time fixating the distractor ($p > .05$). **d** Saccade accuracy for trials where an abrupt onset was either absent or present. Both groups were equally accurate on the onset-absent trials; however, AVGPs produced more accurate saccades than did NVGPs when an abrupt onset was present in the display ($p < .01$). Error bars represent the standard errors of the means

Quicker to disengage?

To assess whether AVGPs and NVGPs differed in the time needed to reorient to the target following capture, AVGPs' and NVGPs' mean durations of fixations on the abrupt onset were compared. This analysis revealed no difference between groups, $t(30) = 0.48$, $p > .05$. Both AVGPs and NVGPs, once captured, fixated the onset for almost exactly the same length of time (86.8 and 90.0 ms, respectively) prior to reorienting to the target (Fig. 2c).

Less capture?

Finally, to assess whether the observed performance difference was a result of AVGPs producing fewer saccades to the abrupt onset, a 2×2 repeated measure analysis was conducted on first-saccade accuracy, with onset presence (absent vs. present) and video game experience (AVGPs vs. NVGPs) as factors. This analysis revealed that accuracy was significantly higher for both groups on onset-absent trials than when an abrupt onset appeared in the display, $F(1, 30) = 95.63$, $p < .001$. No main effect of video game experience was observed, $F(1, 30) = 1.90$, $p > .05$; however, the onset presence $\times$ video game experience interaction was significant, indicating that the appearance of the abrupt onset negatively affected the saccade accuracy of NVGPs to a greater degree than AVGPs' accuracy, $F(1, 30) = 9.91$, $p < .01$ (Fig. 2d). A subsequent analysis revealed that NVGPs produced more initial

saccades to the abrupt onset (32.0%), as compared with AVGPs (20.5%), $t(30) = 2.50$, $p < .02$.

Discussion

The demonstration that AVGPs were faster than NVGPs to attend to a target color singleton when a task-irrelevant abrupt onset appeared in the display highlights that the effects of action video game experience observed in covert tasks can extend to an overt attentional task. In addition, the present results are consistent with the notion that AVGPs outperform NVGPs in attention-based tasks as a result of engaging enhanced top-down control over the allocation of visuospatial attention (Chisholm et al., 2010; Clark et al., 2011; Green & Bavelier, 2003; Hubert-Wallander et al., 2010; Karle et al., 2010). To the best of our knowledge, the present study is the first to record and compare AVGP and NVGP eye movement behavior. This allowed for a more direct measure of the allocation of attention to provide insight into the long-standing debate of whether the capture of attention occurs in a purely bottom-up fashion (Theeuwes, 1991, 1992, 2004) or whether it can be modulated by top-down factors (Bacon & Egeth, 1994; Folk et al., 1992). In opposition to the prediction offered by a recent bottom-up account of capture (Chisholm et al., 2010), AVGPs and NVGPs did not differ in the time taken to disengage from the abrupt onset but, instead, differed *prior*

to capture. That is, our results show unequivocally that those believed to possess greater top-down control over the allocation of visuospatial attention produce fewer shifts of attention to a task-irrelevant abrupt onset. The theoretical implication of our finding for AVGPs is that it reflects a general principle of human cognition: Top-down modulation of covert and overt attentional capture can be realized before, not after, attention is drawn to an irrelevant singleton.

One possible mechanism to account for the reduction in oculomotor capture is that top-down control can be engaged to better prioritize targets. Participants were instructed to search for a gray target circle and were not informed of the presence of abrupt onsets; therefore, it is possible that both AVGPs and NVGPs adopted an attentional set (Folk et al., 1992) for the color target, rather than a set against the distractor. The observed reduction in oculomotor capture could, then, reflect an increase in one's sensitivity to known target features. Indeed, some recent evidence provides support for this view, highlighting that AVGPs demonstrate greater sensitivity to target stimuli (Green et al., 2010; West et al., 2008). An alternative account is that top-down control can be engaged to improve distractor inhibition. This notion is consistent with recent neurophysiological evidence indicating that AVGPs are better able to suppress (Mishra et al., 2011) or filter (Bavelier et al., 2011) distracting or irrelevant information. Clearly, whether improved top-down control is enabled via target prioritization or distractor inhibition remains an important issue for further investigation.

It is worth noting that by taking the novel approach of using AVGPs as an individual-difference variable that enabled one to test the role of top-down attentional control in the allocation of visuospatial attention, one could reasonably argue that we cannot claim with complete certainty that AVGPs outperform NVGPs because of their prior experience with action video games. Indeed, due to the cross-sectional nature of the present investigation, some other factor correlated with action video game playing could have mediated our observed effects (Boot, Blakely, & Simons, 2011). For example, AVGPs may be naturally more motivated to perform well in computerized tasks. However, it is unlikely that such an account would specifically predict fewer saccades to an abrupt onset over other equally viable alternatives for AVGPs to outperform NVGPs (e.g., shorter saccade latencies, quicker disengagement).² Although

we acknowledge the limitations of cross-sectional designs, we feel that they do not undermine the empirical or theoretical contributions of the present study. Moreover, previous work has provided ample evidence in support of a causal link between action video game experience and subsequent performance improvements on a number of different visuospatial tasks (Feng et al., 2007; Green & Bavelier, 2003, 2006a, 2006b, 2007; Green et al., 2010; Greenfield et al., 1994; but see Boot et al., 2008). Therefore, the evidence to date suggests that video game playing could provide a quick and reliable individual-difference measure for isolating individuals with enhanced top-down control.

Conclusion

In AVGPs, research has identified a population that demonstrates greater resistance to the interfering effects of distraction. While by no means the only factor, engaging top-down control is a key factor for this performance benefit. The findings in the literature converge on the notion that the AVGP advantage in attention-based paradigms can be accounted for via enhanced top-down control over the allocation of visuospatial attention. Therefore, the use of AVGPs allows for an investigation into competing bottom-up and top-down models of attention. Rather than both groups differing only after capture had occurred, as predicted by a bottom-up account of capture, AVGPs made fewer saccades toward task-irrelevant abrupt onsets than did NVGPs. Thus, our study suggests unequivocally that improved top-down control processes can be engaged to prevent the capture of attention, rather than enhancing the ability to deal with capture after it has occurred. In sum, the present results provide support for the notion that top-down factors can modulate the involuntary capture of attention.

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References

- Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics*, 55, 485–496.
- Bavelier, D., Achtman, R. L., Mani, M., & Focker, J. (2011). Neural basis of selective attention in action video game players. *Vision Research*. Advance online publication. doi:10.1016/j.visres.2011.08.007.
- Boot, W. R., Blakely, D. P., & Simons, D. J. (2011). Do action video games improve perception and cognition? *Frontiers in Psychology*, 2, 226.

² Another potential mediating factor worth noting is priming due to explicitly asking for action video game players and non-video-game players to participate. To address this concern, we analyzed performance as a function of whether participants correctly predicted the purpose of the study or not. No differences were observed between AVGPs who did ($n = 11$) and did not ($n = 5$) predict the purpose of the study, $F < 1$. Comparing performance across groups for only those who did not correctly predict the purpose of the study (5 AVGPs, 9 NVGPs) revealed a pattern of results identical to that for the full sample ($p = .01$). Thus, the concern of a priming effect is unwarranted in the present investigation.

- Boot, W. R., Kramer, A. F., & Peterson, M. S. (2005). Oculomotor consequences of abrupt object onsets and offsets: Onsets dominate oculomotor capture. *Perception & Psychophysics*, 67, 910–928.
- Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta Psychologica*, 129, 387–398.
- Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects 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. A., van den Wildenberg, W. P. M., & Hommel, B. (2010). Doom'd to switch: Superior cognitive flexibility in players of first person shooter games. *Frontiers in Psychology*, 1(8). doi:10.3389/fpsyg.2010.00008
- Dye, M. W. G., Green, C. S., & Bavelier, D. (2009a). The development of attention skills in action video game players. *Neuropsychologia*, 47, 1780–1789.
- Dye, M. W. G., Green, C. S., & Bavelier, D. (2009b). Increasing speed of processing with action video games. *Current Directions in Psychological Science*, 18, 321–326.
- Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science*, 18, 850–855.
- Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 1030–1044.
- Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, 423, 534–537.
- Green, C. S., & Bavelier, D. (2006a). Effect of action video games on the spatial distribution of visuospatial attention. *Journal of Experimental Psychology*, 32, 1465–1478.
- Green, C. S., & Bavelier, D. (2006b). Enumeration versus multiple object tracking: The case of action video game players. *Cognition*, 101, 217–245.
- Green, C. S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological Science*, 18, 88–94.
- 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.
- Greenfield, P. M., DeWinstanley, P., Kilpatrick, H., & Kaye, D. (1994). Action video games and informal education: Effects on strategies for dividing visual attention. *Journal of Applied Developmental Psychology*, 15, 105–123.
- Hoffmann, J. E., & Subramanian, B. (1995). The role of visual attention in saccadic eye movements. *Perception & Psychophysics*, 57, 787–795.
- Hubert-Wallander, B., Green, C. S., & Bavelier, D. (2010). Stretching the limits of visual attention: The case of action video games. *Wiley Interdisciplinary Reviews: Cognitive Science*, 2, 222–230.
- Hubert-Wallander, B., Green, C. S., Sugarman, M., & Bavelier, D. (2011). Changes in search rate but not in the dynamics of exogenous attention in action videogame players. *Attention, Perception, & Psychophysics*, 73, 2399–2412.
- Hunt, A. R., & Kingstone, A. (2003a). Covert and over voluntary attention: Linked or independent? *Cognitive Brain Research*, 18, 102–105.
- Hunt, A. R., & Kingstone, A. (2003b). Inhibition of return: Dissociating attentional and oculomotor components. *Journal of Experimental Psychology: Human Perception and Performance*, 29, 1068–1074.
- Hunt, A. R., von Muhlenen, A., & Kingstone, A. (2007). The time course of attentional and oculomotor capture reveals a common cause. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 271–284.
- Irwin, D. E., Colcombe, A. M., Kramer, A. F., & Hahn, S. (2000). Attentional and oculomotor capture by onset, luminance and color singletons. *Vision Research*, 40, 1443–1458.
- Karle, J. W., Watter, S., & Shedden, J. M. (2010). Task switching in video game players: Benefits of selective attention but not resistance to proactive interference. *Acta Psychologica*, 134, 70–78.
- Klein, R. M. (1980). Does oculomotor readiness mediate cognitive control of visual attention. In R. Nickerson (Ed.), *Attention and performance VIII* (pp. 259–276). Hillsdale, NJ: Erlbaum.
- Mishra, J., Zinni, M., Bavelier, D., & Hillyard, S. A. (2011). Neural basis of superior performance of action videogame players in an attention-demanding task. *Journal of Neuroscience*, 31, 992–998.
- Moore, T., & Fallah, M. (2001). Control of eye movements and spatial attention. *Proceedings of the National Academy of Sciences*, 98, 1273–1276.
- Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychophysics*, 50, 184–193.
- Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, 51, 599–606.
- Theeuwes, J. (2004). Top-down search strategies cannot override attentional capture. *Psychonomic Bulletin & Review*, 11, 65–70.
- Theeuwes, J., & Godijn, R. (2001). Attention and oculomotor capture. In C. L. Folk & B. S. Gibson (Eds.), *Attention, distraction and action: Multiple perspectives on attentional capture* (pp. 121–149). New York: Elsevier.
- Theeuwes, J., Kramer, A. F., Hahn, S., & Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science*, 9, 379–385.
- van der Stigchel, S., & Theeuwes, J. (2007). The relationship between covert and overt attention in endogenous cuing. *Perception & Psychophysics*, 69, 719–731.
- West, G. L., Stevens, S. S., Pun, C., & Pratt, J. (2008). Visuospatial experience modulates attentional capture: Evidence from action video game players. *Journal of Vision*, 8(16), 1–9.
- Yantis, S. (1993). Stimulus-driven attentional capture and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, 19, 676–681.
- Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 121–134.