Playing Video Games Enhances Visual Attention

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The Entertainment Software Association estimates that 60% of Americans, around 145 million people in all, play some sort of video game. The popularity of video games continues to be spurred on by progress in both hardware and software technology that allow for an overall richer and more enjoyable experience. The increasing use of video games has led to a complementary surge in scientific interest as to the consequences of video game play. Much of the attention, both popular and scientific, has focused on the potential social consequences of video game play. However, because many video games place extraordinary demands on the perceptual, motor, and cognitive systems, and thus require a subset of skills far different than those essential in normal day-to-day life, a smaller subset of researchers, including ourselves, have focused on the potential for video games to alter fundamental aspects of perception and cognition.

One critical reality in examining the consequences of video game use is that there are many types of video games and their perceptual and/or cognitive effects are likely to be quite different depending on their specific characteristics. Our research to this point has primarily focused on the perceptual consequences of action video games, primarily those termed first-person shooter (FPS) games. These games have a number of defining properties that make them extremely interesting in studying learning and its limits in the visuo-motor domain.

The first feature that all action games possess is that peripheral processing is placed at a premium. In general, in everyday living we look directly at any item of consequence and thus the importance of peripheral information is greatly minimized. Even driving, which is perhaps the most peripherally demanding day-to-day activity, has been highly constrained to diminish the contribution of far peripheral vision. When these constraints are broken, at intersections for example, is where most accidents happen. In contrast to this, in action games enemies often first appear in the periphery and their immediate detection is critical for a player's success.

A second feature of action games is their incredible speed. In this case we use speed to denote both the velocity with which items can move, which is often much faster than what is typically experienced in day-to-day life, and also the speed with which items must be processed and decisions made for the player to be successful. Because video games are not necessarily constrained by the physics or technology of the real world, video game objects often move extremely fast compared to what a non-video game player may typically experience. In addition to the speed of video game objects, the speed of processing that is required is also quite high in action games. When a quickly moving object appears, the player often has little time to identify the object and make a decision as to the correct action to take. This decision making process may require the integration of many relevant facts (how much health and ammunition are available to the player, where teammates are positioned, which type of enemy is faced and what are its specific weaknesses, where are the available covered positions, etc) with incredible speed as the player often has only a few seconds to respond. Again, driving is the most temporally demanding task most non-video game playing humans experience and again, it is not a coincidence that when speed limits are increased, the prevalence of accidents often rises proportionally.

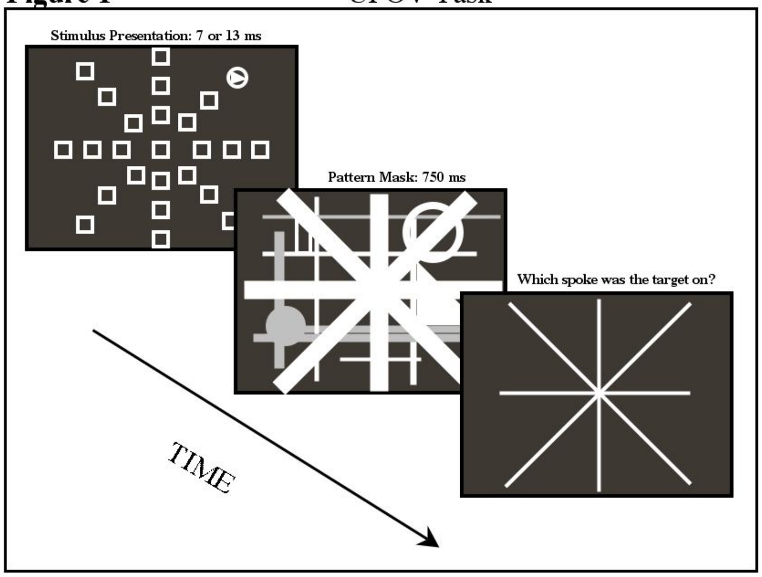
The final feature of action games we will discuss is that the number of items that need to be kept track of may greatly exceed the circumstances experienced in normal life. In many action video games, the enemies are far less considerate than those seen in karate movies, respectfully engaging the protagonist one at a time. In some games, it is not unusual for five, ten, or even thirty enemies to present themselves simultaneously, each having slightly different characteristics and moving along slightly different trajectories at slightly different speeds. There are few real-life situations (outside of the military) that approximate such circumstances.

While it is well known that exposing an animal to a novel environment often results in adaptive modifications to the systems responsible for processing the new information, one could also argue that video games presents challenges so different than those humans have evolved to solve that video games may require adaptations that are beyond our limits for plasticity. Our work has overwhelmingly favored the former argument, demonstrating that in many cases, video game experience leads gamers to possess perceptual and cognitive skills far beyond those exhibited by non-gamers (Green & Bavelier, 2003). As we have discussed, action games stress a number of aspects of perception – peripheral processing, the processing of information over time, and the ability to track many objects at once. In a series of experiments, we demonstrate that each of these abilities is enhanced by video game experience, first by comparing the performance of avid video game players (VGPs) to that of non-video game players and then, to truly demonstrate a causative role for video game experience, by specifically training NVGPs on an action video game and comparing their performance before and after training.

The first aspect of vision we have examined is the processing of information over space. In many action video games, enemies often first appear in the periphery and thus a large field of view must be monitored. Furthermore, it is essential that the extent of the screen not only be vigilantly monitored, but also efficiently filtered, such that distracting information is discarded and only targets are selected for further processing. We therefore hypothesized that action video game experience may enhance the efficiency with which attention is distributed over the visual field. To quantitatively assess this hypothesis, we made use of a task that was originally developed to assess the driving fitness of elderly citizens. Interestingly, although the only visual qualification needed to attain a driver's license is passage of an eye-chart test, safe driving is not actually well correlated with visual acuity (the bottom line you are able to read on the eye-chart at the optometrist). Instead, safe driving seems better correlated with the ability to successfully monitor a cluttered visual world. Therefore, the designers of this task, the Useful Field of View task (UFOV), argue that rather than giving potential drivers an eye-chart test, a test such as the UFOV that evaluates the subjects' ability to deploy visual attention over the whole scene should be employed (Ball, Beard, Roenker, Miller, & Griggs, 1988). From our perspective, this test allows us to obtain an excellent measure of the ability to make effective use of visual information over space in a variety of conditions, with the added bonus that augmented performance on the test is correlated with real-life benefits.

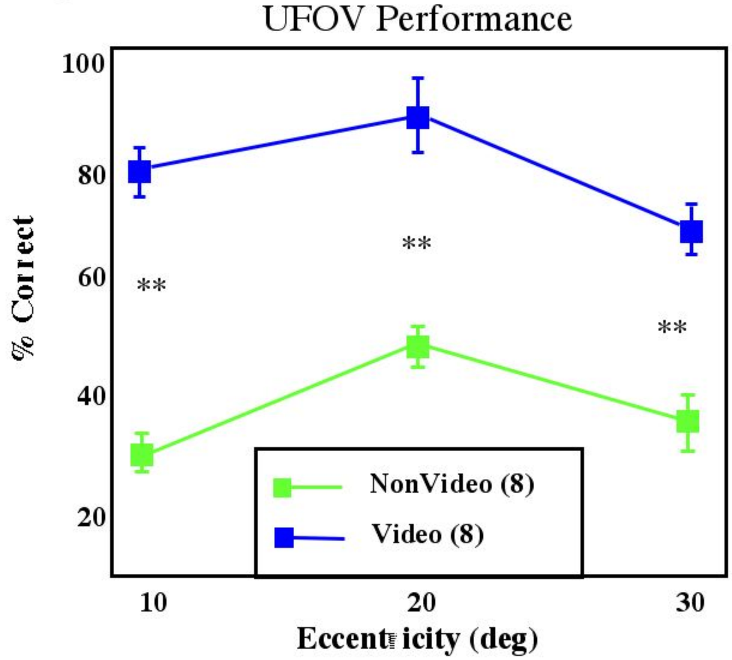
In our version of the UFOV task, subjects are asked to localize a very briefly (less than 20 ms!) presented target (a filled triangle within a circle) (Figure 1). The target can appear on one of eight imaginary "spokes" (the four cardinal directions and four diagonals) and using the keyboard, the subject simply has to indicate on which spoke the target appeared. Furthermore, the target can appear at one of three eccentricities (10°, 20°, or 30°). As most games are played with a maximum eccentricity of around 15°, this task allows us to probe peripheral processing within, at the border of, and well beyond the "trained" region of space. Finally, the target can appear with or without distractor squares, allowing us a measure of the efficiency with which video game players can filter distracting peripheral information.

Figure 1



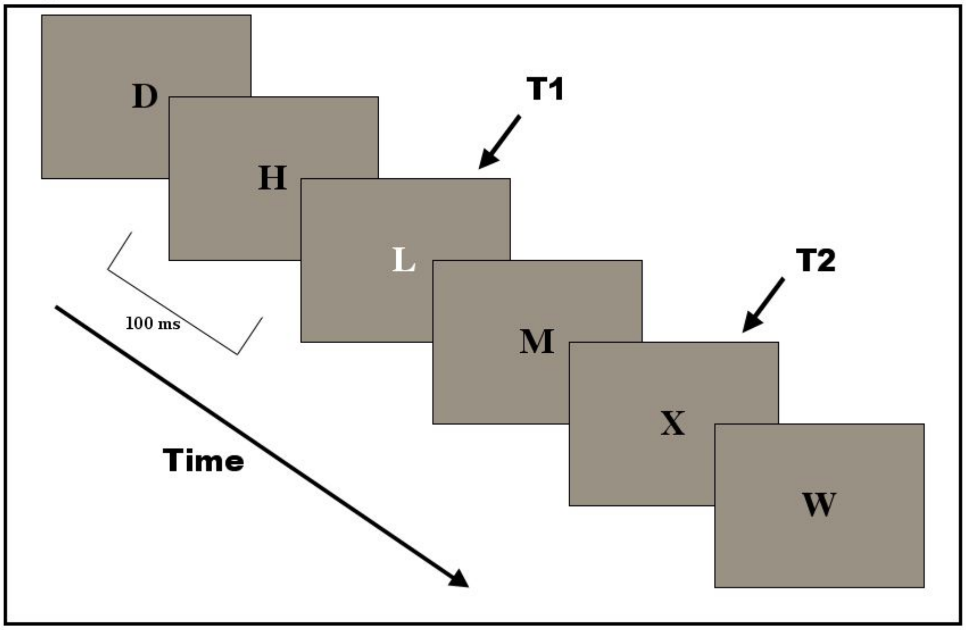
We tested eight VGPs (people who have played action games at least 5 hours per week for the past six months) and eight NVGPs (people who have little or no video game experience) on this task. As hypothesized VGPs far outperform NVGPs on this task (Figure 2). Interestingly, the VGP advantage is consistent over each of the three eccentricities, indicating that the effect of video game play transfers to locations beyond where the "training" took place. Furthermore, VGPs outperform NVGPs both when the target is presented in isolation as well as when it is surrounded by distractor squares. This indicates that VGPs possess not only an enhanced ability to orient to quickly presented targets, but can actually use peripheral information more efficiently to localize a target in a cluttered scene.

Figure 2



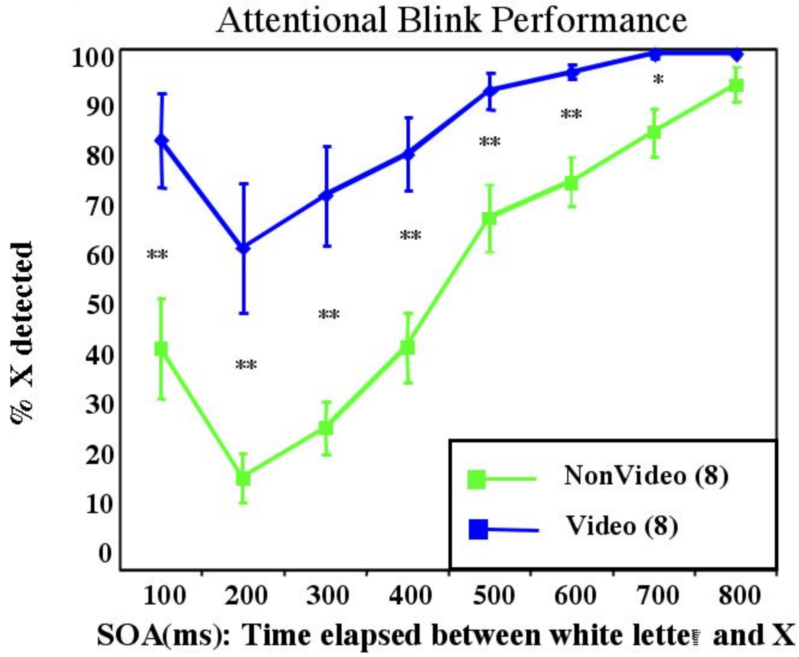
Having established an enhancement in the processing of information over space in VGPs, we turned to the second feature we have discussed as critical in action video games, the ability to effectively process information over time. To measure the temporal characteristics of visual attention we made use of the attentional blink paradigm (Raymond, Shapiro, & Arnell, 1992) (Figure 3). In this task, subjects viewed a stream of quickly presented black letters (presented one at a time for 100 ms each). They are told on each trial that a white letter (T1) will appear somewhere in the stream. At the end of the trial they will have to identify the white letter. They are also told that 50% of the time an 'X' (T2) will appear somewhere in the stream of letters after the white letter (anywhere from the letter directly after the white letter to 8 letters after the white letter). In addition to reporting the identity of the white letter, at the end of the trial they also need to say whether or not an 'X' was presented. A repeated finding in the literature is that subjects fail to detect the 'X' as a function of its distance from the white letter. Subjects most often miss the 'X' when it is presented very close in time to the white letter (within the first three or four letters after the white letter), and detect it more frequently as the 'X' is presented further away from the white letter. The hypothesis to explain these results is that the visual system requires some amount of time to process the identity of the white letter and during this time it is "blind" to any new stimuli that appear. Subjects can only detect the 'X' if it appears after the processing of the white letter has finished. This phenomenon has been dubbed the "attentional blink" because, although the subject's eyes are open, it is as if their visual attention briefly closes (blinks) and no new visual information passes into consciousness. If video game experience increases the speed with which information can be processed, one would predict a greatly diminished blink.

Figure 3 Attentional Blink Task



We tested eight VGPs and eight NVGPs on the attentional blink paradigm. As predicted, VGPs demonstrated a markedly reduced attentional blink (Figure 4). They showed full recovery (nearly 100% detection) after only 500 ms compared to approximately 700 ms for the NVGP group. The magnitude of the blink was also greatly reduced in the VGP population. Their minimum detection rate was approximately 70% at 200 ms, whereas the NVGPs minimum detection rate, also at 200 ms, was approximately 35%. Also of some interest is that more than half of the VGPs tested showed no attentional blink whatsoever, having perfect detection regardless of the distance between the white letter and the 'X'. This result indicates that VGPs can process a rapid stream of visual information with increased effectiveness as compared to NVGPs.

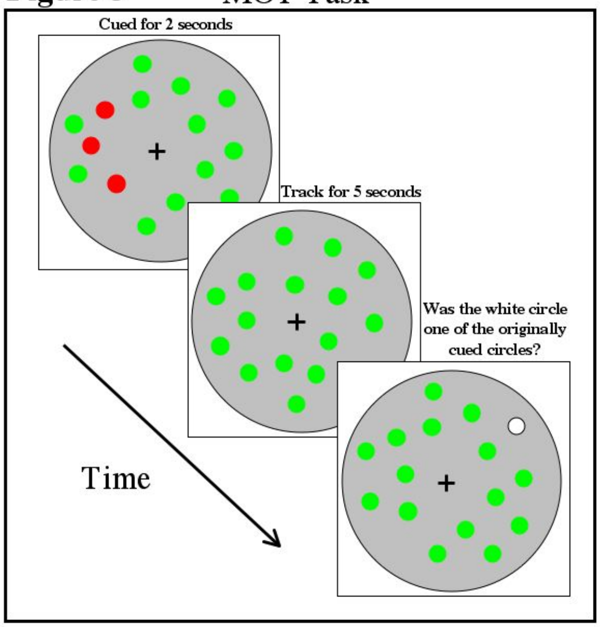
Figure 4



Having observed modifications to the spatial and temporal aspects of visual attention, we asked whether the capacity of the visual attentional system could be increased by video game experience. The average adult can only attend to two or three moving items at once, but in action video games, far more enemies than this often appear and must be engaged simultaneously. We therefore asked whether VGPs are able to track to more items at once than NVGPs.

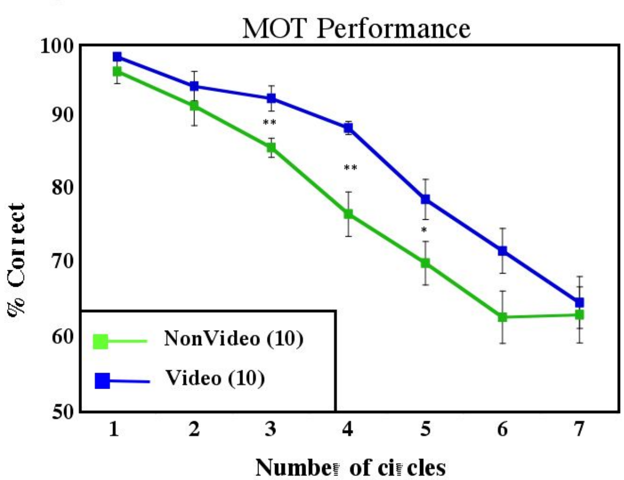
We measured the number of items that can be tracked by using the multiple object tracking (MOT) paradigm (Pylyshyn & Storm, 1988). This task measures the maximum number of moving items that can be successfully tracked within a field of distracting moving items. The number of items that can be tracked is thought to provide an index of the number of items that can be simultaneously attended and therefore of the capacity of the visual attentional system. Subjects are presented with sixteen circles that move randomly throughout the trial (Figure 5). At the beginning of the trial, most of the circles are green, but a small number of the circles (from 1-7 circles) are red. The subject is told that after two seconds the red circles will change to green (making them visually indistinguishable from the other circles) and that they will need to keep track of the circles that had been red. After five seconds of tracking, one of the sixteen circles changes to white and the subject must answer either "yes", the white circle was one of the initially red circles or "no", it was not.

Figure 5



Ten VGPs and ten NVGPs were tested on this paradigm. VGPs were found to be able to track approximately two circles more than NVGPs (Figure 6). At 90% correct, VGPs could track approximately four circles, whereas NVGPs could track only two. These results demonstrate that there is a clear enhancement in the number of objects that can be simultaneously attended in VGPs.

Figure 6



While in the preceding three experiments we have demonstrated that VGPs possess enhancements of several aspects of visual attention, these effects are only correlational. From them one cannot determine whether video game experience is truly driving the enhancements in question. Another possibility is that VGPs were genetically endowed with excellent visual attentional skills and thus enjoyed video games and played them often, whereas NVGPs were endowed with poorer visual attentional skills that caused them to be less successful and to tend not to play action video games. Therefore, to test whether video game experience is sufficient to cause the observed enhancements in visual attention, we first pre-tested a subset of NVGPs on the paradigms we have discussed thus far (the UFOV, the attentional blink, and the MOT). Half of the NVGPs were then specifically trained on an action video game, while half were trained on a control game. Following training, both groups were post-tested on the same paradigms. To assess the effect of action game training, we compared the difference in pre/post-test scores in the action game group and the control group. This comparison ensures that any differences we observe are due to the perceptual demands on the action game and not increases in perceptuo-motor coordination or test-retest improvements. On each of the three measures, the action trained group improved significantly more than the control group. This result definitely establishes that these three basic aspects of visual attention can be modified by video game experience.

Although our primary focus has been on the perceptual consequences of action game play, we are beginning to examine the potential for “higher” cognitive functions to be modified as well. Although many view video games as a rather mindless activity, today’s games involve far more than pointing and shooting. Many games require complex reasoning, creativity, and flexibility of thought to achieve the desired goals. For instance, given the goal of taking over an enemy base, one cannot generally run and shoot wildly and randomly and still hope to reach the stated goal. Instead, in order to be successful, a plan must be constructed that takes advantage of the available knowledge (given the pattern of the guards’ movement and defense structure, what is the appropriate point to enter the base, etc) and which can be flexibility updated when new information or goals are acquired (prior to entering the base the player thought it would be best to go to building A first, but now that he is inside, he realizes that it is actually better to go to building B). While in the future we hope to examine the potential for video game experience to enhance complex reasoning and decision making skills, as an initial foray into the field of cognition we chose to examine the capacity of working memory, or the ability to hold information in mind and manipulate it on-line. For example, adding 239 to 136 requires working memory as one needs to retrieve from memory the outcome of each simple addition and maintain that outcome as the remainder is carried over and the next simple addition is computed. Such working memory process is essential for reasoning and decision making(Conway, Kane, & Engle, 2003).

To assess working memory capacity we used a slightly modified version of the OSPAN task (Turner & Engle, 1989). In this task subjects are presented with a simple math problem and beneath the math problem a word. For instance:

“Does (3 x 2) – 2 = 4?”
Cat

The subject reads the math problem aloud, answers aloud yes or no, and then reads the word aloud. After they read the word, a new math problem and word are presented and the process is repeated. There can be anywhere from two to six pairs of math problems and words in a given trial. The subject is instructed that at the end of each trial they will be asked to recall as many of the words that were presented as possible.

Eleven VGPs and eleven NVGPs were tested on this paradigm. Consistent with the hypothesis that video game experience augments working memory, VGPs recalled on average 82% of the words, while NVGPs recalled only 70%. Furthermore, VGPs outperformed NVGPs at each of the five list lengths. A training study is currently in progress to determine whether training NVGPs on an action video game leads to similar enhancements in working memory capacity.

To conclude, we have demonstrated that VGPs process visual information more effectively over both space and time and are able to simultaneously track more items than NVGPs. VGPs also outperform NVGPs on a simple test of working memory capacity, suggesting the effects of action video games may not be limited to perceptual phenomena. The results of these experiments conclusively demonstrate that, contrary to its perception by many as a "mindless" activity, video game play is actually capable of substantially altering visual attentional processing as well as potentially augmenting higher-level cognitive functions.

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