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The precision of experienced action video-game players: Line bisection reveals reduced leftward response bias

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Abstract Twenty-two experienced action video-game players (AVGPs) and 18 non-VGPs were tested on a pen-and-paper line bisection task that was untimed. Typically, right-handers bisect lines 2 % to the left of true centre, a bias thought to reflect the dominance of the right-hemisphere for visuospatial attention. Expertise may affect this bias, with expert musicians showing no bias in line bisection performance. Our results show that experienced-AVGPs also bisect lines with no bias with their right hand and a significantly reduced bias with their left hand compared to non-AVGPs. Bisections by experienced-AVGPs were also more precise than those of non-AVGPs. These findings show the cognitive proficiencies of experienced-AVGPs can generalize beyond computer based tasks, which resemble their training environment.

Keywords Action video-game play · Response bias · Line bisection · Transfer of training · Visuospatial attention

Action video-game players (AVGPs) have shown superior performance on a wide variety of experimental tasks, especially those targeting attentional and visuospatial capabilities, in studies conducted over the past 30 years (for review see Latham, Patston, & Tippett, 2013a). One major focus of research has been the role action video-games play in the development of these capabilities. 'Action video-games' refers to a collection of video-game genres which include first-person shooter, action real-time strategy, real-time strategy, and massively multiplayer online role-playing games. While each genre has distinct qualities, success in each requires swift and accurate bimanual motor movements in response to complex in-game visual cues. They are also primarily multiplayer, facilitating extensive cooperation and competition between players.

The effect of video-game type was first noted by Subrahmanyam and Greenfield (1994) who found that only children who played the spatially oriented video-game *Marble Madness* showed improved spatial visualization performance, while those who played the language-oriented video-game *Conjecture* did not. Greenfield et al. (1994) also first reported the impact of action video-game expertise and training on visuospatial attention, on a task that required detecting visual tasks in high and low probability locations. Both expert-VGPs and non-VGPs showed a reaction-time benefit to high probability target locations, but only expert-VGPs showed no reaction-time cost to low probability locations, suggesting a superior capacity to divide attention, or, alternatively, a larger attentional field.

Current interest in the potential impact of action video-game play on visuospatial abilities has been stimulated by the work of Green and Bavelier (2003). They compared the performance of AVGPs and non-VGPs on an attentional and visuospatial task battery (flanker; enumeration; useful field of view; attentional blink). Participants were classified as AVGPs if they had maintained a play-time of 4 hours per week over the past 6 months. AVGPs outperformed non-VGPs on all tasks, suggesting they possess a larger attentional capacity and field, and reduced attentional blink. To confirm enhanced performance resulted from action video-game play, Green and Bavelier had a group of non-VGPs play either the action video-game *Medal of Honor: Allied Assault* or control non-action video-game *Tetris*. All participants improved in video-game performance; however, only those playing the action

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video-game improved in the same direction as AVGPs in experimental task performance.

Subsequent studies involving AVGPs and action video-game training suggest video-game play may result in superior stimulus-response mappings (Castel, Pratt, & Drummond, 2005), distribution of attentional resources (Green & Bavelier, 2006), sensitivity to changes in salient visual motion (West, Stevens, Pun, & Pratt, 2008), cross-modal sensory precision (Donohue, Woldorff, & Mitroff, 2010), reduced impact of backwards masking (Li, Polat, Scalzo, & Bavelier, 2010), task-switching costs (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010), and improved dual-task performance (Strobach, Frensch, & Schubert, 2012). Notably, improvements to spatial attention, contrast sensitivity, and mental rotation performance following action video-game play in non-VGPs has been shown to last at least 4 months after play ceased (Feng, Spence, & Pratt, 2007; Li, Polat, Makous, & Bavelier, 2009; Spence, Yu, Feng, & Marshman, 2009). Furthermore, while research has focused on personal computers (PCs) and consoles, improved attentional blink, selective attention, and multiple-object tracking performance has been shown after action video-game on mobile devices (Oei & Patterson, 2013).

Unfortunately, video-game researchers have continued to use computer-based experimental paradigms, often requiring rapid target detection with manipulations to distractor difficulty and target-eccentricity. As noted by Boot, Blakely, and Simons (2011), these experimental tasks measure the same skills trained by action video-games and may not provide clear evidence of cognitive proficiency generalizing beyond the context of video-game play. In the current study, we investigated the proficiency and lateralization of untimed pen-and-paper line bisection task performance in experienced-AVGPs. This is a well-suited transfer task for AVGPs, sharing no resemblance with action video-games or the computerized-training environment.

Very few studies have investigated VGP performance on non-computerized tasks. Dorval and Pépin (1986) showed non-VGPs who played the action video-game *Zaxxon* improved on the spatial relations portion of the Differential Aptitude test. Similarly, Okagaki and Frensch (1994) found that non-VGPs who played *Tetris* significantly improved performance on pen-and-paper measures of mental rotation and spatial relations. More recently, Donohue, James, Eslick, and Mitroff (2012) found no difference between AVGPs and non-VGPs in dual-task performance, including pen-and-paper visual search, although AVGPs had played first-person shooter games on average only 3 hours per week over the previous 6 months, which may be insufficient to produce dual-task benefits. Indeed, Chiappe, Conger, Liao, Caldwell, and Vu (2013) found that when non-VGPs played action video-games for 5+ hours per week, dual-task performance improved on the Multi-Attribute Task Battery.

The issue of AVGP and non-VGP classification is important (Latham, Patston, & Tippett, 2013b). Participants are often classified as an AVGP if they report playing multiple hours per week over the past 6 months, and non-VGP if they report not playing in the same period. This method of classification typically does not consider participants' longer term video-game history, which is problematic for two reasons. First, it fails to appreciate the experiential difference between AVGPs who have played 20 hours per week over the past 10 years and those who played only 3–5 hours per week over the past 6 months, who by other standards might not even be considered an AVGP. Secondly, the former expert-AVGPs would be classified as non-VGP, had they abstained from video-game play 6 months prior to testing. The misclassification of AVGPs, non-VGPs, or both may underpin some of the null results in the video-game literature (e.g., Murphy & Spencer, 2009). In the current study, we use experienced-AVGPs, and non-VGPs with no reported video-game history. Experienced-AVGPs began playing before the age of 10 years, had at least eight years' experience, and had a minimum play-time of 20 hours per week over the past 6 months.

On line bisection tasks neurotypical right-handers typically bisect horizontal lines 2 % to the left of true centre (for review see Jewell & McCourt, 2000), an error termed *right pseudoneglect* (Bowers & Heilman, 1980). This leftward bias is thought to reflect the dominance of the right-hemisphere for visuospatial attention (Oliveri et al., 2004; de Schotten et al., 2011). Expertise, however, may alter this pattern of lateralization. Expert musicians perform line bisections more accurately than non-musicians and make bisections slightly to the right rather than left side of true centre, which may suggest they possess reduced lateralization of visuospatial attention (Patston, Corballis, Hogg, & Tippett, 2006).

Although there are clear differences in the skills required by action video-game play and musicianship, they share some characteristics. Success in both requires translating complex visual cues into precisely timed, accurate bimanual movements. Like AVGPs, expert musicians show enhanced visuospatial skills (Brochard, Dufour, & Després, 2004; Patston, Hogg, & Tippett, 2007) and like video-game training, musical training influences many different cognitive domains (for review see Schellenberg, 2001). Bergstrom, Howard, and Howard (2012) found VGPs and musicians showed enhanced implicit learning of sequential regularities. They suggested video-game play and musical practice may train the same general mechanism that enables them to become more sensitive to sequential regularities in novel environments, and improved efficiency in implicit learning of sequential relationships.

In the current study, we compare the line bisection performance of experienced-AVGPs and non-VGPs. Due to reported effects of musicianship on line bisection performance, only participants with no history of music training were included in either AVGP or non-VGP groups. We predicted that experienced-AVGPs like expert-musicians should bisect lines with a reduced leftward bias and more precisely.

Method

Twenty-two right-handed male experienced-AVGPs and 18 male non-VGPs participated in the experiment. Participants were recruited through public advertisement and through advertisement of opportunities to participate in research in the School of Psychology Research Participation Scheme at the University of Auckland.

AVGPs were defined as experienced if they began playing by the age of 10 years (experienced-AVGPs: M =6.82 age began playing, SD =2.04), had at least 8 years' action video-game experience (experienced-AVGPs: M =16.68 years of experience, SD =4.44), and had a minimum action video-game play-time of 20 hours per week over the past 6 months (experienced-AVGPs: M =33.86 hours per week, SD =13.45). The video-game playing history metrics were asymmetrically distributed due to the required minimum experience to be classified an experienced-AVGP. Video- game experience was restricted to the following action video-game genres (for further discussion see Latham et al., 2013b): first-person shooters (e.g., Counter Strike: Global Offensive), real-time strategy (e.g., StarCraft II), action real-time strategy (e.g., DotA 2), and massively multiplayer online role-playing games (e.g., World of Warcraft). Non-VGPs reported no history of video-game play. Both experienced-AVGPs and non-VGPs reported no history of music training.

Groups did not differ significantly in age (experienced-AVGPs: M =23.50, SE = .85; non-VGPs: M =25.39, SE =1.13; $t(38)$ =1.36, p = .18), years of education (experienced-AVGPs: M =15.23, SE = .48; non-VGPs: M =16.28, SE = .59; $t(38)$ =1.40, p = .17), or handedness, measured by the Edinburgh Handedness Inventory (Oldfield, 1971; experienced-AVGPs: M =92.36, SE =1.67; non-VGPs: M =91.75, SE =2.35; $t(38)$ = .22, p = .83).

The line bisection task (e.g., Schenkenberg, Bradford, & Ajax, 1980; see supplemental material) comprised 17 horizontal black lines of 1 mm width displayed in the center, left-, and right-hand side of a white A4-sized sheet of paper. Line lengths ranged from 100 to 260 mm in 20-mm intervals. Nine lines were in the middle of the sheet, while four lines were lateralized to either side of the page. Lateralized lines were 13 mm away from the margin.

Participants were instructed to bisect lines into two parts of equal length, starting from the top of the page and working down, covering previously bisected lines. The task was done once with each hand, with hand order counterbalanced across participants. Deviation from the true centre was measured to the nearest millimetre and converted to a percentage of line length. Negative values indicated leftward bias while positive values indicate rightward bias.

Ethics approval was obtained from the University of Auckland Human Participants Ethics Committee. Informed written consent was obtained from participants prior to testing. The experiment was performed in a dedicated testing room in the School of Psychology at The University of Auckland.

Results

Deviation scores were compared using a repeated-measures analysis of variance, with group (experienced-AVGPs; non-VGPs) a between-subjects factor, and hand (left; right) and line position (left; centre; right), within-subjects factors. Results revealed a main effect of group with non-VGPs (M = -2.65, SE = .51) bisecting lines further to the left of centre than experienced-AVGPs (M = -.75, SE = .46), $F(1, 38)$ =7.69, p = .009, $\eta p2$ = .168 (see Fig. 1). There was a main effect of line position, $F(1.40, 53.13)$ =10.11, p = .001, $\eta p2$ = .210. As sphericity was violated ($X^2(2)$ =20.83, p < .001), degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .70). Bisections made to centred (M = -2.02, SE =0.35), p = .004, and left-positioned lines (M = -2.64, SE =0.47), p = .005, were bisected further to the left than right positioned lines (M = -.44, SE =0.51). The main effect of hand approached significance with deviations to the left marginally greater for the left hand (M = -2.16, SE =0.42) relative to the right hand (M = -1.23, SE =0.40), $F(1,38$= 4.07, MSE =52.03, p =.051, $\eta p2$ = .097. There were no other significant interactions (p >.35).

One-sample t-tests were used to test whether biases in line bisection performance differed significantly from the mid-point. Non-VGPs showed a significant leftward bias with both their left hand (M = -3.24, SE = .69), $t(17)$ = -4.70, p <.001, and their right hand (M = -2.19, SE = .64), $t(17)$ = -3.41, p = .003. Experienced-AVGPs showed no bias with their right hand (M = -.57, SE = .51), $t(21)$ = -1.13, p = .27 and reduced leftward bias with their left hand (M = -1.18, SE = .46), $t(21)$ = -2.59, p = .02.

Line bisection accuracy was compared between experienced-AVGPs and non-VGPs by converting deviation scores to absolute deviations from zero and redoing the repeated-measures analysis. By taking the absolute value, the influence of deviation direction is removed, leaving only the deviation magnitude from true centre. Results revealed a main effect of group with experienced-AVGPs (M =3.68, SE = .30) bisecting lines more precisely than non-VGPs (M =4.92, SE = .33), $F(1, 38)$ =7.63, p = .009, $\eta p2$ = .167. There were no other significant main effects or interactions (p > .21).

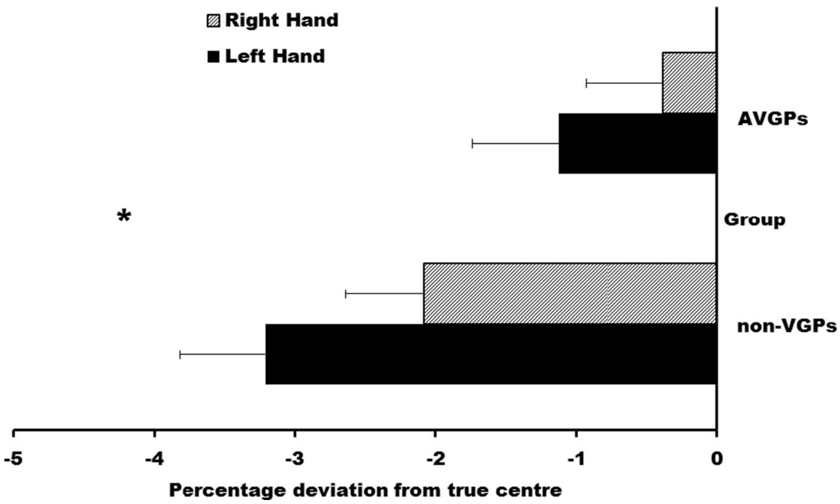

Fig. 1 Mean percentage deviation from true centre by hand in the line-bisection task for experienced-AVGPs and non-VGPs (NVGPs). * indicates a significant between-group difference. Error bars show standard error

Discussion

This study assessed the directional bias and accuracy of experienced-AVGPs on an untimed pen-and-paper line bisection task. Experienced-AVGPs not only showed a markedly reduced leftward bias when bisecting lines than non-VGPs, but no directional bias when bisecting with their right hand and a reduced leftward bias with their left hand. Experienced-AVGPs bisections were also more precise than non-VGPs. Importantly, these results demonstrate experienced-AVGPs are capable of showing superior performance on a non-computerized task that is stripped of speeded perceptual-responses and shares no resemblance to action video-games.

Our results further corroborate the leftward bias, or *right pseudoneglect*, of neurotypical right-handers in the line bisection task (Bowers & Heilman, 1980). Consistent with many previous studies, leftward bias was greater for lines placed in the left or centre of the page than the right. The leftward bias also tended to be greater when participants used their left hand rather than their right hand (for review see Jewell & McCourt, 2000). As this typical leftward bias on line bisection is thought to reflect dominance of the right-hemisphere for visuospatial attention (e.g., Oliveri et al., 2004; de Schotten et al., 2011), it is possible that reduced *right pseudoneglect* in experienced-AVGPs may reflect reduced right-hemispheric dominance and potentially a correspondingly greater contribution of the left-hemisphere to a typically right-hemisphere dominant task. This hypothesis would need to be examined with neuroimaging paradigms as the behavioral differences between experienced-AVGPs and non-VGPs do not provide direct evidence for this and could be explained by other task and performance factors.

Due to the extensive perceptual demands of action video-game play experienced-AVGPs may possess a smaller 'zone of indifference' (see Olk et al., 2004; García-Pérez & Peli, 2014). The zone of indifference is the area about the physical midpoint whose points are subjectively judged as equally deserving of being the perceptual midpoint. A smaller zone of indifference would mean that fewer points would be deserving of being the perceptual midpoint, resulting in more accurate bisection judgments. Interestingly, this would suggest that the reduced directional bias shown by experienced-AVGPs would be present even when no task related action is required.

Success in action video-game play, however, is not solely due to perceptual accuracy, but also to the capacity to produce accurate, swift, and precisely timed bimanual motor movements in response to visual cues. Perceptual biases can be resisted by highly practised and automated actions (e.g., Gonzalez, Ganel, Whitwell, Morrissey, & Goodale, 2008). Due to extensive play by experienced-AVGPs, actions required to perform simple visuomotor tasks, such as the line bisection task, may be generalized from well developed actions developed during action video-game play (Granek, Gorbet, & Sergio, 2010). If visuomotor ability is important for the experienced-AVGPs reduced directional bias in line bisection performance then we would expect them to again show a directional bias when the experimental task is stripped of all its motor demands, such as in the landmark task. This, however, remains to be investigated. Future research is required to disentangle the influence of action video-game play on perceptual judgments and those perceptual judgments mediated by motor action.

A line bisection meta-analysis has shown one of the greatest modulating factors of bisection errors is direction of eye scan, with participants tending towards where the scan originated (Jewell & McCourt, 2000). Readers of languages that scan right-to-left when performing the line bisection show a slight rightward bias (e.g., Chokron & Imbert, 1993). Chokron (2002) proposed that while cerebral functional specializations are present, they can be ameliorated by well trained behaviors. Unless warranted by the in-game environment experienced-AVGPs should develop no direction preference in eye scanning. Behavioral biases resulting from a preference in eye scanning direction would be detrimental to performance and rapidly learned and used against you by opponents (e.g., Bergstrom et al., 2012). It may be possible that extensive-AVGPs may show no directional bias in the line bisection task as they have no, or a significantly reduced, eye scanning preference. Further consideration needs to be given to the important roles of eye movements, specifically scanning and fixation in action video-game play and the results shown by AVGPs.

While the line bisection task has no resemblance to action video-game play or computerized training environments, it is possible that the experienced-AVGPs may have nevertheless expected to and been motivated to outperform non-VGPs because of their targeted recruitment (Boot et al., 2011). It is also possible that individuals who possess more balanced and accurate performance in the line bisection task (potentially for the reasons discussed in this paper) are more likely to be experienced-AVGPs. While these are open possibilities, this cross-sectional study has achieved what Boot et al., (2011) described as a *necessary precondition* for gamer training studies, namely provided evidence that AVGPs perform more accurately and with less bias than non-VGPs on a non-computerized task of line bisection. This provides the basis for future training studies to test whether or not sustained training of novices on action video-games results in more balanced line bisection performance and behavioral performance in general.

Our findings show experienced-AVGPs display more balanced and accurate line bisection performance that generalizes beyond the context of video-game play and computerized-training environment. While a training study is required to demonstrate the causal role of action video-game play, our findings further corroborate the suggestion that experienced-AVGPs, like expert musicians, differ with respect to the general population in their perceptual and cognitive capabilities and potentially their organization.

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