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Reduced attentional capture in action video game players

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Recent studies indicate that playing action video games improves performance on a number of 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. The results show 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 did 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.

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, whereas top-down (endogenous) processes are more important later in processing (e.g., Hickey, van Zoest, & Theeuwes, in press; Theeuwes & Van der Burg, 2007; van Zoest, Donk, & Theeuwes, 2004). According to this idea, attention is pulled in the direction of salient stimuli in a bottom-up manner, independently of attentional resources, during the early exogenous stage. Later, 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, researchers investigating differences between video game players (VGPs) and non-video game players (NVGPs) have reported a whole host of performance differences. For example, VGPs possess quicker reaction times (RTs; Castel, Pratt, & Drummond, 2005; Clark, Lamphear, & Riddick, 1987; Goldstein et al., 1997), improved hand–eye coordination (Griffith, Voloschin, Gibb, & Bailey, 1983), enhanced spatial abilities (Gagnon, 1985; McClurg & Chaille, 1987), and improved target detection (Feng, Spence, & Pratt, 2007; Green & Bavelier, 2006a; West, Stevens, Pun, & Pratt, 2008). 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 VGPs (AVGPs) and NVGPs are impressive, in terms of both breadth and number, whether action video game experience translates into a fundamental change in exogenous or endogenous attentional systems remains unclear.

The 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-

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view (UFOV) and flanker compatibility task. The UFOV task 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, 1993). 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 the 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 relative to NVGPs, because AVGPs could apparently attend to the distractors in all conditions. The AVGPs' compatibility effect did not differ between low- and high-load trials; however, a load $\times$ flanker location (periphery or central) interaction indicated that the 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.

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, had been 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, the 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 of 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 among high- and low-load conditions. Overall, the AVGPs demonstrated greater sensitivity (d') in detecting the target than did the 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. Our goal in the present study was to further investigate the attentional mechanisms underlying the observed attentional benefits gained from action video game experience. To this end, we had NVGPs and AVGPs complete 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 a unique color. The presence of this *color singleton* increases RTs and error rates (Theeuwes 1991, 1992; but 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; but see Leber & Egeth, 2006; for reviews of the capture literature, see Burnham, 2007; Corbetta & Shulman, 2002; Rauschenberger, 2003; Ruz & Lupiáñez, 2002; Theeuwes & Godijn, 2001).

We expected to find that action video game experience would have an impact on RTs 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 was suggested by Castel et al., 2005, or alternatively, AVGPs could simply process information more quickly). Our interest lies in the specific effect of action video game experience on the capture of attention. We approached experimentation with the idea that the results could follow one of two patterns: If action video game experience affects exogenous attention, resulting in increased saliency sensitivity, AVGPs should show increased attentional capture. In contrast, if video game experience has an impact on endogenous control, we should expect reduced capture (Figure 1).

METHOD

Participants

Thirty-two male participants recruited from the University of British Columbia provided written informed consent before participating for course credit or monetary compensation (ages = 18–38 years; M = 21.3 years). All the participants had normal or corrected-to-normal vision. Two participants did not properly follow task instructions and were therefore excluded from analysis. The participants were categorized as either AVGPs or NVGPs on the basis of self-reported video game playing habits. An AVGP was defined as someone who had played a minimum of 3 h per week of action video games over the last 6 months. Those participants classified as AVGPs played action video games from 3 to 15 h per week (average of 7 h 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*). An NVGP was defined as someone who reported playing few or no action video games over the past 6 months. Four of the participants classified as NVGPs reported playing strategic video games but not action video games. These 4 participants on average played 5.5 h per week. The sample of 11 NVGPs, excluding these 4 participants, played, on average, less than 10 min per week of either strategic or action video games.

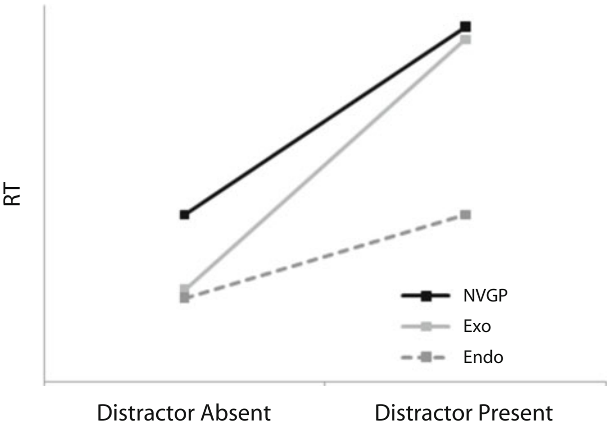

Figure 1. Prediction of non-video game player (NVGP) and action VGP performance as a function of whether action video game experience affects exogenous sensitivity or endogenous control. RT, reaction time.

Apparatus and Stimuli

A standard IBM computer (AMD 1800+ processor) and a 17-in. VGA monitor were used to present the stimuli to the participants. The participants were seated in a chair, and a chinrest was used to stabilize the 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 11º. The displayed items were circles or diamonds colored either red or green. The circle items were 3.5º in diameter, and the diamond items were 4.5º of visual angle each, with a 1.5º × 0.2º inner line segment. Line segments within nontarget display elements were tilted 22.5º 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).

Procedure

Following the completion of a questionnaire regarding video game habits, the participants were seated in front of a computer in a dimly lit testing room. Before beginning the experiment, the participants were given both an oral and a written explanation of the task. Each display consisted of one unique shape (target element) and nine nontarget items of a different shape. The 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%. The participants were also explicitly told to ignore any color information and to focus solely 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 (0.5º) was presented at the center of the visual field. The onset of the display occurred randomly between 600 and 1,600 msec 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 the participants were strongly encouraged and given regular reminders to maintain fixation. The participants initially completed a practice block followed by 15 experimental blocks. Each block consisted of 40 trials (20 distractor-present and 20 distractor-absent trials) for a total of 40 practice trials and 600 experimental trials. In the distractor-absent condition, the unique target and all nontarget items were the same color (either red or green), and in the distractor-present condition, one nontarget item was colored opposite to the other items in the display. The display was presented in a mixed fashion. The location, shape, and color 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 pseudorandomly assigned,[1] with the constraint that the shape and color 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 50% of the trials. At the end of each block, feedback was provided regarding average RT and accuracy.

RESULTS

As can be seen in Figure 3, the results are consistent with the prediction of greater endogenous control. 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, using a recursive outlier trimming procedure (Van Selst & Jolicœur, 1994), resulting in a loss of an additional 3.3% of trials. A repeated measures ANOVA was conducted, with distractor presence (present or absent) and video game experience (AVGP or 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 [$F(1,28) = 301.55$, $p < .001$, $\eta_p^2 = .92$, power = 1.0]. A significant main effect of video game experience was also identified, with the AVGPs responding faster than the NVGPs [$F(1,28) = 12.02$, $p < .01$, $\eta_p^2 = .30$, power = .92]. In addition, distractor presence and video game experience interacted such that the effect of distractor presence was larger in the NVGP group [$F(1,28) = 22.21$, $p < .01$, $\eta_p^2 = .44$, power = 1.0; see Figure 3]. The AVGPs showed a 93-msec capture effect, whereas the NVGP capture effect was 162 msec.

Accuracy data were 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 [$F(1,28) = 11.23$, $p < .01$, $\eta_p^2 = .29$, power = .90; $M_{absent} = 6.4\%$ error; $M_{present} = 7.7\%$ error]. No other effects were significant [video game experience; $F(1,28) < 1$; video game experience × condition interaction; $F(1,28) < 1$]. RTs increased with errors, indicating no speed–accuracy trade-off.

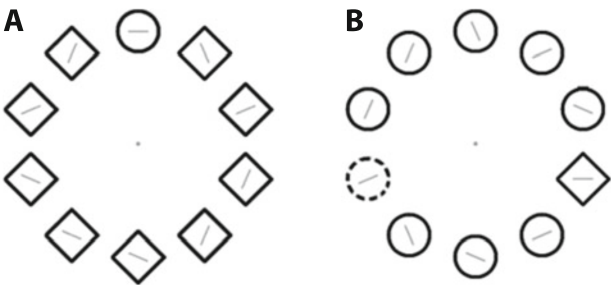

Figure 2. Examples of trial displays. (A) Distractor-absent condition with a circle target and horizontal response. (B) Distractor-present condition with a diamond target, horizontal response, and differently colored (dotted) circle distractor.

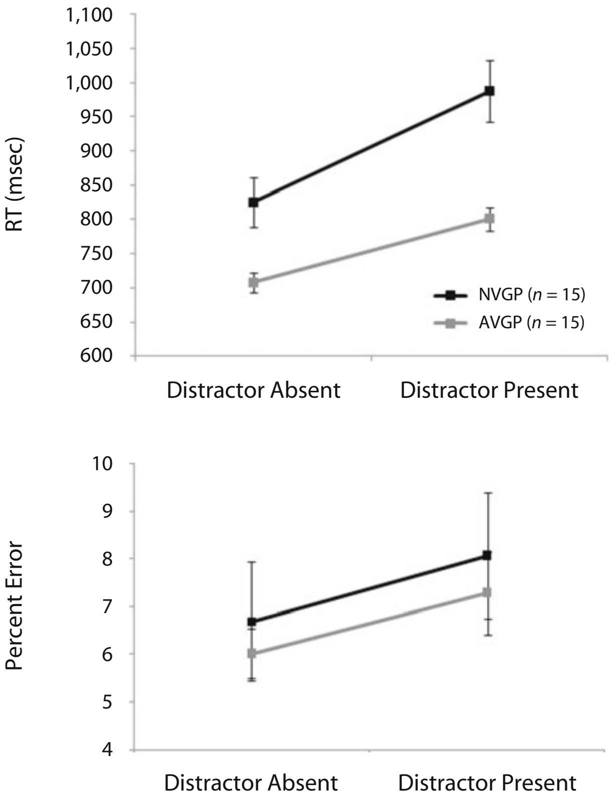

Figure 3. Graphical representation of reaction times (RTs) and accuracy for action video game players (AVGPs) and non-VGPs (NVGPs) on distractor-present and distractor-absent trials (error bars indicate 1 standard error of the mean). AVGPs demonstrated overall faster RTs ($p < .01$) and were less affected by the presence of a task-irrelevant distractor ($p < .01$). Accuracy did not differ between groups for either distractor-present or distractor-absent conditions ($F < 1$).

Note that the interaction between distractor presence and video game experience could have occurred as a result of faster processing in AVGPs. If AVGPs simply respond at some constant rate faster than NVGPs, regardless of any differences in RTs, we would expect to see an equal proportional increase in RTs between distractor-absent and distractor-present conditions in both groups. This would suggest that both groups are equally affected by a salient distractor. An additional analysis was conducted to address this question. Using each individual's average RT in the distractor-absent condition as a baseline, a proportional increase in RT, between distractor-absent and distractor-present conditions, was calculated for each participant and compared across groups. This analysis revealed a significant difference between the NVGP and AVGP groups [$t(28) = 3.85$, $p < .01$]. The NVGPs demonstrated a greater proportional increase in RTs than did the AVGPs (.20 vs. .13), thus providing evidence that the critical interaction between distractor presence and video game experience was not due solely to generally faster processing in the AVGPs. (Note that if one subtracts a constant motor latency with a value that is greater than 0 msec from the individual RTs, the difference in the proportional change between the AVGPs and the NVGPs is reduced. However, the point at which the group difference becomes nonsignificant demands the subtraction of a motor latency that is just 5 msec shy of 400 msec, a value that is far too large to be credible.)

DISCUSSION

As was expected, the 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 the NVGPs than in the AVGPs. We approached experimentation 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 the AVGPs demonstrated less capture suggests that they were 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., to 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 was proposed by Green and Bavelier (2006a), since the availability of attentional resources or working memory capacity has been implicated in reducing the effect of distractors (e.g., Engle, Conway, Tuholski, & Shisler, 1995; Lavie & de Fockert, 2005). However, we feel that it is more likely that AVGPs have a better ability to recover from capture. We feel this way for three reasons: First, it would be consistent with the substantial literature showing that capture is insensitive to endogenous attentional set (Hickey et al., 2006; Theeuwes, 1991, 1992, 1996). 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 counteradaptive in the context of video games.

Our 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 the results from these studies do not make it clear whether video game playing affects one of these control processes discretely or has an impact on both. In any case, the present results demonstrate that the greatest impact of video game training on behavior in the capture task comes from improved endogenous control, not increased sensitivity to visual salience.

A second caveat needs to be attached to our study. Our 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, 2003, 2006a, 2006b, 2007; however, see Boot, Kramer, Simons, Fabiani, & Gratton, 2008, for notable exceptions), and we believe that a similar relationship underlies our results. Only further research will determine whether this is actually the case.

Our goal in 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. We had AVGPs take part in an attentional capture task and found that they showed less evidence of attentional capture, consistent with the idea that they have better control. We believe that AVGPs are not less sensitive to salience than are NVGPs but that they have a better ability to rapidly discard irrelevant stimuli following selection.

AUTHOR NOTE

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REFERENCES

Ball, K., & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association*, **64**, 71-79.

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.

Burnham, B. R. (2007). Displaywide visual features associated with a search display's appearance can mediate attentional capture. *Psychonomic Bulletin & Review*, **14**, 392-422.

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.

Clark, J. E., Lamphear, A. K., & Riddick, C. C. (1987). The effects of videogame playing on the response selection processing of elderly adults. *Journal of Gerontology*, **42**, 82-85.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, **3**, 201-215.

Engle, R. W., Conway, A. R. A., Tuholski, S. W., & Shisler, R. J. (1995). A resource account of inhibition. *Psychological Science*, **6**, 122-125.

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 & Performance*, **18**, 1030-1044.

Gagnon, D. (1985). Videogame and spatial skills: An exploratory study. *Educational Communication & Technology Journal*, **33**, 263-275.

Goldstein, J. H., Cajko, L., Oosterbroek, M., Michielsen, M., van Houten, O., & Salverda, F. (1997). Video games and the elderly. *Social Behavior & Personality*, **25**, 345-352.

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.

Griffith, J. L., Voloschin, P., Gibb, G. D., & Bailey, J. R. (1983). Differences in eye–hand motor coordination of video-game users and non-users. *Perceptual & Motor Skills*, **57**, 155-158.

Hickey, C., McDonald, J. J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention. *Journal of Cognitive Neuroscience*, **18**, 604-613.

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

Lavie, N., & de Fockert, J. (2005). The role of working memory in attentional capture. *Psychonomic Bulletin & Review*, **12**, 669-674.

Leber, A. B., & Egeth, H. E. (2006). It's under control: Top-down search strategies can override attentional capture. *Psychonomic Bulletin & Review*, **1**, 132-138.

McClurg, P. A., & Chaille, C. (1987). Computer games: Environments for developing spatial cognition? *Journal of Educational Computing Research*, **3**, 95-111.

Rauschenberger, R. (2003). Attentional capture by auto- and allocues. *Psychonomic Bulletin & Review*, **10**, 814-842.

Ruz, M., & Lupiáñez, J. (2002). A review of attentional capture: On its automaticity and sensitivity to endogenous control. *Psicologica*, **23**, 283-309.

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. (1996). Parallel search for a conjunction of color and orientation: The effect of spatial proximity. *Acta Psychologica*, **94**, 291-307.

Theeuwes, J., & Godijn, R. (2001). Attention and oculomotor capture. In C. L. Folk & B. S. Gibson (Eds.), *Attraction, distraction and action: Multiple perspectives on attentional capture* (pp. 121-149). New York: Elsevier.

Theeuwes, J., & Van der Burg, E. (2007). The role of spatial and non-spatial information in visual selection. *Journal of Experimental Psychology: Human Perception & Performance*, **33**, 1335-1351.

Van Selst, M., & Jolicœur, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology*, **47A**, 631-650.

van Zoest, W., Donk, M., & Theeuwes, J. (2004). The role of stimulus-driven and goal-driven control in saccadic visual selection. *Journal of Experimental Psychology: Human Perception & Performance*, **30**, 746-759.

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, Art. 13), 1-9.

NOTE

1. In distractor-present trials, the location of the distractor was assigned such that the distractor was 50% likely to be presented at one of the two locations on the vertical meridian of the display and 50% likely to be presented at any other location. Bias toward 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.

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