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DIFFERENT COGNITIVE ABILITIES DISPLAYED BY ACTION VIDEO GAMERS AND NON-GAMERS

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DIFFERENT COGNITIVE ABILITIES DISPLAYED BY ACTION VIDEO GAMERS AND NON-GAMERS
Abstract (200 words)

Playing action video games requires players to develop a cognitive profile that allows them to rapidly monitor and react to fast moving visual and auditory stimuli, and to inhibit erroneous actions. This study investigated whether experience with action videogames is associated with an advantage on standardized cognitive tasks. Specifically, we investigated whether individuals who played action video games demonstrated enhanced cognitive processing speed, task-switching and inhibitive abilities. First person shooter (FPS) and Massive online battle arena (MOBA) experienced video game players (AVGPs) and individuals with little to no videogame experience (NVGPs) performed both a Stroop test and a Trail-Making test (TMT A&B). Results showed that on the Stroop test, AVGPs responded significantly faster than NVGPs but made significantly more errors. Alternatively, on the TMT test AVGPs displayed faster reaction times while error rates did not differ compared to NVGPs. Our findings suggest that while AVGPs may possess enhanced processing speed and task-switching ability, AVGPs adopt a strategy that favours speed over accuracy on a task evaluating cognitive inhibition ability. Our data corroborate and bolster previous findings demonstrating a different cognitive profile for individuals that specifically play action video games.

Keywords: Action Video Games, Gamers, Cognition, Stroop, Trail Making Test
1. INTRODUCTION

Video game play has surged in popularity over the last 30 years and is now a cultural phenomenon. With an estimated 1.2 billion individuals playing video games worldwide (Spil Games, 2013; The Association of UK Interactive Entertainment, 2017) the relevance and popular interest in both the positive and negative facets of gaming has generated much research interest. Increasingly, video games are being utilized by psychologists and neuroscientists to examine our understanding of neurocognition (Bavelier, Achtman, Mani, & Föcker, 2012), skill learning (de Araujo et al., 2016), skill retention (Boot, Blakely, & Simons, 2011), skill transfer (Baniqued et al., 2013), brain plasticity (Betker, Szturm, Moussavi, & Nett, 2006), and ageing (Anguera et al., 2013; Boot, et al., 2013; Wang et al., 2016) among others. Broadly speaking, the behavioral consequences related to playing video games to date has attracted most research with many of the early experiments investigating the negative consequences of violent video games. More recently, a notable shift has occurred prompting increased interest in the benefits of video game play and the practical ramifications of gaming on our everyday lives. In particular, the potential for video game play to augment perceptual, motor and neurocognitive abilities has been the focus of recent research attention.

1.1. The link between cognition and video gaming

Video games, particularly action video games (AVGs), can impose high cognitive demands on the user (Lee & Heeter, 2017). Many of these games encourage players to focus on multiple demanding and overlapping component tasks, taxing the attentional control, working memory and executive functions of the players (Boot, Kramer, Simons, Fabiani, & Gratton, 2008). With a plethora of cognitive demands required for successful gaming performance, action video games make for a rich and fertile arena in which to examine differences in the cognitive abilities between action video game players (AVGPs) of all skill levels and non-video game players (NVGPs). In an early seminal study on the cognitive benefits of playing AVGs, Green and Bevelier (2003) demonstrated through a series of experiments that AVG playing enhances the capacity of the gamer’s visual attentional system compared with non-video game players. Subsequent studies have highlighted a range of fragmented and dichotomous findings in relation to the claimed enhancing or diminishing effects video game playing has on cognition.

Recent meta-analytic evidence nicely illuminates some of these discrepancies in the literature to date. Recently, Sala, Tatlidil, & Gobet (2017) published a paper comprising three meta-analyses examining whether video game training enhances cognitive ability and concluded that ‘playing video games has negligible effects on cognitive ability’ (p.3). Furthermore, they cautioned against the purported benefits of cognitive training with a small overall effect (g=-0.10). Alternatively, Powers, Brooks, Aldrich, Palladino and Alfieri (2013) published a paper comprising two meta analyses of 72 studies and 318 comparisons and concluded that video games significantly improved information processing in both quasi-experimental studies (d = 0.61, 95 % CI [0.50, 0.73]) and true experiments (d = 0.48, 95 % CI [0.35, 0.60]). Wang, Liu, Zhu, Meng, Li & Zuo (2016) conducted a meta-analysis on 20 studies and similarly found a positive effect of specifically, action video game (AVG) training on cognitive ability.
in healthy adults. Finally, Bediou, Adams, Mayer, Green, & Bavelier (2017) conducted two meta-analyses of cross sectional studies examining the cognitive abilities associated with AVGs and of long term intervention studies on the impact of AVGs on perceptual attentional and cognitive skills and concluded that ‘…action video game play robustly enhances the domains of top-down attention and spatial cognition, with encouraging signs for perception’ (p.1). However, Simons and colleagues (2016) caution against some of the conclusions drawn in action video game research in their recent review. Overall, it is clear that further methodologically rigorous research is required to illuminate the purported neuromodulating effects of action video gaming.

1.2. Action video games as a distinct and notable videogame type

The focus on the specific game genre of AVG is noteworthy in the previous section as video game play as a whole encompasses a vast array of differing skills, characteristics and experiences (Spence & Feng, 2010; Bediou et al., 2017). Therefore, it seems ill advised to combine all video game types together due to the possibility of confounding subsequent findings. As can be seen from the differing meta-analytic findings above there is considerable debate over the merits of gaming. Notably, AVGs seem a very promising gaming type. These games typically have fast–paced gameplay with a constant focus on movement, quick decision making, hand-eye coordination, combat and reaction time performance characteristics. AVGs are very popular among gamers and offer a set of features which are very pertinent from a research perspective, namely, that these games share (i) a fast pace involving severe time constraints for decisions and motor responses; (ii) a high degree of perceptual and motor load which taxes working memory and goal directed actions; (iii) a dynamic mixture of highly focused attention and vigilance with a widely distributed focus of attention; and (iv) a high degree of distraction and clutter in the gaming environment. The predominant AVG subtypes are considered to be first person shooter games (FPS), wherein the player views the world from his or her avatar (e.g., Counter Strike), and third-person shooter games (TPS), wherein the player sees the back of his or her avatar (e.g., Player Unknown Battlegrounds). Increasingly, real time strategy (RTS) and multiplayer online battle arena (MOBA) games, sometimes labeled as action real-time strategy, also fall under the umbrella term of AVGs. MOBA games have more recently appeared on the eSports scene (Bony, Castenada, & Swanson, 2016), especially with the release of the ever popular League of Legends game in 2009. With over 100 million active gamers per month (Statista, 2016), MOBA games also share many of the constraints and skill sets seen with typical AVGs (Bony et al., 2016; Deleuze, Christiaens, Nuyens, & Billieux, 2017). As a result, it stands to reason that MOBAs deserve strong consideration as a sub-type of AVGs.

However, there lacks consistency over the inclusion criteria for the definition of an AVG among studies to date. Across a wide range of AVG related studies researches included only FPS games (Green & Bavelier, 2003; Spence & Feng, 2010; Bailey & West, 2013; Chisholm & Kingstone, 2015) or in some instances FPS and TPS (Gobet et al., 2014), whereas West and colleagues (2013) added RPG (role playing games) to FPS, while Sala and colleagues (2017) combined FPS and racing video games as AVGs. In contrast to common agreement upon inclusion of FPS into AVGs type, Unsworth and colleagues (2015) separates FPS from
AVGs and shows no or weak correlations between those playing the mentioned genres and their cognitive abilities.

1.3. A Cognitive framework of action video gaming: the case for FPS and MOBA

Evidenced by the lack of consensus above, a key concern relates to whether playing AVGs is associated with different cognitive profiles and, if so, which cognitive domains are affected. This is important not only for our theoretical understanding of whether AVGs related neural and behavioral changes exist but it is also important when considering the movement by many researchers to translate the purported beneficial findings of action video gaming into practical and training programs (Kuhn, Gleich, Lorenz, Lindengerger & Gallinat, 2014; Nouichi et al., 2012; Anguera et al., 2013). It is therefore very timely to examine which cognitive abilities may be more reliably affected by experience with playing AVG’s. Both FPS and MOBA games are suggested to exercise cognitive skills such as task switching, visuomotor coordination, processing speed, working memory and attentional control (Spence & Feng, 2010, Bony et al., 2013) in addition to inhibitory skills (Deleuze et al., 2017). Increasing interest in the behavioral and cognitive consequences of gaming (Bavelier & Green, 2016; Bediou et al., 2017; Powers et al., 2013) has led us to examine whether prominent cognitive differences exist between AVGPs and NVGPs. Two appropriate well-cited and often deployed cognitive test measures were utilized for this purpose (Stroop and Trail Making).

1.4. Stroop Test

The Stroop Test examines an individual’s ability to shift their cognitive set (Spreen & Strauss, 1998) in the presence of distraction, or, alternatively to suppress irrelevant information and maintain focus on a given task. As such, it is believed to provide a measure of cognitive inhibition (Archibald & Kerns, 1999; Boone, Miller, Lesser, Hill, & D’Elia, 1990), described as the ability to inhibit an overlearned response (dominant response) in favour of an unusual one (Spreen & Strauss, 1998). Imaging studies implicate lateral prefrontal regions and the anterior cingulate cortex to be involved in interference processing and inhibition while performing the Stroop Test (Adleman et al., 2001). Additionally, studies suggest inferior parietal activation (Carter, Mintun, & Cohen., 1995, Adleman et al., 2001) may play a role in attention processing during the Stroop test, which can measure selective attention independently of processing speed (Morrow, 2013). During AVGs, being able to suppress learned responses and to show a high degree of attention processing are very important and as a result, individuals who consistently play AVGs may adopt a cognitive advantage in these areas when compared to NVGPs.

1.5. Trail Making Test

The Trail Making Test (TMT) is widely used as neuro-psychological instrument which evaluates visual search speed and tracking with a motor component. Functional MRI studies show activation of a number of brain regions, including ventral and dorsal visual pathways and the medial pre-supplementary motor area during TMT (Allen, Owens, Fong, & Richards, 2011). Moreover, activation of frontal regions and areas in the left hemisphere (Zakzanis,
Mraz, & Graham, 2005) also implicates the TMT in working memory, attention, psychomotor speed, set-shifting, sequencing and inhibition (Lezak, Howieson, & Loring, 2004; Salthouse, & Fristoe, 1995, and Strauss, Sherman, & Spreen, 2006). Finally, a version of the TMT requiring participants to alternate their connecting trails between numbers and letters is shown to be sensitive to cognitive flexibility, sequencing and the ability to maintain diverse tasks simultaneously (Korette, Horner & Windham, 2002; Salthouse, 2011). The ranging set of cognitive abilities required to perform the TMT well make this test ideally suited to examine whether AVGs demonstrate an enhanced set of cognitive abilities compared to NVGs.

1.6. Research question

This study sought to examine the cognitive discrepancies between AVGs and NVGs. We hypothesized that AVGs would display enhanced attentional inhibition as well as faster cognitive task switching, working memory and processing speeds compared to NVGs. We aimed to compare AVGs and NVGs on these cognitive abilities by examining performance differences on two, well-established cognitive tests: the Stroop Test and Trail Making Test (TMT). We hypothesized AVGs would display faster reaction times and fewer errors in the Stroop Test when compared to NVGs. We also hypothesized that faster times to complete the component tasks of the TMT (TMT-A and TMT-B) with fewer errors would provide evidence of a cognitive advantage for AVGs.

2. METHODS

2.1. Participants

One hundred and fifty five participants (120 males, 35 females) recruited from the University of Limerick student population and from attendees at the Gamescom gaming conference in Cologne, Germany provided informed consent prior to participating in the study. Approval for the study was authorized by the research ethics board at the University of Limerick in accordance with the Declaration of Helsinki.

Participants were categorized into an ‘AVGs’ group based on their experience with action video games (played first person shooter (FPS) or multiplayer online battle arena (MOBA) games at least 1 hour per week). Those in the ‘NVGs’ group reported having no experience with the AVGs. AVG participants (N=102) completed a survey that gathered information about their age (groups: 18-24; 25-34; 35-45; 45+ with $M_e$='18-24', n=80), sex (91 Male AVGs and 11 Female AVGs), how serious a gamer they perceived themselves to be (Casual, Core/Mid-Core, Hardcore Gamer), the number of hours per week they spent playing AVGs (1-7, 8-15, 9-22, 23 +) and the type of AVG they played (FPS, MOBA).

NVGs included fifty-three sport sciences students who reported their age and gender ($N=53$; 29 males, age $M=21.4$ years, SD=2.5) and were recruited at the University of Limerick.

2.2. Procedure:

Both AVGs and NVGs performed computerized versions of two cognitive tests: a Keyboard Color-Word Stroop Test (Stroop, 1935) and a Trail Making Test (TMT; Army
Individual Test Battery, 1994). The order of test administration was randomized across participants. The tests were run with Inquisit 4.0 software by Millisecond. A consistent monitor refresh rate (144Hz) and screen resolution (1920x1080) were used.

During each trial of the Stroop task, participants were presented one of three types of stimuli. Stimuli types were classified as control (colored rectangle), congruent (i.e. the word blue written in blue ink) or incongruent (i.e. the word blue written in red ink). Participants were required to identify one of 4 colors (red, green, blue, black) 7 times for each condition by keying their response on the keyboard with the keys D, F, J and K respectively. Participants were always asked to indicate the color of the ink used for each stimulus (84 total trials) as fast and as accurately as they could.

During the Trail Making Test, participants sequentially completed two different tasks. In the first task, TMT-A, participants were presented with 25 circles each with the numbers 1-25 written inside them randomly allocated about a computer screen. They were required to move their cursor and click on each of the 25 circled numbers in numerical order. In doing so, their cursor created a trail of its path on the screen. Participants were asked to complete the task as quickly and accurately as possible while both the time to complete the task (TTC) and number of errors made were recorded (errors were defined by mouse clicks not in the correct numbered circle). During the second task, TMT-B, participants again were presented with 25 circles, however 13 of the circles contained the numbers 1-13 and 12 of the circles contained the letters A-L. Moreover, 15 empty circles were also presented as distractors. During TMT-B, participants alternated between clicking on numbers (1-13) and letters (A-L) in order (i.e. \(1 \rightarrow A \rightarrow 2 \rightarrow B \rightarrow 3 \rightarrow C \ldots\) ) (See Figure 1). Again, participants were instructed to complete the task as fast and accurately as possible. Completion time (TTC) and the number of errors were recorded. Both TMT-A and TMT-B were each preceded by a short practice trial, where participants familiarized themselves with the task.
2.3. Data processing

Reaction times (RTs; calculated as the elapsed time between trial presentation and key response) and response accuracy (the number of correct responses divided by the number of trials) across control, congruent, and incongruent trials were averaged for each participant from the Stroop Test. A Participant’s data were excluded for a given condition when their average reaction time exceeded 2 SD’s. This resulted in the exclusion of data from 5 AVGPs and 4 NVGPs. In the TMT-A and TMT-B tasks, time to completion (TTC) and the number of errors were recorded separately for each participant. Again, a participant’s data were excluded when their TTC was 2 SDs beyond the mean. This resulted in the exclusion of 4 AVGPs and 3 NVGPs for TMT-A, and 5 AVGPs and 1 NVGP for TMT-B.

2.4. Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics v.22.0 software. The Shapiro-Wilk statistic and Levene’s test were used to verify the normality and variance homogeneity of our dependent variables. Student’s t tests were then used to test whether Stroop and Trail-Making Test measures differed between AVGPs and NVGPs (See Table 1). Non-parametric U-Mann Whitney tests were used to compare groups where data assumptions were not met. We also performed a one way ANOVA to determine whether differences within dependent variables existed between participants when they were categorized based on the number of hours they spent playing AVGs per week (Groups: NVGPs, 1-7 Hrs, 8-15 Hrs, 16-23 Hrs, 23+ Hrs). Cohen’s d and $\eta^2$ were chosen to calculate effect sizes for each comparison and are reported in Table 1 (Fritz, Morris, & Richler, 2012; Sullivan, & Fein, 2012). To examine the potential for sex to confound the effect of gaming, we ran two-way
ANOVAs to test for a sex by gamer type interaction for RTs in each Stroop condition and both Trail Making Tests.

3. RESULTS

3.1. Stroop Color-Word Task

In the Stroop task, AVGPs displayed significantly faster reaction times overall compared to NVGPs ($t(78)= -2.343, p= 0.022$). Moreover, this speed advantage for AVGPs over NVGPs extended to each of the three trial types (Congruent; $t(144) = -2.237, p= 0.027$, Control; $t(82) = -2.049, p= 0.044$ and Incongruent; $t(73) = -2.306, p= .024$) (Fig. 2). Although AVGPs displayed faster RTs, they were found to be significantly less accurate compared to NVGPs both overall ($U = 1474, p< 0.001$) and within each trial type (Control; $U = 1405.5, p= .0001$, Congruent; $U = 1866.5, p= .031$ Incongruent; $U = 1866.5, p= .001$) (Fig. 3). Interestingly, when separating AVGPs by the number of hours they spend playing AVGs per week, a significant difference in overall RTs was found $p= .042$ between NVGPs ($N=49$, $M=1116.39$ ms, $SD=329.10$ ms) and AVGPs who reported to play more than 23 hours per week ($N=23$, $M=918.56$ ms, $SD=220.71$ ms) (Fig. 4). Additionally, analysis revealed a linear trend of differences between groups of AVGPs at varied levels of time devoted for gaming, $F(1,141)=7.785 p= .006$. No interaction existed between sex and gamer type across all variables and conditions for Stroop Test.

![Figure 2. Differences in reaction time (RT) between AVGP and NVGP for Stroop Task. * indicates a significant difference between AVGP (black bars) and NVGP (grey bars).](image-url)
Figure 3. Accuracy as a percentage of correct answers given in each condition and overall for the Stroop Test. * indicates a significant difference between AVGPs (black bars) and NVGPs (grey bars).

Figure 4. Stroop Test RTs for NVGPs and AVGPs categorized by the number of hours per week they spent playing AVGs. * indicates a significant difference from NVGPs.
3.2. Trail Making Test

In both tasks of the Trail Making Test (TMT-A and TMT-B), AVGPs took significantly less time to complete the task compared to NVGs (see Table 1, Fig. 4). While no significant difference in the number of errors made was found between AVGPs and NVGs (TMT-A; $U=2347.5$, $p=0.598$, TMT-B; $U=2186.5$, $p=0.135$), AVGPs on average did make fewer errors on both tasks (Table 1). When separating AVGPs based on the number of hours per week they spent playing AVGs, a significant difference in TTC on the TMT-A task was found between NVGs ($N=50$, $M=43.19$, $SD=9.8$) and AVGPs who reported playing 8-15 hours per week ($N=39$, $M=36.64$ s, $SD=7.7$ s, with $p=0.009$) and AVGPs who reported playing more than 23 hours per week ($N=23$, $M=36.04$ s, $SD=9.19$ s, $p=0.024$) (see Fig. 5). Further analysis showed linear trend between groups of AVGPs at varied levels of time devoted for gaming for both: TMT-A $F(1,143)=10.836$ $p=0.001$ and TMT-B $F(1,141)=7.682$ $p=0.006$. For both Trail Making Tests no interaction existed between sex and gamer type.

![Figure 5](attachment:figure5.png)

**Figure 5.** Times to completion (TTC) (A) and the average amount of errors (B) for both tasks (TMT-A and TMT-B) of the Trail Making Test. * indicates a significant difference between AVGPs (black bars) and NVGs (grey bars).
Figure 6. RTs on the TMT-A and TMT-B tasks of the Trail Making Test for NVGPs and AVGPs categorized by the number of hours per week they spent playing AVGs. * indicates a significant difference from NVGPs.

4. Discussion

The main purpose of the present study was to examine the cognitive profile of AVGPs in comparison to NVGPs. We hypothesized that AVGPs would display enhanced attentional inhibition as well as faster cognitive task switching ability and processing speeds compared to NVGPs. As a result we employed the well-established Color-Word Stroop and Trail-Making Tests and found that while AVGPs display enhanced task switching abilities and processing speed compared to NVGPs, they do not necessarily possess enhanced attentional inhibition. However, on the Stroop task, AVGPs did show evidence of an alternative task strategy compared to NVGPs that prioritized response speed over accuracy. Additionally, our results corroborate previous findings that associate individuals who play action video games: FPS and MOBA in particular, with a superior cognitive profile. Lastly, we found that the participants who devoted more time to gaming, happened to perform better on both cognitive tests.

A key finding from the present study is that AVGPs attained faster TTCs relative to NVGPs within both components of the Trail-Making Test. As the TMT evaluates visual search speed, reflects working memory, attention, psychomotor speed, this outcome provides strong evidence that AVGPs display enhanced cognition and corroborates previous findings with visual search tasks (e.g. Green & Bavelier, 2003; Castel et al., 2005, Bailey & West 2013). For example, similar differences between AVGPs and NVGPs are presented by Castel, Pratt & Drummond (2005) where they found that AVGPs were able to more quickly find a target letter among other letters used as distractors. Perhaps even more interesting is the fact that AVGPs maintained faster TTCs while demonstrating no difference in error rate compared to NVGPs. The fact that AVGPs display faster processing speed and task switching ability without a difference in error rate strengthens the conclusion that AVGPs exhibit better processing speed and task switching ability, due to spare resources that can be devoted to the visually demanding TMT, and are not simply employing an alternative strategy that prioritizes speed over accuracy when compared to NVGPs (Skewes, Roepstorff, & Frith,
In the light of the statement by Unsworth and colleagues (2015) that "most of these studies have used extreme-groups designs (...) In a typical study, subjects with significant video-game experience (typically 5+ hr a week) are compared with non-videogame players (less than 1 hr of video-game play a week) on a variety of tasks, with more intermediate, casual gamers omitted" (p.2) our study took into consideration gamers with varying experience (from 1 to 23+ hours per week) with results indicating that those who devote more time to AVGs per week can benefit more, on average, in comparison to non-gaming participants. This outcome is supported by studies demonstrating enhanced cognitive abilities following video-game training (Green & Bavelier, 2003; 2016).

Another key finding from this study is that on the Stroop Test, AVGs display significantly faster RTs, suggesting that AVGs possess enhanced attentional capacity. However, emerging evidence also poses that gaming influences visuo-motor coordination (Kennedy, Boyle, Traynor, Walsh, & Hill, 2011). As a result, AVGs may be more adept and trained with handling a keyboard, resulting in faster RTs. Nonetheless, within the Stroop test there is no practice prior the test's performance, so both groups need to familiarize with task demands and key pattern to follow from the same starting level and as a result the test is a pure cognitive skill test. This is consistent with the findings from numerous studies suggesting AVG players exhibit an elevated level of executive functioning (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Stroback, Frensch, & Schubert, 2012). Interestingly, this outcome combined with the lowered accuracy displayed by AVGs compared to NVGs in the Stroop test suggests that a different strategy prioritizing speed over accuracy is used by AVGs. This contrasts the results from the TMT, where AVGs and NVGs do not differ in terms of errors rate. Similar findings about speed-accuracy tradeoff reported by McDermott, Bavelier & Green (2014) support the idea that tasks with a strong focus on RT may lead to lowered accuracy, whereas without time constraint AVGs outperform NVGs. In light of this, it is recommended that brain imaging techniques be applied for further investigation into the reasons why differences in accuracy-speed trade off in AVGs may occur.

While some early research has suggested AVG training may benefit certain cognitive abilities (Powers et al., 2013; Wang et al., 2016), plenty of research still exists suggesting that there are no such improvements to be had (Sala et al., 2017). In our study, we set strict criteria identifying action video game players as having experience specifically with FPS and MOBA gaming genres. These genres specifically have been widely agreed upon to constitute AVGs (Powers & Brooks, 2014; Bediou et al., 2017; Multiplayer Online Battle Arena, 2017). Moreover, the cognitive tests utilized in this study were carefully chosen given their reliability and the agreement over the unique set of cognitive skills they evaluate (Stroop, 1935; Keele, 1972; Sugg & McDonald, 1994; Strauss et al. 2005). Therefore, we are confident that our results undoubtedly reflect whether cognitive profile differences exist between NVGs and AVGs. Similar observations for cognitive profiles to differ with expertise have also been found in other domains, notably, music and chess (Bart, 2014; Hanna-Pladdy, & MacKay, 2011; Landry, & Champoux, 2017; Sala & Gobet, 2016).

**Limitations**
There is a caveat to these purported benefits reported in the current study. It must also be considered that the participants who scored better on the cognitive tests in this study may have a propensity for engaging in action video games where these skills might provide an advantage. There are some noteworthy obstacles that occur with data collection during game-related trade fairs: noise levels and observers that might influence the task performance or evoke anxiety. Although these factors may reduce cognitive performance on tests undergone in these non-laboratory conditions, we nonetheless were able to show enhanced AVGP performance in this study. Future research conducted in laboratory settings may be beneficial to better reflect the cognitive advantage displayed by AVGPS. It should also be noted that recruiting participants from gaming tournaments and trade-fairs has its advantages in that a wide sample of AVGPS can be easily obtained with ranging levels of experience.

**Future studies**

With an ever growing number of people engaging with AVGs, future research should consider both the positive and negative consequences that playing AVGs can have on perceptual and motor skills. Increasing research interest in esports makes more important the clarification of the inclusion criteria, specifically those that constitute AVGS. In this way the field can stand over the purported benefits of AVGs and present a clear picture of the specific and enduring cognitive demands and benefits associated with gaming. First and foremost, to clearly evaluate those discrepancies, future research should look to differentiate AVG types (FPS, MOBA, RTS, RPG) as there is emerging evidence that FPS gamers differ from other gamer types in terms of their inhibitory control (Deluze et al., 2017). Different performance strategies for AVGPS and NVGPS revealed in our study, and increases in pupil diameters recorded by Laeng, Ørbo, Holmlund & Miozzo (2011) in Stroop interference suggest that evaluating cognitive load and cognitive demands of different AVG types using eye-tracking techniques may be beneficial. We plan in the future to investigate a number of other common cognitive tests that we feel will possibly be affected by the playing of AVGs. Possible areas include testing visual short-term memory (VSTM), attentional biases and priming affects. We feel the study of these effects may be of particular interest for AVGPS and in particular FPS due to the extreme focus on temporal aspects of their interactions and the aspects of the gameplay whereby exposure to one stimulus may influence their response to a subsequent stimulus, without conscious guidance or intention.

Future research in this area needs to stringently follow best research practice guidelines (sufficiently powered, appropriate control group usage, etc.) and look to carefully design training studies for resolving some of the previously highlighted discrepancies over the purported cognitive-enhancing attributes of video game play. An emerging technique in the area of cognitive neuroscience that is allowing researchers to investigate the mechanisms implicated in different cognitive tasks is functional near-infrared spectroscopy (fNIRS). Early research using fNIRS seems to provide promising and valuable outcomes in terms of cognitive task load measures (Izzetoglu, Bunce, Izzetoglu, Onaral, & Pourrezaei, 2003). With respect to the current findings, neural imaging techniques like fNIRS and EEG may better
allow us to explain some of the reasons why AVGPs adopt different strategies when performing cognitive tests. Additional studies may also investigate possible clinical applications of AVGs, as playing these games is highly connected with increasing activity in certain brain regions responsible for working memory and visual attention and search. Perhaps improving connectivity and activity in these regions through the playing of AVGs can slow or reverse some of the age-related detriments in function observed within these areas (Anguera et al., 2013; Wang et al., 2016).

References


Table 1. Differences between AVGPs and NVGPs in Stroop and Trail Making Test.

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<td>RT [ms] (SD)</td>
<td>868.02 (218)</td>
<td>956.53 (240)</td>
<td>-2.237</td>
<td>-</td>
<td>.027</td>
<td>1.720</td>
<td>0.0360</td>
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<td>ACCURACY [%] (SD)</td>
<td>95.97 (5)</td>
<td>97.52 (3)</td>
<td>-</td>
<td>1886.5</td>
<td>.031</td>
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<tr>
<td>RT [ms] (SD)</td>
<td>994.98 (233)</td>
<td>1116.39 (329)</td>
<td>-2.306</td>
<td>-</td>
<td>.024</td>
<td>5.362</td>
<td>0.0434</td>
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<td>ACCURACY [%] (SD)</td>
<td>89.38 (8)</td>
<td>91.91 (14)</td>
<td>-</td>
<td>1559</td>
<td>&lt; .001</td>
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<td>RT [ms] (SD)</td>
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<td>957.88 (259)</td>
<td>-2.049</td>
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<td>.044</td>
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<td>ACCURACY [%] (SD)</td>
<td>94.75 (6)</td>
<td>97.81 (3)</td>
<td>-</td>
<td>1405.5</td>
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<td>TTC [s] (SD)</td>
<td>37.3 (5.55)</td>
<td>43.19 (9.79)</td>
<td>-3.778</td>
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<td>Error Number [count] (SD)</td>
<td>0.32 (0.6)</td>
<td>0.4 (0.7)</td>
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<td>TTC [s] (SD)</td>
<td>46.18 (12.3)</td>
<td>52.9 (13.4)</td>
<td>-3.079</td>
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<td>0.55 (0.8)</td>
<td>0.83 (1.1)</td>
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<td>.135</td>
<td>0.015</td>
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Research Highlights

- For Stroop, AVGPs responded faster than NVGPs but made significantly more errors
- For TMT AVGPs displayed faster RTs while error rates did not differ compared to NVGPs
- AVGPs display more efficient processing speed and task-switching ability
- AVGPs adopt a strategy favouring speed over accuracy on a cognitive inhibition task
- Our data corroborate previous findings of a different cognitive profile for AVGPs
Funding

This work was supported with the financial support of the Science Foundation Ireland grant 13/RC/2094 and co-funded under the European Regional Development Fund through the Southern & Eastern Regional Operational Programme to Lero - the Irish Software Research Centre (www.lero.ie)

Data Availability

All data from this study is freely available to any wishing to access it. Please email mark.campbell@ul.ie and we would be happy to send on the data.