The benefits of action gaming on cognition

Those who play video games frequently have long been assumed to have poorer cognitive capabilities than those who don’t play video games. Research suggests that those who play action video games for approximately five to fifteen hours a week have better attention, vision, and visual search capabilities performance than those who do not play action video games. Due to the societal myth of too much video game consumption being bad for users, it is worth exploring options within the sub-genre of action video gaming that show that motivational game based learning and training-induced cognitive improvements actually serve to mitigate the aforementioned consequences associated with playing video games. A number of cognitive measurements are explored in this literature review to show the gradual cognitive and perceptive improvements that can occur from playing action video games regularly. It is concluded that implementing more action video game play to provide cognitive training, especially in education, could result in the improvement of not only learning rates for students, but also learning rates for students who suffer from impairments be it attentional or visual.

This literature review will discuss the current research that exists on the effects of action video game playing and the benefits it’s been shown to have from various studies done on users’ cognition. With an estimated 1. 2 billion individuals playing video games worldwide (Bailey and West, 2013), the relevance and popular interest in both the positive and negative facets of gaming has generated much research interest (Kowal et al., 2018). This is why many forms of games, specifically action video games, are being utilized by cognitive scientists today to examine and further the understanding of neurocognitive functions when participating in the sub-genre of action video games. Studies that have examined perception and cognition have focused on ‘ action’ video games in particular because playing this type of game has garnered results in a wide range of behavioral benefits, including enhancements in low-level vision, visual attention, and speed of processing (Bavelier and Green, 2003).

Neuroplasticity is the ability to create and organize new neural pathways, which is the key to cognitive training, a tool which is currently being utilized by educators and health care professionals to expand their repertoire of therapeutic interactions with patients. (Kowal et al. 2018). Brain training is defined as the process of undergoing regular and repetitive mental activities to improve one’s cognitive abilities. Various tasks used to establish new neurak pathways in neurocognitive experiments in this literature review will discuss how cognitive training has the potential to improve a number of cognitive functions such as attention, vision, and processing speeds. Brain training as a tool is primarily used by neuropsychologists and psychologists, psychiatrists, and other medical specialists. But properly controlled brain training studies conducted by professionals have demonstrated a causal link between action video game playing and a result of enhanced cognitive abilities, showing that action gaming can serve to improve one’s cognitive performance through practice (Bavelier and Green, 2003). Action video games are fast-paced, motor skill-based games that are often rooted in situations that are violent and combat driven. Action video games are perceptually loaded, attentionally rich, and cognitively demanding which has been hypothesized as to why they seem to enhance a number of sensory and perceptual abilities in action video game players (AVGPs) versus non video game players (NVGPs) (Bavelier et al., 2014). According to this hypothesis, AVGPs may train different neurocognitive abilities at an increased capacity when gaming to process information when compared to NVGPs (Clark et al., 2011).

First, it is essential to understand an action video game is defined as a form of a digital game which centers on physical challenges, often times these involve making kills, beating other teams, or taking over territories. The physical nature of action video games requires players to use many elements of cognition and perception such as hand-eye coordination, reflexes, fast processing speeds and reaction and response times (Castel et al., 2005). The field of action gaming is vast, but almost all action video games require similar keys to success, quick responses and a fair amount of attention allocation. Some of the most popular varieties of action games on the market are first person shooters (FPS), third person shooters (TPS), and massive online battle arenas (MOBA).

The effects of action gaming on AVGPs neurocognitive abilities involves a multiplicity of discourses. Currently, cognition and perception are being researched through the phenomenon of action video gaming. This is worth studying because action video games are becoming increasingly popular and strongly support evidence that exposing a user to altered visual platforms or systems, like action video games, has a way of training and modifying cognition and perception (Bavelier and Green, 2003). Some of these forms of abilities that are changed due to training with action video games are attention, vision, mental rotation, response time, visualization, top down and bottom up processing speeds, object tracking, task switching, decision making speed, and visual searches. Specifically, it is these measurable phenomenon that have created an emerging area of interest for how action video games seem to exercise cognitive abilities and additionally provide cognitive training at these tasks to increase performance(Kowal et al., 2018). Playing action video games trains different cognitive abilities which results in increases in performance that have been found in those who play action video games versus those who do not play action video games. (Spence and Feng, 2009) Because of the demonstrated causal relationship that has been found in testing AVGPs of all ages including children, young adults, and the elderly, there is significant interest in how the use of action video games can be used for rehabilitative, educational, or cognitive training purposes. (McDermott et. al., 2014) The ability to improve one's abilities through training has yielded results, especially in AVGPs who suffer from low level vision afflictions.

Daphne Bavelier, Shawn Green, Doug Han, Perry Renshaw, Michael Merzenish, and Douglas Gentile are six experts in neuroscience interested in how the brain learns, and improving the brain's processes when researching the way the brain responds to playing action video games in their article " Your Brain on Video Games". Bavelier et al. argues that action video games, if used appropriately, can have beneficial effects on the brain, in particular, vision. Bavelier et al. argues if monitored and applied appropriately, the playing of action video games can have positive cognitive effects on the brain. Although it is said that too much exposure to screens makes eyesight worse, those who play 5-15 hours of action video games a week actually scored better on vision capabilities when tested than people who don't play action video games (NVGPs). Bavelier et al.'s studies found that action video game players (AVGP) have better abilities than non-video game players when it comes to deriving details. This includes deriving detail in an environment of clutter, or being able to resolve different levels of gray – both of which are often required in one of the action video games Bavelier et al used in their study called *Call of Duty: Black Ops* . In addition to using low lighting settings, " action games include high speed, high perceptual and motor load, unpredictability and an emphasis on peripheral processing" (Bavelier et al., 2011). For these reasons, Bavelier et al. is in the process of developing games for patients with low vision abilities in order to retrain their cognitive processes to improve their vision and use their vision at enhanced rates.

Daphne Bavelier and Shawn Green's research from 2003 in " Action video game modifies visual selective attention" addresses the longstanding quarrel of video games leading to attentional deficit problems or greater distractability. Bavelier & Green continued to explain that AVGPs, with training induced increases in performance, have stronger visual skills than NVGPs. Visual skills and visual attention were tested by asking AVGPs when in their experiment they were asked to solve a flanker compatibility task and a attentional blink task, both of which are a measure of attention. A flanker compatibility tesk measures attention with the efficiency of which targets are selected or determined irrelevant and purposefully ignored. An attentional blink task is when there are two targets, and participants are asked to keep track of both but the second target cannot be detected or identified when it appears, because it appears so close in time to the first target. AVGPs were able to perform both of these tasks better than non-video game players, because they had trained up a greater attentional capacity through frequent action video game playing. At levels where NVGPs had depleted their attentional resources, AVGP still had enough attentional resources to perform the target tasks, implying AVGP enhanced attentional and visual capacity and the ability to avoid bottlenecks of attention that occur when processing too many items at once. AVGPs also showed their attention is responsible for improved ability to track objects, which is critical to surviving in combat based games such as first person shooter action games.

Similar to Green and Bavelier's tasks, the studies of Daniel Brooks, Heida Sigurdardottir, and David Sheinberg's " The Neurophysiology of Attention and Object Recognition in Visual Scenes ", whichdiscussed experiments where monkeys were rewarded for identifying a target object presented with an array of several distracter objects while the monkey maintained central fixation. (Brooks et al., 2014) The idea behind the experiments was to perform a visual search task which focused on the ability to select a region of space in the context of a simple environment, to do this monkeys were given colored patches or lines in various directions. The critical component of the study was how the frontal and parietal lobes contributed to this cognitive process of recognizing the object within the process of selective attention. The region of the dorsal or visual stream is interconnected with areas of the frontal cortex involved in the allocations of attention (Brooks et al., 2014). Brooks et al. discovered that locations of objects might be prioritized so that neural machinery in the ventral stream is mostly used to process objects that are deemed most important. Brooks et al.'s research found that people search more effectively through scenes with familiar distracting objects than through scenes with distracting objects that are unfamiliar (Brooks et al., 2014). Visual information from a scene that reaches the primary visual cortex is therefore already processed in a manner that accentuates features that are important for finding and segmenting objects in scenes (Brooks et al., 2014). What can be concluded from this study on visual searches and spatial attention is that video game players pay closer attention to detail, and therefore have enhanced vision capabilities that makes them adapt at evaluating scenes, even those of a complex or dangerous nature.

Further supporting Bavelier's claim that AVGPs tend to outperform NVGPs on a variety of attentional and perceptual tasks was the research of Kait Clark, Mathias Fleck, and Stephen Mitroff. Clark et al. in " Enhanced change detection performance reveals improved strategy use in avid action video game players" addresses bottom-up and top-down processing skills utilized in action video games. The research experiment by Clark et al. used a change-detection task to explore whether top-down strategies can contribute to AVGPs improved processing abilities. The change-detection task had AVGPs view alternating presentations of an image and a modified version of the image and were then asked to identify the changed elements on the image. Consistent with prior claims of enhanced perceptual abilities, AVGPs were able to detect the changes while requiring less exposure to the change in the image than NVGPs. This improved change detection performance resulted from a improved processing strategy, something Bavelier suggests AVGPs do exceptionally well. This is because of AVGPs keen processing and attentional performance but also due to the fact that they employed broader search patterns when scanning scenes for potential changes. These results complement prior demonstrations of enhanced bottom-up perceptual benefits by providing new evidence of video game players' potentially enhanced top-down strategic benefits (Clark et al., 2011). What can be gathered from these studies are that AVGPs search more thoroughly than NVGPs, leading to better change detection performance (Clark et al., 2011). Clark et al. argues for the necessity of process tracing approaches such as think-aloud protocols, retrospective reports, and eye movement recordings to eliminate other explanations for gaming effects, so that cognitive scientists will have more definitive answers to the benefits of video games on cognition. With definitive answers in hand, these approaches can be implemented in classrooms to better aid students at not only processing new information but also improving their learning rates, similar to the way new stimuli showed the effects of improved processing speeds in AVGPs vs NVGPs in this cognitive task.

Alan Castel, Emily Drummond, and Jay Pratt in " The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search" conducted research on AVGP's and their abilities of information processing, which yielded results that AVGPs have better visual selective attention than NVGPs. This was accomplished through reflexive cueing by a flanker compatibility task, like that of Bavelier and Green's study. A flanker compatibility task measures the attention of subjects when presented with distractors and a target in a visual search. NVGPs suffered more of a distraction effect than AVGPs when performing a visual search, where as AVGPs had more attentional resources when performing higher level difficulty visual searches. By measuring eye movement throughout the experiment of both NVGPs and AVGPs, subjects responded to the targets that would appear in the game by pressing the space bar. The results were that AVGPs proved to have not only faster response times for both easy and difficult visual search tasks, but they also were also attributed to being able to perform faster stimulus-response mapping. Given the need for rapid responses in action video games to stimuli, Castel et al. suggests that playing video games may improve one's attentional performance and motor responses. By incorporating more action video game play regarding essential subjects in the field of education, students can benefit not only from a new interactive way to learn, but with enough repetition students could likely improve their attentional resources like AVGPs have due to cognitive training.

Patrick Cavanagh's and George Alvarez's " Tracking multiple targets with multifocal attention " examines their research on how attention can be divided through their studies on multiple object tracking. Because the ' object' is suggested to be the primary unit used for tracking, Cavanagh and Alvarez's research had subjects keep track of 4-5 target objects that moved around and bounced off each other within rectangle. Cavanagh and Alvarez's study presented target items in a rectangle and asked participants to determine if objects shown at the end of the trial were one of the target items that were moving around inside the rectangle (Alvarez and Cavanagh, 2005). Cavanagh and Alvarez used the multifocal model of attention for tracking, which relies on the idea of individuals only being able to give objects individual attention. But Cavanagh and Alvarez suggest individualized attention is not the only form of attention, but rather attention can have more than one focus, such as tracking multiple objects at a time. With even the earlier models of attention, selection, tracking, end encoding can be seen through the use of *object files* , which are descriptions of bookkeeping functions of attention, " If attention can be deployed to multiple objects, then clearly the information encoded for each would have to be maintained separately, as is the case with object files" (Alvarez and Cavanagh, 2005). Therefore their findings suggested any target must be attended to with either multifocal attention or switched attention, if targets are not attended to it's easy to mix them up with distractors when tracking. Alvarez and Cavanagh's research suggests that the multifocal attention model holds up as the most plausible for how AVGPs can perform tracking of multiple target objects at once. These findings on multifocal attention and tracking are comparable to the findings of Bavelier and Green's, and Clark et al. on attentional processing when playing video games. Ultimately AVGPs were able to keep track of more objects and proved to have higher attentional skills due to their experience with cognitive training (playing action video games).

Chien-Heng Lin and Chien-Min Chen conducted a study " Developing spatial visualization and mental rotation with a digital puzzle game at primary school level " using puzzles and spatially designed video games for further insight into the way cognitive spatial abilities affect children at a primary school level. Focusing on spatial visualization, which is the act of imagining movements of shapes or objects and mental rotation, which requires rotating objects in 2D or 3D, Lin and Chen tested subjects with traditional puzzle games and the video game they designed. Their design for their game targeted practicing mental rotation and visualization to further stimulate spatial abilities because ways for children to build these abilities are scarce in the educational system, as are video games that utilize these spatial skills. Subjects were composed of two groups playing different games, the first group played the traditional jigsaw puzzle game and the second played the spatially designed puzzle video game. The results of the study showed those who played with traditional puzzles had good visualization skills but those who played the video game had exceptional visualization and mental rotation speeds due to cognitive self-training. Subjects who played the digital puzzle video game had improved spatial visualization, this is because they had to both rotate and imagine the movements of the object (a cube) within a block diagram. “ Spatial abilities, such as mental rotation and spatial visualization, show a very significant growth after a short span of time in the use of the digital games” (Lin and Chen, 2015). Although not all digital games will improve cognitive abilities, the digital puzzle video game resulted in being an effective training tool for improving cognitive capabilities, findings that echo the benefits of action gaming on cognition such as those of Bavelier et al., Clark et al. and Castel et al.

Daphne Bavelier, Rebecca Achtman, Mahalingam Mani, and Julia Föcker’s study on “ Neural bases of selective attention in action video game players ” suggests that AVGPs are better at filtering and process attention allocation more automatically than NVGPs. Bavelier et al.’s research tested subjects who either played action video games or control games, in the study subjects were presented with square and diamond targets as well as other shapes for distractors. Subjects were asked to keep track of squares and diamonds in both a low cognitive load setting and high cognitive load setting to measure reaction times and distractor suppression abilities. The findings revealed by using brain imaging suggest that selective attention as well as divided attention is enhanced in subjects who frequently played action video games. (Bavelier et al., 2012). NVGPs were more disrupted by distractors in their visual periphery when performing a visual search task at a high load, where as AVGPs attentional processing was more efficient in suppressing distractors in a high cognitive load. Echoing the thoughts of Castel, Pratt, and Drummond, enhanced nuerocognition capabilities speak for themselves by the attentional resource allocation that can be found in AVGPs in comparison to NVGPs.

In Magdalena Kowal, Adam Toth, Chris Exton and Mark Campbell's study " Different cognitive abilities displayed by action video gamers and non-gamers ", they investigate whether AVGPs have an advantage over NVGPs when it comes to task switching, visuomotor coordination, processing speed, working memory and attentional control (Kowal et al., 2018). Kowal et al. tested these theories by using two cognitive tests: the stroop test and a trail-making test (TMT). The stroop test, examines the subjects ability to focus on a task while also suppressing irrelevant distractions, the trail-making test examines visual search speed, and tracking skills (Kowal et al., 2018). The results of Kowal et al.'s research is that AVGPs had faster responses in the TMT task, and on average had fewer mistakes between both cognitive tests. On the stroop task in particular AVGPs showed alternative task strategies which prioritized response speed over accuracy, similar to the findings on speed accuracy trade-off reported by Mcdermott, Bavelier, and Green in 2014 (Kowal et al., 2018). Overall, this speaks to AVGP’s as having better executive functioning and accentuates previous findings on AVGPs excelling at visual search tasks (Castel, Pratt & Drummond, 2005; Green & Bavelier, 2003).

Action video games can have beneficial effects on the brain, Bavelier and Green’s work shows some of these benefits coming from playing action video games as better attention, vision, and visualization/visual searches. Lin and Chen’s study involving digital and physical puzzles shows the capabilities of those who game experiencing improved mental rotation, and Kowal et al.’s research highlights the improved tracking abilities of gamers through various cognitive tests. Research by Brooks et al. further states object recognition and selective attention improves through video game playing, and research performed by Clark et al. and Castel et al. also supports these theories of improved processing capabilities through attentional performance and motor responses. Lastly, Alvarez and Cavanagh’s findings on the logistics of attention, particularly on multifocal attention, supports the idea of AVGPs having enhanced cognitive abilities when compared to standard single attention tasks in NVGPs. Because of the high stakes environment of action gaming in particular, many participants in the covered studies actually became better at various cognitive skills as a result of their exposure and repetitive training with action video games. Increased attention, vision, visual search skills, and response times, in addition to mental rotation found when comparing AVGPs and NVGPs speaks to the fact that not all video games have degenerative effects on cognition. The cognitive tasks covered from the current research on the effects of action video games shows that the implementation of more action video games could benefit students of all ages, including those with poor vision, attention, or motor responses. These post-test gains from a multiplicity of studies speaks to the possibility of implementing action video games as not only a motivational way to learn, but a tool for rehabilitative education when it comes to training induced increases in cognitive performance

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