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Research Report

Cognitive enhancement in video game players: The role of video game genre

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ABSTRACT

Several cross-section and training studies have shown that video game play can improve cognitive functions such as visual attention, cognitive control, visual short-term memory, and general processing speed. Unfortunately the replication of these effects is not always successful, even when using similar cognitive tests to measure performance. We investigated an important aspect of this field that has not yet been empirically addressed: the role of video game genre. Our comparison of two video game player groups of specific genres (first-person shooter and real-time strategy) indicates that cognitive abilities (measured by task switching and multiple object tracking) may be differentially enhanced depending on the genre of video game being played. This result is significant as research to this point has focused on "action video games", a loosely defined category that encompasses several video game genres, without controlling for effects potentially stemming from differences in mechanics between these video games. It also provides some evidence for the specificity of video game play benefits as a function of actions performed within the game, which is not in line with a generalized "learning to learn" accounting of these enhancements.

1. Introduction

It is now well established that video game players (VGP's) outperform non-video game players (NVGP's) on a wide range of cognitive abilities, including visual attention (Durlach, Kring, & Bowens, 2009; Green & Bavelier, 2006a, 2006b, 2007), aspects of cognitive control (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010; Glass, Maddox, & Love, 2013; Strobach, Frensch, & Shubert, 2012), visual short-term memory (Blacker & Curby, 2013; McDermott, Bavelier, & Green, 2014; Wilms, Peterson, & Vangkilde, 2013), and general processing speed (Dye, Green, & Bavelier, 2009). Several training studies have also shown that relatively short video game training sessions can improve the functioning of NVGP's (Basak, Boot, Voss, & Kramer, 2008; Feng, Spence, & Pratt, 2007; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Li, Polat, Scalzo, & Bavelier, 2010).

However, in the case of both cross-section and training designs, the occurrence and replication of video game effects has been inconsistent (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Irons, Remington, & McLean, 2011; Murphy & Spencer, 2009). A number of methodological issues present in both cross-section and training designs have been pointed out which may be contributing to this inconsistency, including the use of unspecified recruiting methods and differential placebo effects in training studies (Boot, Blakely, & Simons, 2011). We would like to address one additional factor that has not yet been explored which could be a significant contributor to the occurrence of cognitive enhancements stemming from video game play: the role of video game genre.

Most researchers use the term "action video game", defined by Green and Bavelier (2003) as "those (video games) that have fast motion, require vigilant monitoring of the visual periphery, and often require simultaneous tracking of multiple targets", when describing the video games played by their participants. As this definition is quite broad, many different video game genres can qualify as action video games. Video games are categorized into genres based on their gameplay mechanics, or the in-game tasks and rules that players must attend, and the qualitative differences between game genres can be considerable. Boot et al. (2013) suggest that this may be why training studies produce inconsistent results, as differences in game mechanics between video games used during training likely produce differential requirements of cognitive functions.

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In the case of past cross-section studies, video game genre has not been controlled (with the notable exception of Colzato, van den Wildenberg, Zmigrod, & Hommel, 2012, who used first-person shooter players only) and groups of VGP's who play different video games genres have never been compared. This makes it difficult to determine whether video game genre, beyond the general "action video game" categorization, is also a significant determinant of the cognitive functioning advantages found in VGP's when compared to NVGP's. Latham, Patston, and Tippett (2013) point out that expertise related changes likely reflect not only the length of video game experience but also the nature of that experience, and suggest that greater care should be taken when classifying "expert" video game players in light of the many "action" video game genres.

Showing that the type of video game genre being played has a significant role in determining which cognitive functions are improved would provide evidence in favor of a task-specific accounting of these enhancements. The current view is that action video game play improves a skill known as "learning to learn" by increasing the ability to extract patterns or regularities from an environment (Bavelier, Green, Pouget, & Schrater, 2012). This implies that video games improve general learning mechanisms which then carry over to improved performance on various, unrelated cognitive tests.

In a recent review of studies on action and non-action video games, Oei and Patterson (2014) propose an alternative accounting in which functions are trained separately due to the similarities between video game and cognitive tasks. They cite evidence in the form of training data that demonstrates specific, limited transfer effects in cases where the video game and cognitive tasks share common demands, as well as neuroimaging data showing that transfer is more likely when both tasks recruit overlapping neural regions. This "common demands" hypothesis also accounts for previously found transfer effects in non-action video games, in which evidence for transfer was equivocal when video game and task did not share common demands.

In order to address the topic of video game genre, we have designed a study comparing the cognitive functioning of first-person shooter (FPS) and real-time strategy (RTS) players. It should be noted that both FPS and RTS games qualify as action video games despite bearing relatively little resemblance to each other.

FPS games are played from the first-person (egocentric) perspective of a single protagonist who is generally charged with combating enemies while navigating through a three dimensional environment. Players must rapidly adjust to changes in weapon, vehicle, and enemy characteristics as each of these can require specific strategies and handling.

RTS games are played from a top-down (allocentric) perspective and require players to manage a host of units and buildings placed within an expansive environment. Games of this type are typically comprised of three separate tasks that must be managed simultaneously: gathering resources (by assigning units to do so), spending the resources to create units (which vary in terms of cost to create and abilities), and directing fighting units in battle against the enemy.

Both FPS and RTS games have previously been shown to improve cognitive functioning in training studies, but players of each genre have never been compared. We propose that the differences in game mechanics found between FPS and RTS games will be reflected in cognitive performance. Our reasoning behind this prediction is quantitative. While both FPS and RTS games require frequent switching and tracking of multiple stimuli, the egocentric perspective of FPS games places restrictions on the number of stimuli that can appear on screen simultaneously (and in the players field of view).

A typical FPS game may contain up to 64 players (moving stimuli) in a single area, though the player rarely has more than a few within their field of view. In contrast, RTS games can have a much higher number of moving stimuli. The highly popular StarCraft II: Wings of Liberty has a unit cap of 200, meaning that the player may have to attend up to 400 units (including those of his opponent). Furthermore, due to the allocentric viewpoint, players can view most or all of these units within their field of view. This viewpoint also allows for greater task switching demands as players are often required to switch between very different "screen states", or viewpoint positions on the map, in order to attend to various task demands. In FPS games players attend to a continuously changing screen state.

As we are suggesting that game mechanics are related to functioning improvements, we have chosen to measure performance on two cognitive tasks which we suspect are trained more by one game type over the other due to the reasons outlined above: task switching and multiple object tracking.

Task switching is a measure of mental flexibility that is frequently used to study the shifting aspect of executive functions, referring to the ability to flexibly and quickly switch between different tasks or mental sets (Miyake et al., 2000). Multiple object tracking (MOT) measures the ability to keep track of the positions of a number of moving target items among a set of distractors (Trick, Jaspers-Fayer, & Sethi, 2005). This task requires visual attention to be actively allocated towards target stimuli among competing distractors (Green & Bavelier, 2006b) and is thought to contain a large dynamic attentional component (Scholl, Pylyshyn, & Feldman, 2001).

We hypothesize that the more complex switching and object tracking requirements of RTS gameplay should provide greater engagement of those functions when compared to FPS gameplay, leading to comparatively better cognitive performance.

2. Method

2.1. Participants

90 participants (out of 1806 respondents) were recruited via an online questionnaire advertised on local bulletin boards and at the University of Social Sciences and Humanities in Warsaw, Poland. These participants were placed into one of three groups ($n = 30$ per group, two females in each group) based on our recruitment criteria: FPS players, RTS players, and a control group of NVGP's. RTS players were required to have played seven or more hours per week of RTS games in the past six months and 5 h or less of FPS games per week during the same time frame. FPS players had the same requirements but reversed. NVGP's were required to have played less than 2 h per week of both FPS and RTS games in the past six months, and no more than 5 h of video game play weekly in total.

Mean age was 22.1 ($SD = 3.9$) for FPS players, 22.2 ($SD = 4.5$) for RTS players, and 25.4 ($SD = 4.4$) for NVGP's. The developmental literature on task switching (e.g. Kray & Lindenberger, 2000; Reimers & Maylor, 2005) and multiple objects tracking (e.g. Kennedy, Tripathy, & Barrett, 2009) suggests that the three year age gap between our NVGP and VGP groups is unlikely to factor into performance. Mean playtime was 18.83 h for FPS players and 19.10 h for RTS players (see Table 1 for full report on gameplay times). We also collected data on the number of hours weekly spent playing the following game genres: platform, fighting, adventure, turn-based strategy, role-playing, racing, puzzle, and multiplayer online battle arena. Participants were not excluded on the basis of gameplay time in these video game genres. As our primary interest was in FPS and RTS players, we only required that participants play the genre of their group more frequently than any of the other genres.

Table 1
Mean weekly hours played of each video game genre. *SD* in parentheses.

Video game genre	FPS players	RTS players	NVGP's
First-person shooter	18.83 (6.55)	1.87 (1.83)	.50 (.82)
Real-time strategy	.70 (1.51)	19.10 (8.62)	.20 (.55)
Platform	1.20 (2.64)	.27 (.58)	.13 (.35)
Fighting	1.23 (2.05)	.50 (1.57)	.10 (.40)
Adventure	1.97 (3.62)	.90 (2.34)	.30 (.88)
Turn-based strategy	4.03 (4.78)	6.27 (8.77)	.27 (.58)
Role-playing	4.53 (7.71)	5.43 (7.56)	.33 (1.03)
Racing	3.23 (4.09)	1.43 (2.85)	.37 (.77)
Puzzle	1.23 (1.78)	1.33 (2.59)	.27 (.69)
Multiplayer online battle arena	.30 (1.64)	.93 (2.99)	.17 (.91)

2.2. Experimental tasks

All stimuli were displayed on a 22 inch ViewSonic VX2268wm LCD monitor at a refresh rate of 100 Hz, with participants sitting 60 cm from the screen. JVC HA-NC250 noise cancelling headphones were provided to minimize disruptions.

2.2.1. Task switching

Based on the procedure used by Colzato et al. (2012), with target stimuli adapted from Huizinga, Dolan, and van der Molen (2006). Participants were required to respond to either large (global) or small (local) geometric figures depending on the presented cue. Global figures were comprised of local figures. Three blocks of trials were administered: two training blocks (randomized order) of 50 trials each in which response instruction was constant across all trials, and one experimental block of 160 trials in which participants switched between global and local tasks.

2.2.2. Multiple objects tracking

Based on the procedure used by Green and Bavelier (2006b). At the beginning of each trial participants were presented with 16 circles, of which from 1 to 7 could be labeled as targets requiring attention. Once the trial began targets were indistinguishable from non-targets and moved randomly on a gray background. The end of each trial prompted participants for a yes/no answer on whether a highlighted circle was part of their tracked set. Three practice trials (1, 2, and 3 circles) were given, and each cue number was randomly presented 20 times for a total of 143 trials.

2.2.3. Similarity ratings

Participants in our FPS and RTS groups were asked to rate how similar they found the games which they play to the cognitive tasks that they performed. Responses were given on a seven point Likert scale anchored by "not similar at all" and "very similar."

2.3. Procedure

Participants who fulfilled our recruitment requirements were contacted individually by phone. Before being invited to the laboratory, they were asked to name the games which they currently play most often in order to confirm that their declared gameplay information was accurate. Control participants were simply asked to confirm that they were non-video game players. Only participants who vocalized playing games in the genre which they were recruited to (for FPS and RTS players) were invited for testing. RTS candidates were additionally asked if they primarily played games such as League of Legends or DOTA 2, as they are very popular multiplayer online battle arena games which are often mistaken for RTS games by players. Up to this point participants were given no information as to the purpose of our study.

Upon arrival to our laboratory participants signed an informed consent form and were told that they would be performing computerized tasks on which we expect to find video game players and non-video game players to differ. Participants in our video game playing groups were told a cover story that we expect to find players to outperform non-players. Non-players were told the opposite in an attempt to equalize task performance motivation levels. Instructions were given verbally and provided on screen prior to the start of each task. Once completed, participants in our FPS and RTS groups were additionally asked to give similarity ratings. When the experiment was concluded, participants were thanked for their participation, debriefed as to the true study outcome expectation (a video game player advantage), and given financial compensation (approximately 10 USD).

3. Results

3.1. Data treatment

Three outliers were removed from task switching analyses based on switch cost scores (calculated as the difference in reaction time between repetition and switch trials) exceeding our cut-off of 2.5 standard deviations, making the final sample 29 FPS players, 30 RTS players, and 28 NVGP's. Switch cost was the main performance indicator.

MOT data from four participants were removed from analyses: two due to computer malfunction leading to loss of data and two cases exceeding our cut-off *SD* value based on mean accuracy across all trials. The final sample was 28 FPS players, 28 RTS players, and 30 NVGP's. Accuracy was the main performance indicator.

A significance level of $p < .05$ was adopted for all conducted tests and post hoc comparisons were corrected using Tukey's HSD procedure. Reaction time and accuracy values are presented with SEM. All reaction time analyses were conducted on correct trials only.

3.2. Task switching

Task Switching results were first analyzed in three separate 3 (Group) × 2 (Trial Type) ANOVAs. Trial types include repetition/switch trials, congruent/incongruent (congruency of target at relevant and irrelevant levels), and global/local (target level). Analysis of reaction times showed the expected within-subjects main effect of switch, $F(1,84) = 225.94$, $p < .001$, $\eta_p^2 = .729$, with repetition trials requiring less response time than switch trials (552 ± 14.8 ms vs. 700 ± 19.6 ms). Critically, the size of the switch effect varied with group, $F(2,84) = 6.36$, $p = .003$, $\eta_p^2 = .132$. RTS players (switch cost: 113 ± 17 ms) were less affected by switches than NVGP's (198 ± 18 ms), $p < .001$, and FPS (137 ± 17 ms) players displayed a similar but non-significant trend when compared to NVGP's ($p = .078$). A main effect of congruency was also found, $F(1,84) = 29.77$, $p < .001$, $\eta_p^2 = .262$, with faster responses for congruent (605 ± 16.2 ms) vs. incongruent trials (650 ± 17.6 ms). However, this effect did not interact with group, $p = .741$. Finally, there was no main effect of target level ($p = .221$) nor interaction with group ($p = .491$).

Analysis of accuracy using the same model also revealed a main effect of switch, $F(1,84) = 24.29$, $p < .001$, $\eta_p^2 = .224$, with lower accuracy on switch trials than on repetition trials (87.6% ± 1.0% vs. 91.0% ± 1.1%). No interaction between trial type and group was found ($p = .504$). A congruency effect was also present in our accuracy data, $F(1,84) = 86.28$, $p < .001$, $\eta_p^2 = .507$, indicating greater accuracy for congruent (96.4% ± .4%) vs incongruent trials (83.6% ± 1.6%). No other main effects or interactions were significant (see Fig. 1).

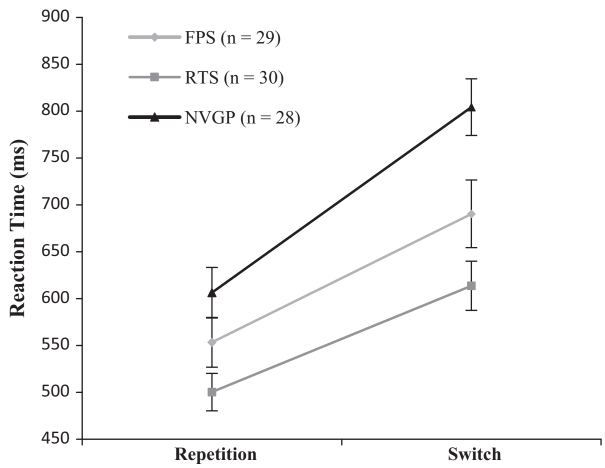

Fig. 1. Task switching reaction times on repetition and switch trials. Error bars denote SEM.

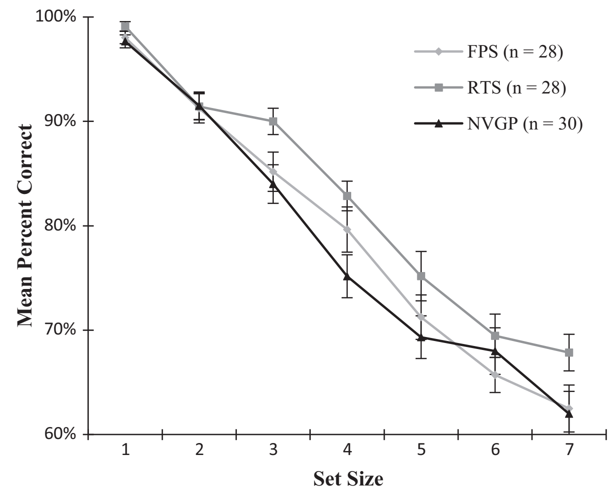

Fig. 2. Multiple object tracking accuracy across all set sizes. Error bars denote SEM.

3.3. Multiple object tracking

MOT accuracy data was first analyzed in a 3 (Group) × 7 (Set Size) ANOVA. As prior analyses confirmed that there was no effect of response bias on our groups (equivalent accuracy for "yes" and "no" trials), all trials were included in the analysis. Within-subjects testing indicated a main effect of set size, with accuracy decreasing as the number of objects to track increased: $F(6,498) = 192.81$, $p < .001$, $\eta_p^2 = .699$. Set size and group did not interact ($p = .34$), indicating that accuracy decreased with set size similarly in all three groups.

Most interestingly, one-way ANOVA revealed a significant group difference in overall accuracy: $F(2,83) = 4.91$, $p = .01$, $\eta_p^2 = .106$. RTS players (82.3% ± 0.8%) significantly outperformed NVGP's (78.2% ± 0.9%), $p = .01$. RTS players also outperformed FPS players (79.0% ± 1.0%), but this difference did not reach the established significance level, $p = .058$. No differences were found between FPS players and NVGP's ($p = .806$). We also performed individual analyses at each set size to identify where the between-group differences were concentrated. These differences occurred at set sizes three and four ($ps < .05$), with RTS players outperforming NVGP's in both cases ($p = .037$ and $p = .015$, respectively) (see Fig. 2).

As the version of MOT used here allows for the calculation of d', a sensitivity index used in signal detection theory, we performed an additional comparison of our groups using one-way ANOVA with d' (calculated as recommended by Macmillan and Creelman (1991)) as the dependent variable. Data from one additional RTS player was not included in the analysis due to classification as an outlier. The main effect of group was significant at a trend level: $F(2, 84) = 3.05$, $p = .053$, $\eta_p^2 = .068$. Post-hoc comparisons revealed that the main effect was driven by a greater perceptual sensitivity of RTS players ($d' = 1.86$) when compared to NVGP's ($d' = 1.62$), $p = .053$. FPS players ($d' = 1.68$) did not differ from NVGP's ($p = .845$) or RTS players ($p = .182$).

3.4. Similarity ratings

Independent-samples t-tests were used to compare FPS and RTS players on their ratings of how similar the cognitive tasks they performed were to the games which they typically play. Only data from participants included in the final task switching and MOT analyses were analyzed. FPS ($M = 3.48$, $SD = 1.42$) and RTS ($M = 4.29$, $SD = 1.84$) players did not differ on how similar they found task switching to their games ($p = .07$). However, RTS players ($M = 6.11$, $SD = 1.06$) found MOT to be significantly more similar to their games than did FPS players ($M = 4.85$, $SD = 1.63$), $t(44.503) = 3.36$, $p = .002$.

4. Discussion

Our data show that playing action video games of different genres may not have an equivalent enhancing effect on the shifting aspect of executive functions and visual attention as measured by task switching and multiple object tracking. Real-time strategy players showed superior performance to non-video game players on task switching and MOT, and also showed a trend level advantage over first-person shooter players on overall MOT performance. FPS players held a trend level advantage of lower switch costs, but did not outperform NVGP's at MOT.

While RTS players did display greater task switching performance than FPS players when compared to NVGP's, both gamer groups had comparable switch costs and it therefore cannot be said that RTS gameplay enhances mental flexibility more than FPS gameplay. It instead appears that the advantage of RTS players lies in their quicker overall reaction times (557 ms, 622 ms, and 704 ms for RTS, FPS, and NVG players, respectively), suggesting superior speed of processing. A recent meta-analysis by Dye et al. (2009) provides evidence for a general speeding of perceptual reaction times in action video game players, but their data does not discern between different video game genres. Since FPS games also place heavy emphasis on quick responding it seems unlikely that RTS games are somehow especially well-suited to improving processing speed, but no determinations can be made based on our data.

However, our switch costs results do address a question raised by Colzato et al. (2010). The authors showed that FPS players have lower switch costs (but not reaction times) than NVGP's on the same task switching paradigm used in the current study, but questioned whether such an effect was specific to video games using the first-person perspective. Our results suggest that this is not the case, as RTS games are characterized by the use of a top-down or allocentric perspective and our RTS players also had lower switch costs than NVGP's.

Our MOT results are in line with the expected advantage of RTS players over FPS players and NVGP's. The fact that RTS players showed marginally better perceptual sensitivity when compared to NVGP's suggests that at least part of their advantage in MOT may be due to early perceptual processing enhancements, supporting one earlier finding in which an unknown mix of action VGP's displayed greater perceptual sensitivity than NVGP's on a visuospatial task (West, Stevens, Pun, & Pratt, 2008). Although we cannot directly attribute the superior performance of RTS players to the requirements of in-game mechanics, our similarity ratings provide evidence in favor of such an explanation by showing that RTS players found the MOT task to be significantly more similar to their games than did FPS players. We interpret this as an association between the types of stimuli found in RTS video games and the MOT task.

It is interesting to find that FPS players do not show any performance advantages over NVGP's at MOT. Two previous comparisons of VGP's and NVGP's on this task (Green & Bavelier, 2006b; Boot et al., 2008) reported significant VGP advantages, but the authors did not restrict their action video game player samples to a predominance of one video game genre. As the VGP groups in both studies were relatively small, it may the case that RTS players were responsible for the observed performance advantages.

Overall our results suggest that players of RTS games have greater cognitive abilities, in particular their object tracking abilities, than do FPS players given similar amounts of playtime. Together with our similarity ratings, this pattern of data is most readily accounted by the "common demands" theory (Oei & Patterson, 2014), with our RTS players benefiting from a greater common demand in the form of visual attention resources. Bavelier et al.'s (2012) "learning to learn" framework does not account for this selective performance advantage. While we agree that the wide range of cognitive functions found to be enhanced in VGP's is suggestive of improvements to a general learning mechanism, the variance stemming from including several different video game genres into the category of action video games should not be ignored.

It may well be the case that action video games improve so many cognitive functions because of the differential ability requirements placed on players by the various in-game mechanics present across genres. Though many video game genres share the same basic game mechanics, the extent to which they are employed or are critical for successful gameplay is not uniform. In the case of cross-section studies using action video games, this may result in numerous cognitive enhancements that appear to be driven by a general factor (action video game play) when they are actually being caused by the frequent repetition of specific in-game actions that are dependent on individual or a limited range of functions.

As this study is correlational in nature, a follow-up training study is needed to establish the causative role of video game genre in the development of enhanced cognitive abilities. Such a follow-up should include a wider range of carefully selected tasks than the admittedly limited set used here and employ video games belonging to distinct genres. In closing, we suggest that video games should not be treated as a "black box" which enhances cognition, but should instead be viewed from the perspective of what is necessary to succeed within the game and how that relates to specific cognitive functions.

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