Training through gaming
The effect of frequent gaming on cognitive performance

Joakim Lundqvist
TRAINING THROUGH GAMING
THE EFFECT OF FREQUENT GAMING IN COGNITIVE PERFORMANCE

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Video games are complex tasks and put a large demand on the player's cognitive abilities. Players must be able to efficiently search a limited visual space while being able to make split-second decisions and keeping track of several variables. Research has shown that playing video games can enhance performance on visual attention and spatial distribution after just 10 hour of training. The present study aimed to investigate if performance on cognitively demanding tasks would increase with hours spent playing video games. Small sample size hampered the studies statistical power. Tendencies showed to consistently go against study hypothesis though with small effect size. One exception was decrease in shifting cost in the local-global shifting test. To build upon this study would mean to have a better spread of video game experience, divide groups based on what type of game was played rather than the amount of experience in addition to including a larger battery of tests.

Playing video games is a task that can help engage and enhance a wide variety of attentional and perceptual cognitive functions (Green, Li, & Bavelier, 2010). Game makers combine visual and sound elements to create environments that immerse the player with a goal of making the player feel like they are there in the world. The high demand on cognitive resources is very apparent in action video games where players need to track and manage several variables in a fast paced environment (Bavelier, Green, Pouget, & Schrater, 2012). Popular action games like Counter-Strike, require players to coordinate with their team (one of two) on a large map to either plant a bomb or stop the other team.
from doing so. Players must track their health, ammunition count, position on map relative to their teammates, recoil pattern of their gun and more while also scanning their visual field for possible threats. This is not exclusive to Counter-Strike but is widely shared among most action games and especially first-person shooter (FPS) games and action games in general. It’s not only action games that have the player make quick decisions. Real-time strategy (RTS) games like Starcraft 2, an asymmetrical base building game, where the player must switch between many units, rules and goals in real-time. In Starcraft 2 the goal is to build a base and an army to conquer a map and destroy the opposing player(s) base. The player gets to choose from one of three factions, each with unique structures, units and playstyles. To be successful the player needs to be able to play to their faction’s strength and weaknesses, micro-manage units for gathering resources, building structures, completing skirmishes and defending. All this is handled in real-time, swapping between units on a battlefield and ordering new units at the base. So, are there any real-world benefits from playing video games on a regular basis?

Recent studies have demonstrated that video-game players (VGP) that play action games, outperform non-video-game players (NVGPs) on attentional and visual search tasks (Bavelier, Achtman, Mani, & Föcker, 2012; Castel, Pratt, & Drummond, 2005; Chiappe, Conger, Liao, Caldwell, & Vu, 2013; Dye, Green, & Bavelier, 2009; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006, 2007). This would indicate that VGP are better at allocating visual and attentional resources than NVGPs when completing cognitively demanding tasks such as tracking several independent elements in a visual scene. Green & Bavelier, (2003) showed that video game players (VGP) outperformed non-video game players (NVGPs) in attentional control and selection. Participants were treated as VGP if they had played any action games for 4 hours a week the past six months, NVGPs had less or no experience at all. The authors employed a test battery with flanker compatibility effect, enumeration task and a ‘useful field of view task’. In these tasks VGP performed better than the NVGPs showing a greater capacity for attending items in the visual field and controlling attention. The researchers could find differences between groups even after a short amount of training. After training for one hour per day for 10 consecutive days, the action game group saw significant improvements over the Tetris group in their visual attention capacity and its spatial distribution and temporal resolution. Chiappe et al., (2013) investigated if playing action games could enhance participant’s multi-tasking ability in high workload environments. A test group trained by playing action games, specifically FPS games, for at least five hours a week for 10 consecutive weeks, another group didn’t train anything and acted as control. The groups were pre- and post-assessed using the Multi-Attribute Task Battery. They found that the VGP group performed better on the secondary tasks without it interfering on the performance of the primary task. These effects have not only been found with action games. Glass, Maddox, & Love (2013) showed that improvements on cognitive flexibility could be achieved through playing RTS games. Participants playing Starcraft 2 for 40 hours saw a significant improvement to their cognitive flexibility not seen in controls.
playing the sims, a slow-paced life and decorating simulator where the player controls the life of a family in a neighborhood.

While there is evidence of an effect from training cognitive functions with video games some have not been able to replicate this. Boot, Kramer, Simons, Fabiani, & Gratton (2008) found in a cross sectional study that VGP were better at tracking objects moving at a greater speed, were better at detecting visual changes, performed better on switch tasks and on mental rotation. Participants were considered experts if they had played 7 hours of video games each week for the last 2 years and main type of game being action games. In the longitudinal part of the study, NVGPs trained under three different conditions, Action game; Strategy game; puzzle game, for 21.5 hours over four to five weeks. Contrary to earlier research with training paradigms, there was no evidence of improvement in the trained group compared to controls except for in the mental rotation test. This, according to the authors, might suggest the need of far more experience playing video games or pre-existing group differences for some effect to be observed. While Castel et al., (2005) found VGP to perform better on response times for visual search tasks no differences could be observed between groups when supposed to inhibit the return of attention to a previously cued position.

Current research suggests that VGP can manage attentional resources more effectively and have a larger resource reserve than that of NVGPs (Bavelier et al., 2012; Chisholm & Kingstone, 2015; Green & Bavelier, 2003; Hubert-Wallander, Green, & Bavelier, 2011). This is also apparent in visual search tasks where VGP could track more items that are independent from each other (Green & Bavelier, 2006), utilize a greater field of view (Green & Bavelier, 2007) and operate in high workload environments (Chiappe et al., 2013) more efficiently than NVGPs. The aim of this study was to investigate whether benefits to executive functions such as participants ability to shift attention between mental sets such as the color or shape of an object (shifting). And their ability to monitor and hold information in working memory. Ability to sort out and replace old and no longer relevant information for up to date information (updating) (Miyake et al., 2000) increased with level of gaming expertise. The study tries to assess possible associations by employing tests aimed at evaluating participants updating and shifting capabilities. Gaming expertise was treated as a continuous variable, hours played the past seven days and six months. For a player to be successful when playing video games there are high demands on being able to quickly shift attention, remember patterns and search their visual field. Therefore, performance on the tests was expected to increase with level of gaming expertise regardless of whether action or strategy games had been played, while experience with mobile games was not included.
Method

Participants

22 participants, whom all filled out a questionnaire asking for age, gender, years of education, highest attained degree and their video game habits for the last week and six months (7 females, 15 males, mean age 24.3, 17-31 years, SD 3.5, mean years of education 13.9, SD 2.4, 9-20, mean hours played last week 14.2, SD 17.688, 0-52, mean hours played last six months 349, SD 461.9, 0-1740) were recruited via flyers posted around Umeå university campus and Facebook. All participants spoke Swedish as their native language and all instructions where given in Swedish. After completion of the tests, each participant received compensation for their participation.

Material

Lab equipment
All computer based tests where run with E-prime (V2.0.10.356, Service Pack 2) and written in E-studio (V2.0.10.252) (Psychology Software Tools, Pittsburgh, PA). The computers ran windows 10 64bit education edition with 16gb RAM and an intel® core™ i7-6700 CPU @ 3.40 GHz 3.41 GHz processor. Two screens, one for each participant, HP Compaq LA2405 Wg, 24', 63Hz and HP L2245w 22', 76 Hz. Each participant used a HP KU-0316 keyboard for input. Tests where held in a controlled lab environment with up to two participants taking the tests at the same time. Participants had opaque screens between them reducing visibility of one another.

Questionnaire
Participants filled questionnaire made to collect data on age, gender, years of education, highest attained degree, what video games they have played during the last week and last 6 months. And on what console as well as the amount of sessions and hours. Based on the questionnaire used by Dye et al., (2009).

Cognitive reflections
The Swedish version of cognitive reflections test (CRT-6) was used to control for participant’s ability to suppress initial intuitive response and critically assess a problem with participant being graded from 1-6. Score was only given if the answer given was correct (Erceg & Bubić, 2017).

Updating Test
A test for updating was administered in the form of a verbal 2-back test. Participants were presented with several numbers, one at a time for a total of 40 trials. Each number was presented in the center of the screen, colored white with a black background. The goal for each participant was to figure out if the presented number was equal to the one presented two numbers earlier. Each number required an answer but only remained on screen for
2.5 seconds before cycling to the next one, the task was self-paced. Participants responded with either yes, ‘M’ key, or no, ‘X’ key using two hands and their respective index finger. Before testing started participants where shown instructions on screen and after that a short practice phase with 15 trails were conducted before the test phase.

**Shifting Tests**

Two tests for shifting ability were used (Local-global and Color-shape). In Local-global, participants got presented with a figure depicting one of four shapes (X, Square, Circle or Triangle) with a size of 595x595 pixels for a total of 98 test trails. The figure consisted of several smaller figures depicting one of the four shapes. All the smaller shapes in each figure depicted the same shape. If the figure was blue participants were supposed to answer what the larger (global) shape was depicting, if it was black the participants answered what the smaller (local) shapes depicted. The figures remained on screen until an input was given but where asked to answer as soon as they could. When answering the participants used the number keys on the keyboard. ‘1’ for Circle, ‘2’ for X, ‘3’ for Triangle, ‘4’ for Square. Used their dominant hand when responding. Before the test instructions were shown on the screen and a short practice phase with 38 trails was conducted.

In Color-shape, several figures got presented one by one. There were four possible figures: red circle, red triangle, blue circle and a blue triangle. Triangles came in 205x172 pixels and circles in 178x169 pixels and each figure appeared in the center of the screen for 4 seconds with a 0.5 second delay and a fixation before it presented the next figure. Figures were reduced to 75% size when displayed in the program. The test had three phases, in the first phase participants got instructions to answer on what color the presented figure had and to answer to quick as possible for 38 trials. They used the ‘Z’ key for blue and the ‘X’ key for red. The keys were marked with their respective color on the keyboard. Before the actual test, a short practice phase with eight trials took place. In the second phase participants had to respond on what shape the presented figures had for 38 trials. It was the same possible figures as the first phase. Participant's responded by pressing the 'N' key for circle and the 'M' key for triangle. The keys had been marked with their respective shape on the keyboard. A short practice phase with eight trails took place before the actual test.

The third phase combined the two earlier. Participants received instructions that each presented figure would be paired with a smaller figure placed above the main figure. The smaller figure could be a Rainbow, which signaled that the program asked for color, or it could be a triangle with a circle in the middle which meant that the program asked for shape of the figure. The smaller figures had a size of 75x42 pixels for the rainbow and 84x46 pixels for triangle with a circle. When displayed in the program, size was reduced to 25%. The smaller figure appeared 0.25 seconds before the larger figure and remained until the larger figure disappeared. This smaller figure decided if they should answer what color or what shape a figure had. Participants made their answers with the same keys as in the earlier phases. Before the actual test there was a short practice phase with eight trials. The third phase had three parts each spanning 50 trials. Each part was functionally
identical and was separated with a minute-long brake prompted by the program. When responding, participants used their left hand for color ('Z'-'X'-key) and right hand for shape ('N'-'M'-key) regardless of phase.

Procedure

Participants took part in the study one or two at a time, with no interaction between them during testing. Participants filled a letter of consent before they got to take part in the study. Firstly, participants filled out the questionnaire. After which CRT-6 was administered. Instructions were read aloud and located on the front of the paper test. Once the CRT-6 was complete participants moved onto the computer based tests. First the verbal 2-back was administered, followed by local-global and lastly color shape. Each test had their instructions on screen and orally by the test leader. After each practice session, any questions were answered and corrections made if needed. During the color-shape test, instructions were given for each individual phase right before that phase started so the participant wouldn’t get it all from the start and confuse instructions. After each completed test, a short informal interview with the purpose of finding misunderstandings with the instructions took place. The test session took approximately 1 hour. 4 participant’s data showed that they had misunderstood the 2-back test instructions and their data was removed from analysis (N total = 18, 7 females, 11 males).

Results

Reaction time (RT) in milliseconds and mean accuracy, number of hits out of total, were calculated for performance in the 2-back test and shifting cost (SC) for local-global and color-shape. Score on CRT-6 was calculated for each participant (scale 0-6, 0 = lowest, 6 = highest). Table 1 shows descriptive statistics of performance on administered tests and table 2 shows participant descriptive statistics; Gender, Age, Years of education, CRT-6, participant’s self-estimated game time (GT) for the past week and past 6 months (N = 18).

Table 1. Accuracy (hits of total amount), mean RTs and SDs in milliseconds for all participants in all administered tests. RT shifting cost in milliseconds for the shifting tests local-global and color-shape. Participant self-estimated hours spent playing games for the past week and 6 months mean and SD.

<table>
<thead>
<tr>
<th></th>
<th>Mean Accuracy</th>
<th>Mean RT(MS)</th>
<th>SD(MS)</th>
<th>Mean SC (MS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-back</td>
<td>32.72 (40)</td>
<td>1057.85</td>
<td>172.32</td>
<td></td>
</tr>
<tr>
<td>Local-Global</td>
<td></td>
<td></td>
<td></td>
<td>176.58</td>
</tr>
<tr>
<td>Switch</td>
<td>45.50 (49)</td>
<td>1868.58</td>
<td>518.15</td>
<td></td>
</tr>
<tr>
<td>No-Switch</td>
<td>45.72 (49)</td>
<td>1692.01</td>
<td>526.54</td>
<td></td>
</tr>
<tr>
<td>Color-Shape</td>
<td></td>
<td></td>
<td></td>
<td>134.99</td>
</tr>
</tbody>
</table>

4
Table 2. Gender, Age, Years of education, CRT-6 score, participant self-estimated hours spent playing games for the past week and 6 months mean and SD.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Male</th>
<th>SD</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>11</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Age</td>
<td>24.17</td>
<td></td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>Years of Education</td>
<td>13.83</td>
<td></td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>CRT-6</td>
<td>3.17</td>
<td></td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td>GT week</td>
<td>11.94</td>
<td></td>
<td>18.31</td>
<td></td>
</tr>
<tr>
<td>GT 6 months</td>
<td>316.31</td>
<td></td>
<td>473.30</td>
<td></td>
</tr>
</tbody>
</table>

For the 2-back test no significant correlation was found between ACC and time spent playing video games ($GT \ 6 \ months, r = -.135, p > 0.05; GT \ week, r = -.169, p > 0.05$), or 2-back RT and time spent playing video games ($GT \ 6 \ months, r = .013, p > 0.05; GT \ week, r = .170, p > 0.05$). The negative correlation for 2-back accuracy would indicate a decrease in performance rather than an increase when considering time spent playing video games. This is also illustrated when looking at reaction times, it seems to increase with time spent playing video games. No significant correlation could be observed between time spent playing video games and shifting cost in the local-global task ($GT \ 6 \ months, r = -.150, p > 0.05; GT \ week, r = -.269, p > 0.05$). However, the direction of the correlation indicates a decreased SC with GT week. This negative relation is consistent with the hypothesis that performance would increase with time spent playing, here in the form of a decreased shifting cost. While not extremely large, effect size magnitude is large enough to be considered meaningful, further implying consistent decrease in shifting cost. In contrast shifting cost in the color-shape task ($GT \ 6 \ months, r = .179, p > 0.05; GT \ week, r = .84, p > 0.05$) seemed to increase with time spent playing video games, which is opposite the hypothesis. With an effect size considerably smaller. Performance on CRT-6 had no significant correlation with time spent playing video games ($GT \ 6 \ months, r = .056, p > 0.05; GT \ week, r = -.244, p > 0.05$). As expected, there was a significant correlation between time spent playing games the last six months and time spent playing games during the past week ($r = 0.764, p < 0.05$). Naturally the time spent playing games in a week would have an impact on time spent each month. A significant correlation between 2-back ACC and reduced SC in the Color-Shape was observed ($r = -.479, p < 0.05$). CRT-6 score showed to decrease with increased reaction times on 2-back test, at a very significant level ($r = - .594, p < 0.01$) with a considerably large effect size.
Table 3. Correlation matrix for time spent playing video games, 2-back accuracy and reaction time, local-global and color-shape shifting cost, and CRT-6 score.

<table>
<thead>
<tr>
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<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GT 6 months</td>
<td>-</td>
<td>.764**</td>
<td>-.135</td>
<td>.013</td>
<td>-.150</td>
<td>.179</td>
<td>.056</td>
</tr>
<tr>
<td>2. GT week</td>
<td></td>
<td>-</td>
<td>-.169</td>
<td>.170</td>
<td>-.269</td>
<td>.084</td>
<td>-.244</td>
</tr>
<tr>
<td>3. 2-back ACC</td>
<td></td>
<td></td>
<td>-</td>
<td>-.355</td>
<td>-.348</td>
<td>-.479*</td>
<td>.181</td>
</tr>
<tr>
<td>4. 2-back RT</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>.342</td>
<td>.343</td>
<td>-.594**</td>
</tr>
<tr>
<td>5. Local-Global SC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>.378</td>
<td>-.049</td>
</tr>
<tr>
<td>6. Color-Shape SC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-.272</td>
</tr>
<tr>
<td>7. CRT-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>-</td>
</tr>
</tbody>
</table>

Note. * p < .05, ** p < .01.

Discussion

The aim of this study was to investigate whether performance on cognitive shifting and updating tasks increased with number of hours spent playing video games. Participants reported their gaming habits for the past week and past six months. Each participant underwent tests aimed at assessing their cognitive abilities; Shifting and updating. With recent literature showing that VGPs outperform NVGPs in visual and attentional tasks (Bavelier et al., 2012; Boot et al., 2008; Castel et al., 2005; Chiappe et al., 2013; Chisholm & Kingstone, 2015; Dye et al., 2009; Glass et al., 2013; Green & Bavelier, 2003, 2006, 2007) the expected outcome was for task performance to increase with video game expertise.

Few tendencies were found to support the hypothesis. Direction of correlations between test performance and time spent playing video games seem to largely go against the hypothesis. Accuracy in the 2-back test seem to decrease and reaction time to increase, as does color-shape shifting cost. While this trend of a decrease in performance with increase in time spent playing is consistent the magnitude of the effect sizes is rather small. A discrepancy between time spent last week and last six months can be observed when looking at correlation to CRT-6 score. Performance seem to decrease with time spent last week but increase with time spent last six months, though effect size should indicate the decrease in performance as the most likely. These findings contradict the hypothesis, rather than an increase in performance from more time spent playing video games an overall decrease has been observed, although with a small effect size. However,
two correlations could be observed in line with the hypothesis. Shifting cost in the local-global test saw a decrease with time spent playing, both for last week and last six months. Relation between the shifting cost in local-global and time spent playing video games for the last week show a negative correlation with a comparatively large effect size to that of the other correlations. This would thus indicate a gain in shifting capabilities that increase with the time spent playing video games. Furthermore, time spent playing for the last week shows a larger effect than time spent playing the past week. This could be because the significant difference in number size, hours played during last week are far from the number of hours played during the last six months. But this can also be interpreted to mean that upkeep is important, one might have to be consistently playing as not to lose out on any possible benefits. Having played several hundreds of hours last six months might start to lose value if one decides to take an extended break from playing.

Some limitations with the present study should be considered. First the sample size was rather low (N = 22 total) and was further decreased with the removal of participants who failed to understand task instructions (N = 18 total). With a larger sample size the spread of reported video game experience could have been improved and possibly given more power to statistical analyzes. Another way to look at the results, or lack thereof, is that there simply was no relation between the variables.

Second, treating the variable as continuous and using a within groups design could pose problems. Earlier research largely used a between groups design with VGPs and NVGPs and included longitudinal experiments where NVGPs received a small amount of training. While the effect of video game experience is apparent between those who are experts or received training and those without or minimal experience there might be a point of diminishing returns so that when comparing experts to intermediate players the effects are indistinguishable. Most forms of training are very specific to the task (Green & Bavelier, 2008) and as a result differences might be observed in a particular game but any transferrable benefits are already gained from a small amount of training.

Third, the use of self-assessment for hours and games played over such a large timespan meant that numbers given were rough estimates which could be greatly exaggerated. Several participants mentioned problems with remembering exactly what games they played during a session since they would often swap between several different games. Those who had games that they played habitually, games that they came back to at a scheduled rate had less trouble accounting for sessions and hours spent on what games even for longer periods of time. One solution for the rough estimation could be to collect user data from gaming platforms such as Steam or Origin. These platforms actively track usage of games that are played; date, session time, number of sessions and total hours are all easily accessible through the user’s accounts. This would require that the participant use any of these platforms and agree that this data, that might be private, is used.

There was no analysis of what type of games participants played more frequently, inasmuch at that might have substantially influenced performance on the tests. Video game expertise was treated as blanket of all hours played with any video games during
the specified period. Commonly in research action games are used because of the inherent demand on rapid decisions and visual search demands. There is however evidence for different types of benefits depending what is emphasized during gameplay (Oei & Patterson, 2013). Grouping participants not based on video game experience but in what type of game the experience lies could be worth for future research to investigate if a deeper understanding of how games train cognitive and perceptual functions is to be achieved. As shown by Cohen, Green, & Bavelier, (2008) there are differences in the type of game, even within the same category, being played when assessing any training benefits.

The goal of the present study was to investigate whether video game experience was associated with better performance on cognitive shifting and updating tasks. The study would have benefited from a larger sample size, test battery and grouping of participants based on the games they played. While there is a growing body of research on benefits from playing video games, it mostly focuses on benefits from action games. These studies tend to use tasks which emphasize similar tasks to those found in action games. To fully investigate games benefits the type of game must be considered when choosing what tasks so to investigate for transferrable effects.

References


