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Playing video games does not make for better visual attention skills

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The current study aimed to replicate and extend the findings of Green and Bavelier (2003) which showed video game players (VGPs) to have superior temporal attention, spatial distribution of attention and enhanced attentional capacity compared to non-video game players (NVGPs). Sixty-five males aged 17 to 25 years completed an Attentional Blink task (temporal attention), a Useful Field of View task (spatial distribution of attention), an Inattentional Blindness task (attentional capacity) and a Repetition Blindness task (attentional processing ability). It was expected that VGPs due to their superior attentional skills would perform better on all tasks than the NVGPs. Results for all tasks replicated the standard effects. VGPs were found to perform better than NVGPs in the Attentional Blink task only at the shortest target interval. There were no other group differences for any task suggesting a limited role for video game playing in the modification of visual attention.

Video games have become an increasingly popular pastime in today's society (Green & Bavelier, 2003; Greenfield, 1994) and have progressed from a simple test of basic skill and ability, to a fully interactive experience in an environment that is visually and attentionally demanding (Blumberg, 1998; Green & Bavelier, 2006a). They require the player to simultaneously and rapidly process numerous items whilst attending to relevant objects and ignoring irrelevant information (Castel, Pratt & Drummond, 2005; Green & Bavelier, 2006a). There can be dire consequences for failing to process a target or allowing irrelevant information to interfere with this processing during game play. Conversely, there are significant rewards for accurately processing information (Green & Bavelier, 2006a). For example, failing to see an enemy appear can result in instant death of an onscreen character, whilst noticing the enemy amongst other distracting stimuli can lead to advancement in the game. Greenfield (1994) suggests that this goal-directed nature of video games, along with the instantaneous feedback they provide, can account for not only their popularity but also their power in stimulating a variety of cognitive skills.

Video game players (VGPs) relative to non-video game players (NVGPs), have been shown to have shorter response times (RTs) (Castel et al., 2005), improved visual-spatial skills (Greenfield, Brannon & Lohr, 1994; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994), including better spatial resolution of visual processing (Green & Bavelier, 2007), superior performance on divided attention tasks (Greenfield, DeWinstanley, Kilpatrick & Kaye, 1994), and increased attentional capacity and abilities (Castel et al., 2005; Green & Bavelier, 2003, 2006a, 2006b).

One of the earliest studies to demonstrate a link between video game playing and enhanced visual attention was conducted by Greenfield, DeWinstanley et al. (1994). VGPs and NVGPs were required to locate a flash (target) that could appear left or right of fixation or in both positions simultaneously on each trial. NVGPs' RTs were shorter for targets presented in the high probability location (80% of trials) and longer for targets presented in the low probability location (10% of trials) compared to the dual-target control condition (10% of trials). VGPs also showed a RT benefit for targets in the high probability location. However there was no difference in RTs for the dual-target and low probability target conditions, indicating superior visual attention skills in VGPs. In experiment 2, Greenfield, DeWinstanley et al. (1994) demonstrated this same visual attention advantage for a group of NVGPs trained on a video game compared to the control group, suggesting a link between video game playing and improved divided attention skills.

Recently Green and Bavelier (2003) showed that VGPs had greater visual attentional capacity, better spatial distribution of attention and superior temporal attentional abilities compared to NVGPs. They also implemented an experimental training design in which NVGPs were trained for ten hours on either an action game (i.e., one that involves simultaneously occurring events at different locations on the screen that the player must attend to), or a non-action game (i.e., one that requires focus on only one object at a time, but still challenges visuo-motor skills). Those who were trained on the action video game improved on all tasks compared to those trained on the non-action game (Green & Bavelier, 2003). This illustrates that action video games modify and enhance the capacity and spatial distribution of visual attention, and temporal processing ability.

VGPs have also been shown to have a superior resolution of visual attention compared to NVGPs in a visual crowding task (Green & Bavelier, 2007). Participants were required to indicate the orientation of the letter T and the degree of separation between the target and distractors was manipulated. VGPs were able to identify target orientation accurately at a closer target-distractor distance than the NVGPs. Further when NVGPs were trained on an action video game they improved more on the visual crowding task than the NVGPs trained on a non-action video game. In the Green and Bavelier (2003, 2007) studies the inclusion of the non-action game training control condition, demonstrates that attentional improvements are not simply due to superior visuo-motor coordination or test-retest improvements (Green & Bavelier, 2003). Hence it is clear that there is a causal relationship between video game playing and enhanced visual attention skills.

This study will examine differences between VGPs and NVGPs in temporal attentional abilities (Attentional Blink task) and spatial attention abilities (Useful Field of View task) with the aim to replicate Green and Bavelier's (2003) findings on these tasks. In addition this research will extend previous work in this area, by using an Inattentional Blindness task under manipulated perceptual load conditions and a Repetition Blindness task to examine differences between VGPs and NVGPs in attentional processing abilities.

Attentional Blink

The Attentional Blink (AB) (Raymond, Shapiro & Arnell, 1992) is a widely reproduced finding in the attention literature, and refers to the impaired processing of a second target (T2) if it is presented within a few hundred milliseconds after the first target (T1) in a rapid serial visual presentation (RSVP) stream of items (Arnell & Jolicoeur, 1999; Broadbent & Broadbent, 1987; Chun & Potter, 1995; Raymond et al., 1992; Shapiro, Arnell & Raymond, 1997). The AB effect is most pronounced for stimulus onset asynchronys (SOAs) of 200 to 500 ms, with little AB effect typically found for SOAs of 500 ms or more (Chun & Potter, 1995; Martens, Munneke, Smid & Johnson, 2006; Olivers, 2004). T2 detection at the 100 ms SOA relative to the 200 ms SOA usually remains high, which is known as Lag-1 sparing (Visser, Zuvic, Bischof & Di Lollo, 1999). Numerous studies have shown that the magnitude of the AB can vary amongst different populations. For example, a larger AB relative to matched control groups has been shown for elderly participants (Maciokas & Crognale, 2003), participants with ADHD (Li, Lin, Chang & Hung, 2004), or schizophrenia (Cheung, Chen, Chen, Woo & Yee, 2002) and for NVGPs relative to VGPs (Green & Bavelier, 2003).

The AB task used by Green and Bavelier (2003) required participants to task switch from identification (write down the T1 letter) to detection (was T2 "X" present after T1?). This task switching effect is most evident when both targets are temporally adjacent and decreases as the T1-T2 interval increases. It is proposed that performance at the 100 ms SOA (Lag 1) reflects processes associated with an amodal bottleneck, as opposed to the visual bottleneck that is operational at the 200 ms SOA (Chun & Potter, 1995; Green & Bavelier, 2003). As VGPs outperformed NVGPs at all SOAs within the AB task, Green and Bavelier (2003) concluded that VGPs had better task switching and temporal attention skills due to more efficient operations of their amodal and visual bottlenecks compared to NVGPs.

Many models have been proposed to account for the AB, including the Response-Competition Interference Model (Raymond et al., 1992), and the Short-term Consolidation Model (Arnell & Jolicoeur, 1999). However this study will focus on Chun and Potter's (1995) Two-Stage model, as it is one of the most widely accepted within the literature. According to this model in the first stage (Stage 1) all stimuli undergo preliminary processing with simple features and meaning being registered, but not sufficiently for identification. In the second stage (Stage 2), which has limited capacity, these basic representations are consolidated into more permanent representations that are sufficient for reporting. Due to this limited capacity, no items are processed beyond Stage 1 until preceding items have completed Stage 2 processing. Therefore, an AB occurs when T2 cannot undergo Stage 2 processing because that limited capacity stage is occupied by the processing of T1 and by the time attentional resources are free to process T2 this representation has been lost (Chun & Potter, 1995). At SOAs greater than 500 ms, the AB effect is substantially reduced because the second stage processing of T1 is generally completed, allowing identification of T2s presented after this time. When T2 is presented directly after T1 (e.g., 100 ms SOA) performance is unaffected as both targets are processed together into Stage 2, producing a Lag-1 sparing effect (Visser et al., 1999).

As video games require efficient search of the onscreen environment and the processing of several visual items in quick succession, this may enhance the player's ability to consolidate items more efficiently. This would enable VGPs to complete Stage 2 processing of T1 more efficiently than NVGPs, freeing resources for Stage 2 processing before the T2 representation has been lost, resulting in less of an AB. Thus it is predicted that VGPs will outperform NVGPs on the AB task.

Useful Field of View

The Useful Field of View (UFOV) is described as the total area of the visual field within which individuals can obtain useful information without moving their head or eyes (Ball, Beard, Roenker, Miller & Griggs, 1988). Targets are presented rapidly at varying degrees from the centre of the visual field (eccentricities) to provide a measure of this spatial distribution of attention. The size of the UFOV has been shown to be reduced for older compared to younger individuals (Ball et al., 1988; Myers, Ball, Kalina, Roth & Goode, 2000), and males have been shown to have better performance than females on tasks such as the UFOV (e.g., Terlecki & Newcombe, 2005; Voyer, Voyer & Bryden, 1995).

Some studies (Feng, Spence & Pratt, 2007; Green & Bavelier, 2003, 2006a) have examined the spatial distribution of attention for VGPs and NVGPs, using a UFOV where participants were required to locate targets amongst distractors at different eccentricities. The different eccentricities represent locations within the normal range of video game play (i.e. the training range; 10°), at the boundary of this range (20°), and outside of this training range (30°; Green & Bavelier, 2003, 2006a) and the ability to localise a peripheral target was expected to decrease with increasing eccentricity (Ball et al., 1988). Green and Bavelier (2003, 2006a) and Feng et al. (2007) demonstrated that VGPs detected more targets than NVGPs at all eccentricities in the UFOV task, indicating that VGPs' enhanced spatial distribution of attention was not limited to trained locations within the visual field. Additionally, Green and Bavelier (2003, 2006a) and Feng et al. (2007) showed that when NVGPs were trained on an action video game this resulted in better UFOV task performance than the group of NVGPs trained on a non-action video game, further demonstrating the link between video game playing and improved visual attention skills.

Green and Bavelier (2006a) investigated if the enhanced visuospatial attention observed in VGPs was limited to the visual periphery. They introduced a centre task condition into the UFOV paradigm where participants completed a centre-shape discrimination task (identifying which of two shapes appeared within the central fixation square) on each trial before completing the peripheral localisation task. VGPs exhibited better performance than NVGPs at all eccentricities, replicating other studies (Feng et al., 2007; Green & Bavelier, 2003). VGPs also displayed superior performance on the centre task itself, supporting the idea that VGPs have enhanced visuospatial attention throughout the visual field (Green & Bavelier, 2006a).

Additionally, the performance of the VGPs on the peripheral localisation task was not affected by inclusion of the centre task, suggesting that the combined load of the two tasks was still below their capacity for dual-task performance. In contrast, the impaired performance of the NVGPs on the target localisation task with the additional load of the centre task suggested a reduced capacity limit, or less attentional resources available to accurately complete both tasks (Green & Bavelier, 2006a). Based on this evidence of superior spatial attentional capacity it is expected that VGPs will show superior performance relative to NVGPs on the UFOV task.

Inattentional Blindness

Inattentional Blindness (IB) refers to the failure to detect the appearance of an unexpected, task-irrelevant object in the visual field, even if a person is looking directly at it (Koivisto, Hyönä & Revonsuo, 2004; Mack, 2003; Most et al., 2001). This effect has been observed in both laboratory conditions and real world scenarios (Koivisto et al., 2004; Mack, 2003; Simons & Chabris, 1999). For example, Simons and Chabris (1999) found that just over half of the participants in their study noticed either the woman holding the umbrella, or a person wearing a gorilla suit, walk directly across the centre of the screen, whilst they were engaged in a primary task of counting basketball passes between players, who were shown on screen at the same time. Simons and Chabris (1999) found that the level of IB depended on the difficulty of the primary task (total number of passes made) and also on the similarity of the unexpected event to the attended items. They also demonstrated that the unexpected object could still remain undetected even if it passed directly through the spatial extent of attentional focus.

Similar results have also been found for computer-based IB tasks (Koivisto et al., 2004; Most et al., 2001). Most et al. (2001) asked participants to count letters of a certain colour whilst ignoring others of a different colour, as they moved around a computer display. Five seconds into the critical trial, an unexpected cross moved horizontally across the centre of the screen passing behind the fixation point. It was found that an unexpected stimulus was more likely to be noticed if it was similar to the attended items and dissimilar from the ignored items. However across all conditions only 50% of observers noticed the unexpected object on the critical trials, even though it passed directly behind the point of fixation.

Memmert (2006) measured eye movements whilst subjects completed Simons and Chabris' (1999) basketball passes counting task. The results showed that IB occurred with sustained and highly salient events using both real-life and computer stimuli, and that simply 'seeing' the unexpected, task-irrelevant object was not enough to facilitate its report. Memmert (2006) extended this work examining expert-novice differences between basketball players and those with no experience at the sport. As expected more basketball experts noticed the unexpected stimulus than the novices even though both groups performed equally on the primary counting task. In the current study, expert-novice differences between VGPs and NVGPs will be examined using a computerised IB task under manipulated levels of perceptual load. This IB task was specifically selected to avoid using a task that would be like an action video game.

Perceptual load can be defined as the demands placed on visual processing capacity (Lavie, 1995), and can range from a low level of perceptual load (e.g., having to process one relevant stimulus), to high levels of perceptual load (e.g., having to process six or more stimuli; Forster & Lavie, 2007). According to the Perceptual Load Theory (Lavie, 1995), when a task involves a high level of perceptual load, attentional capacity is exhausted leaving no additional resources left to process irrelevant stimuli. Conversely, if a task involves low perceptual load, there is leftover attentional capacity to attend to the irrelevant stimuli (Lavie, 1995).

Cartwright-Finch and Lavie (2007) manipulated the level of perceptual load in a computer-based IB task by increasing the number of letters in a visual display (the primary task), during which an unexpected object flashed rapidly on the screen. Nearly 90% of participants noticed the unexpected object under conditions of low perceptual load, and only 50% under high load conditions verifying that perceptual load plays a role in determining the explicit awareness, and therefore report, of these unexpected stimuli in IB tasks (Cartwright-Finch & Lavie, 2007).

The IB task will be based on the design of Most et al.'s (2001) study and perceptual load will be manipulated by increasing the number of both the attended and ignored letters in the primary monitoring task. In light of the findings of Cartwright-Finch and Lavie (2007), it is proposed that there will be no difference between the groups in detecting the unexpected stimulus for the low load condition, as the level difficulty should be within the capacity limits for both groups. However, for the high load condition, VGPs are expected to detect more instances of the unexpected stimulus than NVGPs because they will have attentional resources in addition to those taken up in task-relevant processing. This expanded capacity for perceptual load could be due to the stimulus-rich, multi-cued nature of many games in which players have to be aware of the sudden appearance of unexpected objects (e.g., enemies).

Repetition Blindness

Repetition Blindness (RB) is the difficulty in detecting and reporting both occurrences of a repeated item in a RSVP stream (Buttle, Ball, Zhang & Raymond, 2005; Campbell, Fugelsang & Hernberg, 2002; Coltheart, Mondy & Coltheart, 2005; Kanwisher, 1987; Morris & Harris, 2004). RB has been shown for words, letters, colours, pictures and brand logos (Buttle et al., 2005; Campbell et al., 2002; Kanwisher, Driver & Machado, 1995) and it has been explained by numerous models. This study will adopt Kanwisher's (1987) Token-Individuation Hypothesis, as it has received wide empirical support (e.g., Morris & Harris, 2004; Park & Kanwisher, 1994).

The Type-Token approach (Kanwisher, 1987) postulates that in a RSVP stream, type codes (a representation from long term memory) are activated for all items but if an item is repeated, the second instance of the type code will not be token-individuated (tokenised) (the creation of a specific episodic memory token). This occurs because once a type has recently undergone token individuation it is temporarily unavailable for tokenisation for a period of time. Therefore the repeated instance of the item is not tokenised and is not able to be recalled from short-term memory for report. Thus, RB can be seen as a failure of token individuation.

No studies to date have examined RB in VGPs, however VGPs could be expected to show less of an RB effect compared to NVGPs due to their increased attentional capacity. For example as video games involve rapidly attending to identical stimuli, this may allow VGPs to become more efficient at tokenising second instances of repeated items. Both word and picture stimuli will be used in a RB task. If playing video games affects the tokenisation stage of the Token-Individuation model (Kanwisher, 1987), then VGPs should show a reduced RB effect for word and picture stimuli compared to NVGPs. If their superior performance is due to practice at rapidly attending to objects like those seen in video games, then VGPs should only show a reduced RB effect relative to the NVGPs for picture stimuli.

Method

Participants

The initial sample consisted of sixty-five male first year psychology students aged 17 to 25 years ($M = 20.55$, $SD = 2.40$), who participated in return for course credit. The age and gender of the sample were restricted to closely match that used by Green and Bavelier (2003). All participants reported normal or corrected-to-normal vision. Participants were classified into either the VGP or NVGP group as per the criteria used by Green and Bavelier (2003). VGPs played video games for a minimum of four one-hour sessions per week in the six months prior to the study, while NVGPs never or rarely played games in the previous six months. All VGPs reported playing various action video games (e.g., Halo) or a combination of action and strategy games (e.g., World of Warcraft). Four participants were excluded because they did not fit the inclusion criteria for either group. Thus the final sample comprised of 61 males (VGP: $N = 32$; NVGP: $N = 29$) aged between 17 and 25 years ($M = 20.56$, $SD = 2.41$).

VGPs spent significantly more hours per week playing video games ($M = 13.80$ hours, $SD = 10.37$) than NVGPs ($M = 0.21$ hours, $SD = 0.22$) [$t(59) = -7.05$, $p < 0.0005$, $d = 1.86$]. There was no difference between the groups in age [$t(59) = 1.27$, $p = 0.21$, $d = .33$] (VGPs: $M = 20.19$ years, $SD = 2.35$; NVGPs: $M = 20.97$ years, $SD = 2.44$), years of education [$t(59) = 0.11$, $p = 0.915$, $d = .03$] (VGPs: $M = 13.09$, $SD = 1.65$; NVGPs: $M = 13.14$, $SD = 1.55$), mean hours of non-video game computer usage per week [$t(59) = -1.78$, $p = 0.08$, $d = .46$] (VGPs: $M = 9.75$, $SD = 7.84$; NVGPs: $M = 6.67$, $SD = 5.25$), or average hours of sport or exercise undertaken per week[1], [$t(59) = 1.38$, $p = 0.172$, $d = .36$] (VGPs: $M = 4.95$, $SD = 3.52$; NVGPs: $M = 6.64$, $SD = 4.34$). Thus the groups were matched on all critical variables, and only differed on the number of hours per week spent playing video games.

Procedure and Apparatus

All participants undertook one testing session lasting up to two hours during which the four computer administered tasks were completed. At the start of the session, participants

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[1] Sporting skill has been shown to be linked with enhanced attentional abilities in a number of studies (e.g., Beilock, Wierenga & Carr, 2002; Turatto, Benso & Umiltà, 1999). Thus participants were asked to report their sporting history in order to control for any possible confounding variables in the samples that could influence attentional ability.

provided informed consent to take part in the study and completed a brief questionnaire outlining demographic information, video game playing experience, other computer use and sporting history. The self-report questions relating to video game playing experience asked participants "How many times per week would you have played video/computer games or arcade games over the last six months?", "On average how long did each of these video/computer game or arcade game sessions last?", and "Please list the games that you typically play - name and type". At the beginning of each task participants were given verbal instructions with accompanying demonstration figures, and were also asked to read instructions presented on the computer screen. Task order was counterbalanced across participants to minimise order effects throughout the study. The UFOV, AB and RB tasks were run on a Pentium IV 2.66GHz PC with a Dell Ultra flat CRT monitor using the DMDX program (Forster & Forster, 2003). The IB task was run on the same computer using Java version 7.0.

Tasks

Attentional Blink. Each trial commenced with a central fixation '+' presented for 180 ms, followed by a rapid stream of letters presented for 15 ms each with a blank interstimulus interval (ISI) of 85 ms. Participants were instructed to record on a response sheet the identity of the white target letter (T1) in the RSVP stream, then indicate if an 'X' (T2) was present or absent in the stream after the white target letter. All letters in the stream were shown in black font except for T1. At the end of each trial, participants were prompted to recall their answers then press spacebar to start the next trial. The 'X' (T2) was present of 50% of the trials and occurred equally at all SOAs of 100 to 500 ms. (Ten trials at each T1-T2 SOA). Responses were scored as correct if T1 was correctly identified and T2 was correctly detected as present. The 'X' absent trials and the total number of T1 correct were also scored for each participant. Participants completed 20 practice trials followed by one block of 100 trials presented in random order for each participant.

Useful Field of View. The trial structure consisted of a central fixation square (4° x 4°) presented for 100 ms, followed by an array of 8 spokes made up of small white squares (4° x 4°) forming a circular wheel. On each trial, the target stimulus (a filled triangle within a 3° x 3° circle outline) appeared on one of the 8 spokes at one of three possible eccentricities (10°, 20° or 30° from the centre of the visual field), creating 24 possible locations at which the target could appear. The target appeared for 6 ms at 10°, or for 12 ms at 20° or 30°. The difference in target presentation times was to allow for the increased difficulty of detecting the target at 20° or 30° as opposed to at 10° (Green & Bavelier, 2003). A mask screen (random coloured patterns) then appeared for 200 ms, followed by a response screen displaying 8 intersecting lines in the form of the wheel. For each trial, participant accuracy and RT from the onset of the stimulus-target array, were recorded by the DMDX program (Forster & Forster, 2003).

Participants were seated 30 cm from the screen and were instructed to locate and identify where the circle with the triangle inside it (i.e. the target) appeared in the display. The target could appear on any one of 8 spokes, which were labelled 1 to 8 around the perimeter of the computer screen. Participants were required to respond by pressing the corresponding number on the key board number pad. There were 20 practice followed by 240 randomly presented experimental trials, 10 at each of the 24 target locations.

Inattentional Blindness. The IB task was based on that used by Most et al. (2001). Participants were required to silently count the number of times either black or white letters ('L' and 'T') touched the sides of a grey 12.7 x 15.5 cm display window whilst fixating on a small blue square in the centre. The 1° x 1° block letters moved randomly and independently of one another at variable rates ranging from 2 to 5 cm/sec and "bounced" off the sides of the display window. The letters could also occlude each other as they moved along their paths.

There were two versions of the task, one with 4 letters in the display (low load condition), and the other with 8 letters in the display (high load condition). There were equal numbers of black and white letters in both conditions. The VGPs and NVGPs were randomly and equally assigned to one of the two load conditions, then within those two load conditions both groups were halved again so that half were instructed to attend to white letters and half attended to black letters. Thus there were four conditions in the IB task; attend black letters low-load, attend black letters high-load, attend white letters low-load and attend white letters high-load.

Participants completed five trials lasting 15 seconds each. On first two trials, participants silently counted the number of times the letters (of the colour they were told to attend to) hit the sides of the display window, and were then asked by the experimenter how many times the relevant letters touched the sides of the screen. In the third critical trial, an unexpected object (a cross of the opposite colour to the attended letters) appeared on the screen for 5 seconds. The cross (1° x 1°) entered from the right side of the display and moved horizontally on a linear path behind the fixation point and exited on the left side of the display window. Participants were again asked how many times the attended letters touched the sides of the display. They were also asked "Did you detect anything new that was not present on the previous trials; if you did what did you detect?" If participants answered "yes" to detecting something new and could either identify the object, identify where it occurred, its path of motion or pick it from among four other shapes, they were regarded as having detected the unexpected stimulus. The fourth trial followed the same procedure as the third, although as participants had been alerted to the possible presence of an unexpected stimulus, this was deemed a divided attention trial. On the final fifth trial, participants were instructed not to count the attended letters but to simply keep fixated on the fixation point and watch the display. They were then asked the same questions about the unexpected object. As they were not required to count, full attention should have been devoted to the previously unexpected object. Therefore this full-attention trial served as a control to ensure participants had understood and followed instructions.

Repetition Blindness. The stimuli for this task were 120 line drawings of objects taken from a picture database (Szekely et al., 2004) and names of the same objects which were divided into four groups of 30, that were matched for number of letters and syllables, familiarity, concreteness and imagability ratings, Kucera-Francis written frequency, and complexity (Szekely et al., 2004). The four sets of items were cycled through the different positions of the stimuli to create four different versions of the task, so that each set were the critical items in one version and the different positions of filler items in the other three versions.

Each trial commenced with a central fixation '+' for 500 ms, followed by nine 100 ms displays presented successively with no ISI. The first three displays were pattern masks, followed by the first word/object drawing (critical item C1), a filler item, the second critical item (C2), and then three pattern masks. In the repeat trials, C1 and C2 were of the same word/object, and in the no-repeat condition they were different words/objects. For the no-repeat trials, the critical item appeared equally in the first or the third position to ensure that there was no effect of stimulus position.

Participants completed blocked trials for both word and picture stimuli, and the version of the task and the order in which they completed the task (i.e., words first or pictures first) were counterbalanced across participants. There were 8 practice trials and 60 experimental trials for both word and picture tasks, with 30 repeat and 30 no-repeat trials displayed in a random order within each block. Participants were required to write down the three words or picture names in the order that they appeared at the end of each trial. Responses were marked as correct if, for the repeat trials both C1 and C2 were correct, and in the no-repeat trials if the critical item was correct (Buttle et al., 2005).

Results

Attentional Blink Task

Independent-groups t-tests were used to examine group differences on the total number of correct T2 responses for the X absent trials, and the total number of T1 correct for all 100 trials. No difference between the groups on these measures would ensure that any group differences in T2 detection rates (X present trials) were not due to a poor ability to correctly identify T1, or by simply marking T2 as always present resulting in a high score on T2 present trials by default. The data from one participant from the NVGP group was excluded from the analyses due to near chance level performance for total correct T2 absent trials, suggesting that this participant was indicating “X present” on most trials.

There was no difference between VGPs (M = 84.81%, SD = 9.56) and NVGPs (M = 82.64%, SD = 8.43) for the percentage correct T2 detection on the X absent trials [$t(58) = -0.926$, $p = 0.358$, $d = .25$]. There was also no difference between the groups for the percentage of T1 correctly identified [$t(58) = -0.311$, $p = 0.742$, $d = .09$] (VGPs: M = 95.97%, SD = 3.28, NVGPs: M = 95.71%, SD =2.58). Thus any group differences found for the T2 (X) present trials (AB) cannot be attributed to T1 or T2 (X) absent trial performance differences between the groups.

A 2 (group: VGP and NVGP) x 5 (SOA: 100, 200, 300, 400 and 500 ms) mixed factorial ANOVA was conducted for the percentage correct T2 detections (X present trials). Where appropriate the Huynh-Feldt correction was applied to correct for violation of sphericity. The main effect of group was not significant [$F(1, 58) = 0.706$, $p = 0.404$, $\eta_p^2 = 0.012$]. There was an effect of SOA [$F(3.36, 194.99) = 20.15$, $p < 0.0005$, $\eta_p^2 = 0.26$] and there was an interaction between group and SOA [$F(3.36, 194.99) = 3.40$, $p = 0.015$, $\eta_p^2 = 0.06$]. Group comparisons at each SOA showed that VGPs had higher T2 detection rates than NVGPs only at the 100 ms SOA [$t(58) = -2.19$, $p = 0.032$] [SOA 200 ms: $t(58) = -1.32$, $p = 0.192$; 300 ms: $t(58) = -0.565$, $p = 0.574$; 400 ms: $t(58) = 0.62$, $p = 0.533$; 500 ms: $t(58) = 0.68$, $p = 0.497$]. Refer to Figure 1.

An independent groups t-test was conducted to examine group differences in the Lag-1 sparing effect (e.g., a decrease of more than 5% in T2 detection accuracy from the 100 to 200 ms SOA, Visser et al., 1999). Although the VGP group (M = 13.13%, SD = 25.58) showed a larger Lag-1 sparing effect than the NVGP group (M = 8.21%, SD = 19.06) this difference was not significant [$t(58) = -0.833$, $p = 0.408$, $d = .23$].

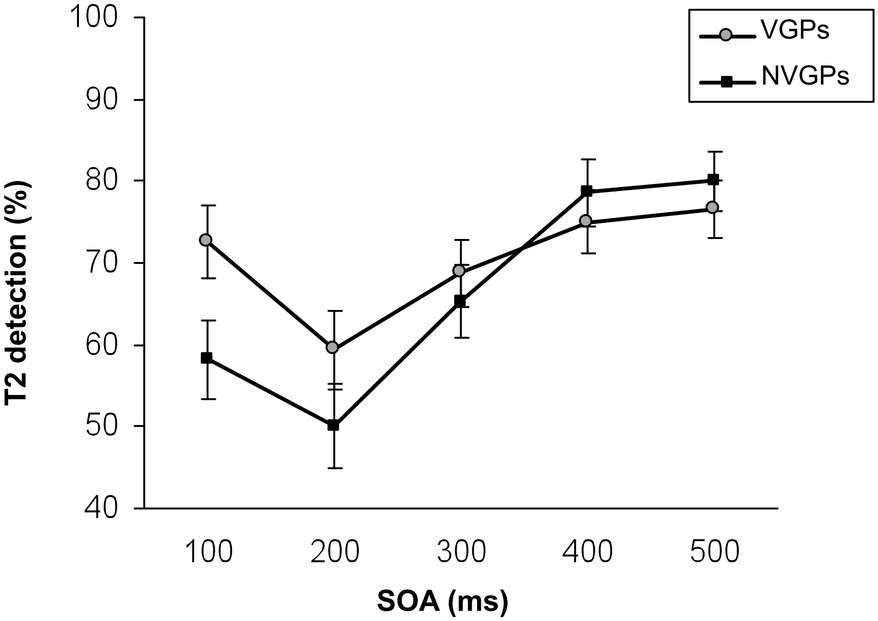

Figure 1. *Mean T2 detection rates for VGPs and NVGPs for all SOAs of the AB task. Note: Error bars represent one standard error.*

Useful Field of View Task

The data from two VGPs were removed from the analyses due to significant errors (> 90%) and aberrant RTs, indicating a failure to follow task instructions. A 2 (group: VGP and NVGP) x 3 (eccentricity: 10°, 20° and 30°) mixed factorial ANOVA was conducted for the DV of target detection accuracy (%). Sphericity was violated, thus Huynh-Feldt correction was applied to all analyses where appropriate.

A significant main effect of eccentricity was found [$F(1.29, 73.78) = 162.52$, $p < 0.0005$, $\eta_p^2 = 0.74$]. Contrasts showed that target detection rates were significantly higher at 10° ($M = 81.45\%$, $SD = 16.37$) than at 20° ($M = 75.54\%$, $SD = 16.65$) [$t(57) = 5.88$, $p < 0.0005$], and higher at 20° than at 30° ($M = 50.79\%$, $SD = 18.63$) [$t(57) = 13.40$, $p < 0.0005$].

The main effect of group was not significant [$F(1, 57) = 0.262$, $p = 0.611$, $\eta_p^2 = 0.005$], nor was the interaction between group and degrees of eccentricity [$F(1.29, 73.78) = 0.064$, $p = 0.862$, $\eta_p^2 = 0.001$]. Refer to Table 1. It is possible that while groups did not differ on the percentage of target detections, there may have been a difference in their RTs. For example, although asked to respond as accurately as possible, it may be that VGPs are able to do this earlier than the NVGPs, which would be evident in the RT data.

A 2 (group) x 3 (eccentricity) mixed factorial ANOVA was conducted for the DV of RT. A MANOVA could not be conducted for the RT and accuracy data as there was no linear relationship between these DVs. Also, it is common practice to investigate these DVs separately in the field of cognitive psychology (Dyckman & McDowell, 2005).

		Accuracy Data		**Response Times**	
Group	Eccentricity	Mean	*SD*	Mean	*SD*
VGPs	10°	82.35	17.63	1278	229
	20°	76.36	16.64	1205	214
n = 30	30°	52.18	19.27	1221	206
NVGPs	10°	80.62	15.22	1417	351
	20°	74.72	16.91	1359	317
n = 29	30°	49.39	18.17	1371	334

Table 1. *Mean percent correct target detection, standard deviations (SD) and mean response time (ms), standard deviations (SD) for the group by eccentricity interaction for the UFOV task.*

Overall VGPs ($M = 1235$ ms, $SD = 274$) had shorter RTs than the NVGPs ($M = 1382$ ms, $SD = 274$) [$F(1, 57) = 4.28$, $p = 0.043$, $\eta_p^2 = 0.07$]. The interaction between eccentricity and group was not significant [$F(2, 114) = 0.163$, $p = 0.850$, $\eta_p^2 = 0.003$]. Refer to Table 1. There was an effect of eccentricity [$F(2, 114) = 12.36$, $p < 0.0005$, $\eta_p^2 = 0.18$], with longer RTs for targets at 10° ($M = 1348$ ms, $SD = 301$) than for the 20° ($M = 1282$ ms, $SD = 278$) [$t(57) = 5.38$, $p < 0.0005$], or 30° ($M = 1296$ ms, $SD = 284$) [$t(57) = 3.38$, $p = 0.001$]. There was no difference in RTs at 20° and 30° [$t(57) = 0.99$, $p = 0.328$]. As the longer RTs at the 10° target eccentricity were associated with the least errors this might suggest a speed-accuracy trade off. To investigate this z-scores were calculated for each condition for both RT and accuracy data. A combined z-score (z-RT + z-accuracy) for each degree of target eccentricity was then used as the DV in a 2 (group) x 3 (eccentricity) mixed factorial ANOVA. There was no effect of group [$F(1, 57) < .001$, $p = 0.98$, $\eta_p^2 < .001$], or eccentricity [$F(2, 114) < .001$, $p = 1.00$, $\eta_p^2 < .001$], and the interaction between group and degrees was not significant [$F(2, 114) = .103$, $p = .902$, $\eta_p^2 = 0.002$], indicating that the differences in the RT and accuracy data were due to a speed-accuracy trade off.

Inattentional Blindness Task

Errors in the letter counting task were calculated for each participant by taking the absolute value of the difference between each count and the actual number of letter bounces on that trial, then dividing that difference by the number of actual bounces on that trial (Most et al., 2001). This produced a mean percentage error relative to the number of actual bounces, and provided a control measure to determine if participants were completing the primary letter counting task correctly. The fifth full-attention trial also served as a control to ensure instructions were being followed correctly. All participants detected the unexpected stimulus on the full-attention trial, so no participant data needed to be excluded from this task.

A 2 (group: VGP and NVGP) x 2 (load-condition: 2 and 4 letters) between-subjects ANOVA was run on the mean percentage errors averaged across the first four trials of the

IB task (participants were not required to count on the fifth trial).[2] The mean percentage of errors was larger in the high-load condition (*M* = 12.39%, *SD* = 6.71) than in the low-load condition (*M* = 3.90%, *SD* = 4.12) [$F(1, 57) = 35.04$, $p < 0.0005$, $\eta_p^2 = 0.381$], indicating that the primary counting task was harder for the high-load than for the low-load condition. There was no difference in mean errors between the VGPs (*M* = 7.61%, *SD* = 8.15) and NVGPs (*M* = 8.58%, *SD* = 5.47) [$F(1, 57) = .580$, $p = 0.449$, $\eta_p^2 = 0.010$], and group and load-condition did not interact [$F(1, 57) = 1.37$, $p = 0.247$, $\eta_p^2 = 0.023$], indicating that any group difference in detection of the unexpected cross was not due to differences in performance on the letter counting task.

Errors in the primary counting task for those who detected the unexpected cross and those who did not, for both the critical (trial 3) and divided attention (trial 4) trials, were compared to ensure that any differences in the ability to detect the unexpected cross were not due to differences in performance on the primary letter counting task. On the critical trial, mean errors did not differ between participants who detected the unexpected cross (M = 7.25%, SD = 10.49), and those who did not (*M* = 9.62%, *SD* = 10.77) [$t(59) = .762$, $p = 0.449$, $d = .20$]. The same result was found for the divided attention trial [$t(59) = .100$, $p = 0.921$, $d = .03$], with no significant difference in mean errors for those who detected the unexpected cross (*M* = 8.52%, *SD* = 10.97), and those who did not (*M* = 8.93%, *SD* = 9.49). Thus, differences in the ability to perform the primary task could not account for any differences in the rate of noticing the unexpected cross.

Chi-square analyses were used to examine the number of participants who detected the unexpected cross (or failed to notice it) under the low and high load-conditions. Participants detected more instances of the unexpected cross in the low compared to the high load-condition on the critical trial [χ^2 (1, $N = 61$) = 8.036, $p = 0.005$], and the divided attention trial [χ^2 (1, $N = 61$) = 5.41, $p = 0.020$]. Refer to Table 2. Therefore, when the primary letter counting task involved a high perceptual load, participants detected fewer instances of the unexpected cross.

Chi-square analyses were conducted separately for the critical trial and divided

Load Condition	**Critical Trial**		**Divided Attention Trial**	
	Detected	Not Detected	Detected	Not Detected
Low-load	13	18	30	1
High-load	3	27	23	7

Table 2. *Number of participants who correctly detected or did not detect the unexpected stimuli in the critical and divided-attention trials for the two load conditions for the IB task.*

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[2] A 2 (group: VGP and NVGP) x 2 (load-condition: 2 and 4 letters) between-subjects ANOVA was run for the mean percentage errors for each of the first four trials separately. There were no significant main effects of group or load-condition. The interactions between group and load condition were all non-significant.

attention trial on the number of VGPs and NVGPs who detected the unexpected cross in the low-load and high-load conditions. There was no relationship between group and load condition on the critical trial [χ^2 (1, N = 61) = 0.007, p = 0.931], or in the divided-attention trial [χ^2 (1, N = 61) = 0.053, p = 0.817], indicating that for each load condition the same number of VGPs and NVGPs detected the unexpected cross. Refer to Table 3.

Group	Load Condition	Critical Trial	Divided Attention Trial
VGPs	Low-load	9	16
n = 32	High-load	2	13
NVGPs	Low-load	4	14
n = 29	High-load	1	10

Table 3. *Number of participants who correctly detected the unexpected stimuli in the critical and divided-attention trials, by group and load condition for the IB task.*

Repetition Blindness Task

The data of one participant from each group, were excluded from the analyses for failure to follow task instructions. A 2 (group: VGP and NVGP) x 2 (stimulus type: words and pictures) x 2 (condition: repeat and no-repeat) mixed factorial ANOVA was run for the percentage of correctly identified stimuli. Correct responses were based on correctly reporting both critical stimuli on the repeat trials and correctly reporting the single critical stimulus on the no-repeat trials (see Buttle et al., 2005).

There was a main effect of stimulus type, with participants correctly identifying more word stimuli (M = 84.77%, SD = 16.89) than picture stimuli (M = 74.91%, SD = 15.20) [F(1, 57) = 36.94, p < 0.0005, η_p^2 = 0.38]. Participants correctly identified more stimuli in the no-repeat (M = 86.04%, SD = 10.60) than repeat condition (M = 73.63%, SD = 22.20) [F(1, 57) = 28.68, p < 0.0005, η_p^2 = 0.34] and the interaction between condition and stimulus type revealed that the RB effect was larger for words than pictures [F(1, 57) = 5.58, p = 0.022, η_p^2 = 0.089]. Refer to Table 4.

There was no main effect of group [F(1, 57) = 0.266, p = 0.608, η_p^2 = 0.005], and no interaction between group and repeat condition [F(1, 57) < .001, p = 0.968, η_p^2 < .001], or group by stimulus type interaction [F(1, 57) = .289, p = 0.593, η_p^2 = 0.005], or group by stimulus type by condition interaction [F(1, 57) = 0.036, p = 0.851, η_p^2 = 0.001]. Descriptive statistics for the non-significant three-way interaction are presented in Table 5.

	Word Condition		**Picture Condition**	
Condition	Mean	*SD*	Mean	*SD*
No Repeat	92.68	9.44	79.94	20.43
Repeat	77.33	25.19	71.06	12.14

Table 4. *Mean correct stimuli identification (%), and standard deviations (SD) for the repeat condition by stimulus type interaction for the RB task.*

		Word Condition		**Picture Condition**	
Group	Repeat Condition	Mean	*SD*	Mean	*SD*
VGPs	No Repeat	93.33	8.94	81.18	13.60
n = 31	Repeat	77.63	26.40	72.47	19.89
NVGPs	No Repeat	92.02	9.91	78.69	10.16
n = 28	Repeat	77.02	23.76	69.64	20.90

Table 5. *Mean correct stimuli identification (%), and standard deviations (SD) for the repeat condition by group by stimulus type interaction for the RB task.*

Discussion

In 2003, Green and Bavelier demonstrated that VGPs outperformed NVGPs on measures of temporal attention (AB task), and the spatial distribution of attention (UFOV task). This study aimed to replicate and extend these findings by examining VGP and NVGP performance with regards to attentional capacity (IB task), and attentional processing ability (RB task).

Attentional Blink Task

Both groups showed the standard AB effect where performance for T2 detection is impaired when it follows T1 by 200 to 500 ms (Arnell & Jolicoeur, 1999; Chun & Potter, 1995; Martens et al., 2006; Olivers, 2004; Raymond et al., 1992; Shapiro et al., 1997). There was also evidence of a Lag-1 sparing effect for both groups (Visser et al., 1999). While the finding that VGPs outperformed NVGPs at the 100 ms SOA is consistent with Green and Bavelier (2003) this difference was not evident at all SOAs as it was in their study. Performance at the 100 ms SOA in this AB task is said to reflect task-switching ability and an amodal bottleneck. Where as performance at the 200 ms SOA (i.e., the point at which the AB is maximal) reflects the ability to process information over time and is recognised as representing a visual bottleneck (Arnell & Jolicoeur, 1999; Chun & Potter, 1995; Green & Bavelier, 2003). Thus in this study playing video games reduced the impact of the amodal attentional bottleneck but not the visual attentional bottleneck. Further the finding of superior task-switching ability in VGPs is consistent with Andrews and Murphy (2006) who showed that VGPs outperformed NVGPs on an alternate runs task switching paradigm.

Given that the AB task used in this study was based on that reported by Green and Bavelier (2003) and the sample size was much larger than their eight participants per group it is unclear why the group differences were not evident at all SOAs. One possible reason could lie in the comparability of abilities of the VGPs and NVGPs across the studies. When comparing the scores on the AB task across studies it becomes apparent that whilst the scores of the VGPs were at a similar level, performance of the NVGPs in this study was particularly good in comparison to the same group in their study. This may suggest that the NVGPs in Green and Bavelier's (2003) study found the AB task particularly difficult.

Useful Field of View Task

The fewer errors made by the VGPs compared to the NVGPs overall in the UFOV task, appeared to be the result of a speed-accuracy trade-off even though participants were asked to respond as accurately as they could on each trial. Therefore, VGPs did not show a better spatial distribution of attention than NVGPs. These results are inconsistent with Green and Bavelier (2003, 2006a) and Feng et al. (2007), who found that VGPs detected more targets than NVGPs at all eccentricities. Comparing the data across experiments did not reveal sub-standard performance by the VGPs in this study relative to previous research and a larger sample of participants completed this task compared to that used by Green and Bavelier (2003). Moreover, the NVGPs in this study performed better on the UFOV task than those in Green and Bavelier's (2003) study, providing further evidence that the NVGPs in their study found task performance difficult. Further, although Feng et al. (2007) reported superior overall UFOV task performance for VGPs relative to NVGPs, it is possible that the inclusion of male and female participants in their study and only male participants in the current study may account for the different outcomes. In Feng et al.'s (2007) study female NVGPs tended to perform more poorly on the UFOV task than male NVGPs potentially magnifying the overall group difference in UFOV task performance. Hence the inclusion of only male participants in the current study may have minimised the potential difference between VGPs and NVGPs on the UFOV task.

Inattentional Blindness Task

Both the IB task load manipulation and the actual IB task itself replicated previous findings in this area (Cartwright-Finch & Lavie, 2007; Lavie, Hirst, de Fockert, & Viding, 2004; Most et al., 2001). However there was no support for the assumption that VGPs would detect more instances of the unexpected object in the critical and divided attention trials of the IB task under high load conditions, due to their increased attentional capacity in comparison to NVGPs. While this might mean VGPs do not possess enhanced attentional capacity, given the results of the AB and UFOV tasks it is possible that the failure to find a group difference on this task was due to the 'differences' in attentional capacity for the NVGP in this study compared to those in Green and Bavelier's study (2003).

Repetition Blindness Task

Results for the RB task were consistent with previous research in that participants correctly identified more word than picture stimuli (Buttle et al., 2005). There was also a typical RB effect with participants correctly identifying more stimuli in the no-repeat than repeat condition (Campbell et al., 2002; Coltheart et al., 2005; Morris & Harris, 2004). The size of the RB effect was larger for words than for pictures, which is inconsistent with previous findings (Buttle, et al. 2005) and requires further investigation. Contrary to expectation there was no difference between the VGPs and NVGPs in this task. Thus according to the Token-Individuation Hypothesis (Kanwisher, 1987), VGPs were not more efficient at tokenizing second instances of repeated items (type codes), and thus reducing the size of their RB effect. However, as mentioned previously this lack of group difference might be attributed to the attentional capacity of the NVGP group in this study.

Further Considerations and Conclusion

The sample size used in this study was larger than that reported by Green and Bavelier (2003) and across the two studies participants were comparable in age, gender and mean hours of video game playing. Moreover, the AB and UFOV tasks were based on those reported by Green and Bavelier (2003). Thus it is unlikely that sample or task differences can account for the non-significant video-game player group differences in the current study. One issue requiring consideration is that Green and Bavelier (2003) reported that their participants only played action video games, whereas in the current study participants either only played action video games or a combination of action and strategy video games. It has been reported that different types of video games develop different attentional skills, and even within the category of action video games specific games can affect these skills differently (Greenfield, 1994). However, data from a number of our own studies have shown that most gamers play a variety of game types making it very difficult to find VGPs who only play action video games or a single action game for a specified time period.

Further, studies demonstrating better task performance for VGPs relative to NVGPs on visual search and inhibition of return (Castel et al., 2005), and divided attention conditions (Greenfield, DeWinstanley et al., 1994, Experiment 1) have tended to use RT as the primary dependent variable. Hence there is evidence to suggest that VGPs show superior attentional processing skills compared to NVGPs when the task assesses RT. As all tasks within this study used accuracy as the primary dependent variable, except for the UFOV task which had RT as a secondary measure, it is possible that group differences may have emerged if the tasks used had allowed measurement of RT in addition to accuracy.

Thus, despite adequate sample size and the use of tasks closely matching that of Green and Bavelier (2003), the current study was unable to replicate their findings making it unlikely that group differences would be found on other visual attention tasks. While this could be due to differences in performance levels for the NVGPs or differences in the types of video games played by the VGP groups across the two studies, further research examining these ideas is needed before we are able to fully understand the impact of video game playing on visual attention.

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