The effects of video gaming on visual selective attention

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Abstract
A growing body of research shows that video games may be used to enhance cognitive skills, with particular reference to attentional abilities. This research study explored the effects of video game playing on visual selective attention in a young adult sample. A secondary research objective explored the possibility that gender acted as a moderating variable with regard to their visual selective attention. This was achieved by means of a quantitative research design, which consisted of a survey research and a quasi-experimental research design. Participants were sampled using purposive sampling ($n = 80$), and to test the effects of video game playing and gender on visual selective attention, participants were exposed to a computerised version of the Stroop task. Data were analysed using a two-way between-group analysis of variance (ANOVA) and results indicated a statistically significant difference in visual selective attention abilities between video game players and the non-players. Video gamers thus exhibited more advanced attentional skills than non-players. There were no interaction effects between video game playing and gender, and gender did not have a statistically significant main effect on participants' visual selective attention.

Keywords
Early adulthood, gender, Stroop task, theory of visual attention, video games, visual selective attention

Video game playing, as a recreational and educational activity, has become more prevalent among children and adults in both developed (Ito et al., 2008; Lenhart et al., 2008; Puri & Pugliese, 2012) and developing economies (PricewaterhouseCoopers [PwC], 2017) due to improved access to technology and the Internet. Within the multicultural context of South Africa, video gaming has also become increasingly more popular among various racial and gender groups (Hall, Watson, & Kitching, 2017). Video gaming is a form of electronic entertainment played on personal computers, console devices (Tavinor, 2008), or devices such as cell phones and tablets (Hall et al., 2017). There are various genres of video games ranging from fast-paced action video games (AVGs) including first-person shooter games (Claypool, Claypool, & Damaa, 2006) to multiplayer online role-playing games (Hsu, Wen, & Wu, 2009) and non-violent video games like puzzle games (Bushman & Anderson, 2002) and strategy video games (Rollings & Adams, 2003).

The rising popularity of video games has driven research in many fields of psychology, including social, developmental, cognitive, and behavioural psychology (King, Haagsma, Delfabbro, Gradisar, & Griffiths, 2013; Sim, Gentile, Bricolo, Serpollini, & Gulamoydeen, 2012; Weinstein & Lejoyeux, 2010). Extensive research has been done to explore the relation between video games and different cognitive abilities including attention, memory, and processing speed (Blacker & Curby, 2013; Cain, Landau, & Shimamura, 2012; Chisholm & Kingstone, 2012; Colzato, van den Wildernber, Zmigrod, & Hommel, 2013; Mack, Wiesmann, & Ilg, 2016; McCarley & Mounts, 2017; Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013; Qiu et al., 2018; Unsworth et al., 2015; Wang et al., 2016).

Generally, research has focussed on the negative outcomes of video gaming. Pawlikowski and Brand (2011), for example, argued that video games often result in people neglecting their work and social responsibilities, while Sherry (2001) emphasised aggressive tendencies among AVG players. Video gaming can, however, also elicit positive effects on cognitive abilities. Video game players (VGPs) outperformed non-gamers on tests of attention control, visuospatial abilities, working memory, and executive functions (Blacker & Curby, 2013; Cain et al., 2012; McCarley & Mounts, 2017; Qiu et al., 2018; Unsworth et al., 2015). VGPs also show faster and more accurate decision-making (Dye & Bavelier, 2010; Dye, Green, & Bavelier, 2009), improved reading abilities (Franceschini et al., 2013), enhanced learning through creativity and visualisation (Amory, Naicker, Vincent, & Adams, 1999), and improved attentional abilities, with particular reference to visual selective attention (VSA; Bavelier, Achtman, Mani, & Föcker, 2012; Mack et al., 2016). Qiu et al. (2018) reported a link between AVGs and cognitive and neural plasticity, while Russoniello, O'Brien, and Parks (2009) claimed that video games can contribute to players' positive emotional experiences. Wang et al. (2016) found that AVG training had a positive effect on both overall and specific cognitive domains in young and older adults. Franceschini et al. (2013) and Watson, Mong, and Harris (2011) highlighted the beneficial use of video games as an educational tool that can be used to improve problem-solving abilities and reading skills. More specifically, Franceschini et al. (2013) found improved reading abilities in children with dyslexia after 12 hr of AVG playing.

Video games, especially AVG, are cognitively demanding tasks that require attention to be directed towards significant information necessary for task performance (Qiu et al., 2018; Schubert et al., 2015). The VSA process involves filtering incoming sensory information by selecting to process important stimuli while ignoring less relevant information (McCarley & Mounts, 2017). To prevent the brain from overload, VSA is necessary to control the processing of incoming visual information. VSA allows significant information access to perceptual awareness needed to guide behaviour (Chelazzi, Perlato, Santandrea, & Libera, 2013), as not all visual inputs reach conscious awareness (Bundesen, Vangkilde, & Petersen, 2015).

Although some studies have revealed that individuals who play video games display superior VSA compared with those who do not (Franceschini et al., 2013; Granic, Lobel, & Engels, 2014; Qiu et al., 2018; Unsworth et al., 2015), other research failed to reproduce these findings (Murphy & Spencer, 2009; Wilms, Petersen, & Vangklide, 2013). There is thus still inconsistent evidence regarding the consequence of playing video games and a lack of consensus among researchers with regards to the value of video games and how it impacts various cognitive abilities (Mack et al., 2016). Several confounds may explain the varied results, including methodological differences, incomparable experimental paradigms, theoretical frameworks, and statistical problems (Schubert et al., 2015; Unsworth et al., 2015). This makes it difficult to identify the actual mechanisms involved across the different studies. Powers et al. (2013), for example, highlighted that small samples were often used thereby resulting in small effect sizes. It was also argued that some studies used extreme groups with regards to defining criteria for gamers and non-gamers (Unsworth et al., 2015). There is also inconsistency about the impact of gender and age in relation to video game playing. Mezzacappa (2004), for example, found that male and female VGPs differ with regards to their attentional abilities, whereas Dye et al. (2009) found no meaningful relations between video game playing and gender. Many research studies examining the impact of video gaming tend to include only an adolescent sample, failing to account for the potential effect on older participants (Brawer & Buckwalter, 2015; Franceschini et al., 2013).

Given the aforementioned, this study examined the effects of video game playing on VSA in a sample of early adults including both male and female gamers and non-gamers. King, Delfabbro, and Griffiths (2013) emphasised the research gap with regards to gender and age and the continuous debate that exists regarding the impact video gaming has on the player, generally due to different methodological approaches and varying sample sizes. Following this, the current investigation can make a valuable contribution regarding the impact of video gaming on cognition (Ferguson & Cerangoglu, 2014; Keser & Esgi, 2012) helping to understand how attentional processes are influenced by gaming habits (Ferguson & Olson, 2013).

Methods

A quantitative approach consisting of a survey research and a quasi-experimental research design, specifically a post test-only design with non-equivalent groups, was used. The survey encompassed a screening measure to categorise participants as either gamers or non-gamers. The experimental group constituted the video gamers, while the non-gamers comprised the control group.

Participants

University students registered for psychology modules were invited to participate in the study. The sample consisted of male and female participants in early adulthood, between the ages of 18 and 25 years. To qualify as a regular VGP, participants had to play video games for an average of 5 hr per week or more. Video game research uses different qualifying criteria to determine what qualifies as regular gaming exposure (Dye & Bavelier, 2010). The 5 hr per week requirement is based on Mathiak and Weber's (2006) classification.

Non-probability, purposive sampling was used to obtain participants in the following four sub-groups: female VGPs, male VGPs, female non-players, and male non-players. In order to allow for comparison, attempts were made to ensure that each sub-group was adequately represented. The sample consisted of $N=80$ students. Participation was voluntary. The screening survey was completed by a total of 124 participants but only 80 participants agreed to complete the second phase of the study. Gamers ($n=40$) consisted of 20 male (25%) and 20 female (25%) participants. The non-gamer group ($n=40$) consisted of 19 females (24%) and 21 males (26%).

Instruments

This study used two means of data collection: an online screening survey and a computerised version of the Stroop task to measure VSA.

Screening survey. Qualtrics (2016), an online research platform, was used to gather the demographic data and to categorise participants into VGP and non-video game players (NVGP) based on their gaming habits. Participants provided their contact details to enable the researcher to invite suitable candidates to take part in the second phase of the study.

The Stroop task. The Stroop effect plays a key role in understanding attention (Macleod, 2002). It refers to the cognitive interference the individuals experience when they are confronted with two conflicting pieces of information at the same time (Crump, Gong, & Milliken, 2006; Stroop, 1935). In the Stroop task, an individual has to respond to the colour a word is written in as quickly as possible, while simultaneously ignoring the spelling of the word. The Stroop task includes both congruent and incongruent conditions that are randomly presented to participants (Galotti, 2008). Congruent conditions include stimuli where the colour of the word along with its meaning is the same. (Lamers, Roelofs, & Rabeling-Keus, 2010). Incongruent conditions participants generally respond quickly. During incongruent conditions, the colour spelled out in the written word is different from the colour the word is written in. This interference requires more concentration from participants resulting in a slower reaction time (Galotti, 2008), due to competing stimuli (Goldstein, 2011). Effectively inhibiting task-irrelevant stimuli is an essential feature of VSA (Pilli, Naidu, Pingali, Shobha, & Reddy, 2013; Qiu et al., 2018). Good VSA skills produce faster reaction times on the Stroop task as poor VSA skills prevent participants from ignoring interference resulting in slower reactions (Macleod, 1991).

The Stroop task is considered the 'gold standard' of attentional measures (Macleod, 2002) and has been widely used in research and applied in different contexts. It is considered to be a highly reliable measure with Cronbach alpha value coefficients ranging from .71 to .88 (Bajaj et al., 2013; Jensen, 1965; Santos & Montgomery, 1962; Schubo & Hentschel, 1977; Strauss, Allen, Jorgensen, & Cramer, 2005). A computerised version of the Stroop task allows researchers to record more accurate reaction times (Davidson & Wright, 2002). The computerised version demonstrated acceptable reliability and validity across various contexts compared with the traditional task (Bajaj et al., 2013; Davidson & Wright, 2002; Parsons, Courtney, & Dawson, 2013; Pilli et al., 2013).

In this study, the computerised Stroop task created by Peirce (2015) using PsychoPy was used and was presented on a laptop computer using the software package, PsychoPy (Version 1.83; Peirce, 2015), developed specifically for fields like psychology (Peirce, 2009).

Procedure

An announcement containing a short description of the study along with a link to the survey on Qualtrics was distributed via clickUP, the communication platform used at the university. Informed consent was obtained electronically before participants were directed to the questionnaire. The initial survey served as a screening tool to determine whether participants met the inclusion criteria. Suitable participants were contacted by the researchers via email and invited to take part in the second phase of the study, the electronic Stroop task.

A face-to-face session was arranged for the second phase of the research in the same room under similar conditions for each participant. All participants received standardised instructions, namely, 'When three words flash individually on the screen, respond to the colour of the word as quickly as possible, while ignoring the meaning of the word'. The 'left' arrow key was assigned for words written in red, the 'down' arrow key was allocated for words written in green, and the 'right' arrow key was used for words written in blue. To minimise possible confounding from the inability to remember instructions, colour labels were applied on the respective arrow keys. A red label, for example, was applied on the left arrow key (Afsaneh et al., 2012; Quero, Baños, & Botella, 2000). After a practice session, the participants were informed that the data collection phase, consisting of

60 trails, would start. The practice session allowed participants to become familiar with the instructions minimising confounding due to unfamiliarity.

Ethical considerations. Ethical approval was obtained from the Faculty of Humanities Research Ethics Committee at the university. Participants gave informed consent before both phases of the study in which ethical issues such as confidentiality and voluntary participation were discussed. Participants were also given the opportunity to ask questions about the research process. Participants were assigned a numerical ID once they completed the screening survey. The participant ID was used to link a participant's survey responses with their results on the computerised Stroop task, thereby ensuring confidentiality.

Data analysis

Data analysis was done using SPSS version 24 (International Business Machines [IBM] Corporation, 2016). A mean response time (RT), representing their VSA, was computed for each participant based on their 60 trails. To investigate whether there were any significant differences with regards to gender, VSA, and video game playing, a two-way between-groups analysis of variance (ANOVA) was conducted.

Results

The majority of participants (24%) were 21 years of age, while the average age of participants was 21.3 years. The sample consisted of 51% males and 49% females.

Video game playing habits

Most VGPs ($n=26$; 65%) played between 6 and 15 hr a week, a further 15% ($n=6$) between 16 and 20 hr per week, while 13% ($n=5$) of the participants played more than 21 hr per week. In relation to the types of games played, AVGs were the most popular video game genre. Within the AVG genre, massive multiplayer online role-playing games ($n=10$; 25%) and first person shooter games ($n=10$) were most popular among VGP.

VSA scores

The mean RT of VGPs was 637 ms, ranging from a minimum of 456 ms to a maximum of 1043 ms with a standard deviation of 125 ms. The mean RT of NVGPs was slower compared with VGP. Non-players had a mean RT of 778 ms, ranging from a minimum of 466 ms to a maximum of 1094 ms with a standard deviation of 133 ms (refer to Table 1).

Male and female VGPs demonstrated similar reaction times of 639 and 635 ms, respectively. On the contrary, female non-players showed a faster reaction time of 746 ms compared with males with a reaction time of 806 ms (Figure 1).

On average, VGPs demonstrated faster reaction times compared with non-players. It can thus be argued that video gamers appear to display more advanced VSA skills when compared with non-players. A two-way between-groups ANOVA was conducted to determine whether this difference was statistically significant. The findings revealed that the interaction effect between VGP and gender was not statistically significant, $F(1, 76)=.97$, $p=.333$. Based on the findings, gender did not mediate participants' VSA in relation to their gaming habits as no significant differences were found between males and females, $F(1, 76)=1.25$, $p=.27$.

Table 1. Mean response times of video game players and non-players in milliseconds.

Video game play status		*n*	Minimum	Maximum	*M*	*SD*
Video game player	Response time average	40	.456	1043	.63717	.124898
Non-player	Response time average	40	.466	1094	.77758	.133121

SD: standard deviation.

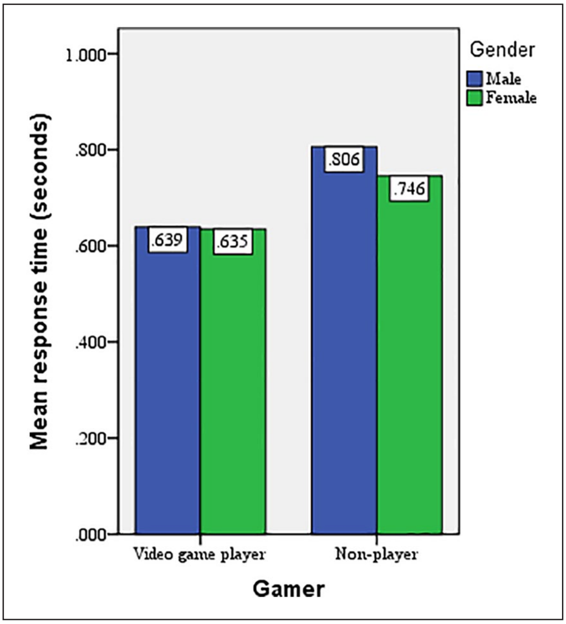

Figure 1. Mean response time in seconds of participants grouped according to video game playing status and gender.

A statistically significant main effect for VGP, $F(1, 76) = 23.19$, $p < .001$, with a large effect size ($\eta^2_{partial} = .24$) was found in the current investigation. The results support the hypothesis that video gamers tend to exhibit better VSA abilities than non-gamers. VGPs thus demonstrate more advanced VSA abilities compared with non-players. Given the differences observed in the VSA scores of VGPs and NVGPs, the authors maintain that the effect size is acceptable in accordance with Cohen's (1988) criteria (refer to Table 2).

Discussion

The results of this study show that VGPs were on average a 140 ms faster than NVGPs. When interpreting the results of RT experiments, Tønnessen, Haugen, and Shalfawi (2013) demonstrated the significance of minor differences in RT scores: An RT that varies by 100 ms or even 10 ms may have a significant impact on performance of sprinters, for example. Similarly, Cherif et al. (2017) also highlighted the impact of RT with regards to sporting performance, while other research emphasised the link between RT and driving ability as well as problem-solving (Haynes, Kliegel, Zimprich, & Bunce, 2018) and the prevention of physical injury, like falling (Graveson, Bauermeister, McKeown, & Bunce, 2015).

Table 2. Two-way between-groups ANOVA.

Dependent variable: response time average						
Source	Type III sum of squares	*df*	Mean square	*F*	Sig.	Partial η^2
Corrected model	.431[a]	3	.144	8.645	.000	.254
Intercept	39.895	1	39.895	2401.008	.000	.969
Gender	.021	1	.021	1.246	.268	.016
Gamer	.385	1	.385	23.189	.000	.234
Gender × gamer	.016	1	.016	.966	.329	.013
Error	1163	76	.017			
Total	41.724	80				
Corrected total	1.694	79				

ANOVA: analysis of variance.
[a]$R^2 = .254$ (adjusted $R^2 = .225$).

Therefore, according to Tønnessen et al. (2013), the RT difference of 140 ms observed in this study may be regarded as a notable difference suggesting that video game playing has beneficial effects on the player, including faster RT and improved VSA abilities. Castel, Pratt, and Drummond (2005) found similar results with gaming experts showing significantly faster RT compared with non-gamers. Similarly, Schubert et al. (2015) suggested that VGPs demonstrate superior abilities in several attention-related tasks compared with non-gamers. In their experiment, Qiu et al. (2018) also found that AVG experts demonstrated superior VSA abilities compared with non-experts. Green and Bavelier (2003) also found that video game play improves reaction times across a variety of cognitive tasks. Furthermore, Bavelier, Achtman, Mani, and Föcker (2012) argued that VGPs have increased VSA skills compared with non-players with AVG players exhibiting more oculomotor control as well compared with non-players (West, Al-Aidroos, & Pratt, 2013). According to Dye et al. (2009) and Qiu et al. (2018), video gaming can be of value, as it appears to improve VSA abilities, thereby enabling gaming experts to use their cognitive resources more efficiently. This permits faster and more accurate responses to stimuli. In addition, Qui et al. (2018) found an association between AVG playing and VGA plasticity even after a 1 hr AVG session. Boot, Kramer, Simons, Fabiani, and Gratton (2008) defined expert VGPs as those who play video games more than 7 hr a week and claimed that long-term, expert video players outperform non-players on various measures of attention. This study's parameters limit definitive conclusions but, as the results suggest, VGP can potentially improve VSA abilities.

Latham, Patston, and Tippett (2013) and Wang et al. (2016) reported a significant overall effect in the medium to large range on the relation between AVG and cognitive abilities. The visual system is constantly overwhelmed with large amounts of information which compete for attention. VSA enables us to prioritise significant stimuli over unrelated information (Theeuwes, 2010). VGP could thus contribute to enhancing our VSA abilities thereby impacting additional cognitive functioning as well including perception threshold and processing speed (Schubert et al., 2015), visual sensitivity (Appelbaum, Cain, Darling, & Mitroff, 2013), visual short-term memory storage (Colzato et al., 2013), and suppression of irrelevant information and perceptual decision processes (Mishra, Zinni, Bavalier, & Hillyard, 2011).

With regards to gender, the resulting differences between male and female VGPs were less pronounced. Female participants in this study – both VGPs and non-players – demonstrated a faster reaction time compared with males, but the difference was not statistically significant

($p = .27$). The present findings thus suggest that gender does not seem to mediate VSA based on video gaming habits.

No definitive conclusions can, however, be made based on this study's findings due to two limitations. The sample consisted of a small number of male and female participants in the respective groups, that is, gamers and non-gamers. As the study was quasi-experimental in nature, the impact from potential confounding variables was not considered.

Conclusion

The primary objective of this study was to measure the difference in VSA between VGPs and non-players. To achieve this, a quantitative design was implemented to test the effects of video game playing on an individual's VSA. Results showed that there was a statistically significant difference between the VSA abilities of VGPs compared with non-players. Generally, most studies investigating the effects of video game playing focus exclusively on adolescent samples. This study, however, included young adults, and findings revealed that video game playing can impact and potentially improve VSA abilities, thereby providing insight into the way video game playing affects adult players. The authors are, however, not making any casual inferences. The results of the study emphasise the prospective value of video game playing and its impact on VSA. Future research should explore the potential use of video games to facilitate learning. The authors reason that video game playing could be applied in various contexts to improve cognitive abilities. Video gaming could, for example, be used within the educational context where it may be implemented as a remedial tool to address learning disorders (Franceschini et al., 2013) and it holds possibility for aiding older adults with progressive degenerative dementia (Parasuraman & Nestor, 1991).

Accordingly, it is recommended that future research explore these initiatives. Including a larger, more diverse sample in terms of age and gender is also suggested. Future research could also consider the role of gender in relation to VSA and RT in more detail. In conclusion, it is argued that given the significant impact of video gaming on VSA and the increasing uptake of video gaming in South Africa, a multicultural focus on VSA abilities and gaming habits is also suggested by including a larger and more diverse sample.

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