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TRAINING ATTENTION WITH VIDEO GAMES

How playing and training with video games impact attentional networks

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Abstract

Video games as an entertainment form are very popular. Understanding what video games do to us in a long-term and short-term manner is therefore of interest. Attention is a widely studied field and research into how attentional networks are affected by video is a research field on the rise. Here, I will be investigating how video game play affects our attentional networks and if it is possible for elderly individuals to train their attentional networks with video games. Video game players have high performance in reaction time and accuracy in different attentional, working memory, and cognitive control tasks. As the difficulty of video games increase video game players seem to more efficiently utilize their attentional networks. Whilst some articles cannot replicate findings in other articles this irregularity might be explained with by level of difficulty or load during task performance. Studies see group differences only when the task difficulty is high. Therefore, an important part of video game research is to find an effective and replicable standard for video game research. Measuring video game play with EEG shows that players better can forgo distracting stimuli in central and peripheral view and discriminating stimuli giving video game players more confidence when making decisions. Video game players also seem to have more efficient processes and functional connectivity in attentional networks but utilizing these networks more as non-video game players as mental load increases. Not only does video game players have more efficient attentional networks, but attentional benefits from video games is also something that can be trained with those who do not play video games. Suggesting that older individuals can utilize video games to train attentional networks.

Keywords: Video games, Attention, EEG, Video game training

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Introduction

Video games are a highly popular form of entertainment. What was once seen as children's entertainment is growing in its demographic with the average age range of video game players in the United States of America being 35-44 years old (The Entertainment Software Association, 2020). The number of people who are said to play video games is just in the United States of America alone more than 214.4 million people and the number of people playing is rising with hours spent playing daily increasing (The Entertainment Software Association, 2020). With the advancements in digitalization and technology computers, tablets and smartphones are more available to a broader audience and with-it populations exposure to casual video games. Media outlets, such as news outlets, help to portray video games as having a positive or negative effect on aspects of behaviour and overall health.

With research on video games still in infancy, unequivocal claims of effect might just be bold claims or sensationalism. Nevertheless, it is obvious that video games are an important topic in everyday life. Video games as a medium have also gone, and are still going, through several stages of development and are rapidly changing how it is played and what video games entail. With technological advances, video games have become more complex with several different genres that often borrow from each other. One video game does not need to belong to one game genre like role-playing or shooter but can contain several genres, and with the advancement of virtual reality video games have also propelled themselves into new ventures. Gone are the times when text-based adventures were prominent.

It is therefore understandable that exposure to video games is a topic of interest when knowing long-term and short-term effects on behaviour and cognition. What are the effects of commercial video game use and is it possible to use video games as training in scientific environments and experiments? This increasing interest can be seen in the number of scientific texts published, approximately 49 in 2000 compared to 858 in 2017 (Medline, 2020; when using the search phrase 'video games' OR 'computer games').

Attention is a widely studied field, however, containing several different definitions over different fields of study. Attention is not a clear concept and Hommel et al., (2019) even claim that “No one knows what attention is” (p.2288). Ironically, since James (1890) already wrote that “Everyone knows what attention is. It is the taking possession by the mind, in clear, and vivid form, of one out of what seems several simultaneously possible objects or trains of thought.” (pp.403–404) Traditionally though attention can generally be defined as control over limited resources, where there is an ability to alter and route informational flow (Lindsay, 2020). Understanding our attentional networks and how attention mediates learning, memory, and cognitive control can be vital for solving puzzles involving, for instance, memory deficits and declines.

In beginning to understand video games, their effects on behaviour and their neural correlates a good place to start is investigating how video games and attention relate to one another and how video game play affects attentional networks. It is therefore the aim of this paper to investigate 1) what benefits video games can have on attention, as measured by EEG and behavioural task performance, and 2) if attentional networks can be trained with video games and if elderly individuals can improve and train their attention with video games.

What is Attention

The world around us contains a vast amount of information. How can some of this information be selected by the brain and how does the brain know which information it can forgo because it is not important? This is the key question of attention.

In its most general form attention has been described as a level of alertness, arousal or vigilance. Arousal referring to the sleep-wake rhythm and, with vigilance referring to one’s ability to sustain one’s attention (Lindsay, 2020). In this way, participants can be measured on their sleep-wake cycle (arousal) when given sedatives or when deprived of sleep. Or tasked with continuously and repetitively tend to a task, that is to stay vigilant.

Here, however, I will focus on selective attention, that is processing relevant information and ignoring distracting, non-relevant information. Selective attention can be divided into endogenous and exogenous attention. Endogenous (or top-down) attention is our goal-oriented voluntary process where we intentionally attend to information. Exogenous (or bottom-up) attention is the reflexive, stimulus-driven process where the stimulus itself captures our attention (Lindsay, 2020; Posner, 2008).

Measuring Attention

The easiest way of explaining the difference between endogenous and exogenous attention is by describing how to measure them. When asking a participant to respond as fast as possible to a target location the participants' response is faster when we correctly suggest or cue where the stimulus will appear. This is called endogenous cuing and works by letting the participants covert attention focus on the suggested location of the upcoming target (Posner, 2008). The participants will themselves shine a sort of covert (not visible to others, without moving eyes for instance) mental spotlight on the predicted area, when the cue and target match in location participants react faster.

One way of measuring exogenous processes is via exogenous cuing where participants most often must deal with an irrelevant, distracting stimulus. Here the irrelevant stimuli will cause an automatic, overt (observable, by moving for instance eyes towards a target) orientation (Posner, 2008). The participant's mental spotlight will reflexively shine on the irrelevant stimuli causing participants to lose time and mental capacity to regain focus.

This might still beg the question though of how some information is selected as important and some information is not processed because it is not important. How attention searches the environments can give an answer to this? For example, I have a bright pink suitcase, when traveling my suitcase is easy to see at the airport baggage claim. Amongst the, often, dark coloured suitcases the pink colour grabs my attention more easily than if my suitcase was the same colour as everyone else's. This example describes how generally visual search paradigms work. Treisman and Gelade (1980) discovered that subject's search time decreased when a target easily was identified by a single feature. But when targets share features this visual search takes more time and mental resources. We, therefore, see that not only can attention search for the location of stimuli (spatial attention) but also features of stimuli (feature-based attention).

From these studies, more attentional tasks have been made to test different aspects of attention. For instance; Flanker compatibility effect, a standard paradigm for attention studies measuring the effect a distractor has when it must be ignored; Enumeration task, where participants had to report the number of items they could see, and therefore attend to; Useful field of view (UFOV) task, where participants must identify a target amongst distractors / eccentricities; Attentional blink task, where two targets in rapid succession are presented where the second target disappears with the rapidness of the task. Measuring a temporal aspect of attention.

EEG and Attention

Attention has been measured in several ways. One of these measurements is electroencephalography (EEG) a measurement in which electrical brain activity is measured via electrodes on the participant's scalp. To see how a stimulus (or events) are perceived by EEG several recordings of an EEG are put together into an Event-related potential (ERP). In this way, multiple noisy activities in the brain can be filtered into an average waveform from several stimulus trials. This waveform will have different components that relate to attention.

The P200 (or P2) and P300 (or P3) components are positive peaks in the ERP waveform that occur 200ms and 300ms respectively after onset stimuli. The P300 component being shown over decades of research to be specifically elicited by the delivery of task-relevant information (Polich, 2007). Whilst P200 reflects more the amount of resources allocated and is connected to processing that seems to be modulated by attention (Luck & Hillyard, 1994a).

The N2pc is an ERP component connected to selective attention. N2pc stands for Negative-2-posterior-contralateral (N2pc) and refers to a negative polarity that occurs ca 200ms after onset stimuli. Compared with the P200 and P300 components, however, this component is visible in posterior electrodes, contralateral to the attended stimuli. That is if a stimulus is attended to in the right visual hemisphere this component should be seen in the left hemisphere. The N2pc component is thought to be linked to selective attention, specifically target selection and distractor inhibition (Luck & Hillyard, 1994b).

Steady-state visual evoked potentials (SSVEPs) is a response to visual stimuli in the peripheral view. Studies showing that the amplitude of the SSVEPs is increased when a stimulus is attended to (Toffanin, de Jong, Johnson, & Martens, 2009).

Alpha and Theta rhythm are two prominent EEG features. These are sensitive to mental effort variations (Gevins, Smith, McEvoy, & Yu, 1997). During continued sustained mental effort and focused attention, theta rhythm increased as task difficulty increases. Whilst the opposite effect can be seen with alpha rhythm where amplitude decreases when the task increases in difficulty. However, as practice on a task increases both the theta and alpha signal increases in amplitude. This would imply that the more a subject practice in a task the more effort is needed to maintain attention to the task (Gevins et al., 1997).

Attention in Elderly Populations

For the older population when performing some attention-related tasks (like the visual search task) they often perform slower and less accurately than younger subjects. It seems as if there is some decline in exogenous processing but at the same time, endogenous processing is increased for older subjects. What this exactly means is not fully understood but it seems as if the older you get the more reliance is made on endogenous attentional networks (Madden, 2007). Age-related decline in attention can also be seen when measuring multitasking performance. With a non-commercial video game, NeuroRacer (a three-dimensional custom-designed video game) participants between 20 and 79 years old were measured in their individual multitasking performance. As age increased performance decreased in a linear fashion (Anguera et al., 2013).

Video Games and Attention

When Green and Bavelier (2003) attempted to investigate video games effect on attentional networks they found that those participants who had experience playing video games (that is had played an action video game at least one hour per day four days per week) performed better during visual attentional tasks when compared to participants who had little or no video game play. This effect was found when participants (18-23 years of age) performed four different tasks: Flanker compatibility effect; which showed that video game players are better capable of discarding distractors even as task difficulty rises. Enumeration task; where video game players were able to attend and keep in mind a larger number of visual items. Useful field of view (UFOV) task; showed video game players outperformed in all eccentricities meaning spatial attention across the visual field was enhanced, even in areas that were untrained. Attentional blink task; in which video game players more correctly identified a second target meaning video game players had less attentional blink.

Furthermore, when training (that is training for 10 consecutive days, one hour per day) non-video game players in either Tetris (a puzzle game) or Medal of Honor (a first-person shooter action game) those who trained with the action video game outperformed on post-test enumeration task, UFOV task and, attentional blink task when compared with the participants who trained with the puzzle game (Green & Bavelier, 2003). This means that video game players who played video games for at least one hour per day, four days per week over the last six months showed a capacity to better ignore distractors during visual attentional tasks and, also, the non-video game players who trained (especially those who trained with an action video game) showed to have this capacity (Green & Bavelier, 2003). It, therefore, seems that not only are video game players better at allocating attentional resources but playing video games resulted in this superior performance. Meaning that training in a video game with a high pace and multiple distractors would help adult participants with performance in attentional tasks.

After Green and Bavelier (2003) findings more studies focusing on (action) video games' effect on attention emerged. These studies had a similar structure to Green and Bavelier (2003) where participants are divided into video game players and non-video game players and performed different attentional tasks. For instance, using a visual search paradigm, with alternating low and high load, with distractors (static or moving) action video game players had faster reaction time than non-video game players (Bavelier, Achtman, Mani, & Föcker, 2012). Going from low demanding task to high demanding task showed in both video game players and non-video game players an increase in reaction time with about 70ms. However, video game players had a faster reaction time than non-video game players in both the high and low load conditions. Video game players showed that their performance accuracy did not change whether distractors were visually presented peripheral or central, whilst for the non-video game players a slight loss of accuracy could be seen for visual distractors presented in peripheral view. Meaning that distracting stimuli in the peripheral view disrupt non-video game players more than for video game players.

In another study, participants performed a combined visual search task with a working memory task. Whilst a visual search task was performed one, two or, four items were asked to be kept in working memory, with the different amounts of items kept in memory working as different loads. The performance and eye movement were recorded, and it was found that participants in the action video game group could more easily suppress exogenous cues or distractors (Zhang et al., 2020). In the low working memory load (load one) this effect was greater in the action video game group than the non-video game group and when load increased to two this effect was still present in the action video game group whilst disappearing in the non-video game group. It seems therefore like action video game players are better at allocating top-down resources to keep attention to the task at hand and maintaining cognitive control (Zhang et al., 2020).

Antzaka et al., (2017) in an visual attention span tasks (global and partial report (with a single letter identification control task)) and a pseudo-word reading task could see that in the global report task (where participants reported all letters from 24 6-letter strings) the action video game group were able to identify more letters than the non-video game players (Antzaka et al., 2017). Not only did participants in the action video game group perform in a similar performance as the non-video game players with identifying the three first letters (that is the letters in position one, two and, three) they were able to identify letters more accurately at positions four, five and, six (Antzaka et al., 2017). For the partial report task, where participants were presented with 72 six-letter strings, they were asked to identify one letter of six. The action video game group was again better at identifying letters than the non-video game group and this performance enhancement could be seen for all six positions. The pseudo-word reading task was performed by letting the participants in the action video game group and the non-video game group read out loud six-letter pseudo-words that were presented to them briefly. The action video game group again performed better and was a lot better at reading the pseudo-words than the non-video game group (Antzaka et al., 2017). These results show that participants in the action video game group had better visual attentional span and were able to more accurately attend to the words, further suggesting that action video game players are able to process multiple elements at the same time. This could mean that players of action video games can have better reading skills.

One can see that experience in video games showed an enhancement in working memory as well. Video game players showed better performance accuracy and as the task increased the working memory load performance was, in contrast to non-video game players, not as affected by this increase (Moisala et al., 2017). Behaviourally, video game players then seem to affect working memory in the way of helping identify and remove distracting factors and recover from shifts in attention. Contrary to, Green and Bavelier (2003) however, Moisala et al., (2017) saw no clear distinction between video game genre when it came to task accuracy and reaction time.

No Attentional Gains and Load

Not all studies find beneficial gains from playing video games though. Jacques and Seitz (2020) investigated perceptual learning and how perceptual learning is affected by differences in attention and by action video game play. Participants were asked to perform a UFOV task (as previously mentioned a measurement of visual attention). The participants were after this trained in Texture Discrimination Task (TDT). The TDT is a measure of visual perceptual learning in which subjects respond to a central stimulus whilst also identifying the direction or orientation of a stimulus in peripheral view. Jacques and Seitz (2020) found that participants with high performance on the UFOV task also performed better in the TDT. Meaning that those individuals who showed high visual attentional performance also showed high performance in visual perceptual learning. However, strong relationships between TDT and action video game players, and between UFOV tasks and action video game players were not found (Jacques & Seitz, 2020). That is, contrary to findings in for instance Green and Bavelier (2003), action video game play did not affect visual attention. It also did not affect perceptual learning.

Trying to replicate findings in Green and Bavelier (2003), Boot, Kramer, Simons, Fabiani, and Gratton (2008) used two experiments; 1) a cross-sectional group, comparing (expert) video game players with non-video game players and 2) a longitudinal group, comparing results if training non-video game players in different game genres. For the longitudinal experiment, they were randomly divided into four training groups; Action game (Medal of Honor), Strategy game (Rise of Nations), Puzzle game (Tetris) and, a non-practice control group (Boot et al., 2008). The longitudinal groups trained in their respective game for approximately 21.5 hours over a four to five-week period. Cognitive tasks were performed at three points before participant's training started, half-way through video game training, and, lastly after training was completed. The cross-sectional group only performed cognitive tasks once. The cognitive tasks were selected based on testing participants executive control, visual and attentional abilities and, spatial processing and memory.

Video game players in the cross-sectional experiment seem to perform better with tracking high speed moving objects, switch from one task to another, more effectively rotate objects mentally and, observe changes to stored objects in visual short-term memory (Boot et al., 2008). However, contrary to Green and Bavelier (2003), after ca 20 hours of video game training, participants who trained in a video game did not enhance their performance when compared to the untrained control group (Boot et al., 2008). However, those individuals who were trained with the puzzle game Tetris, showed better mental rotation performance than other groups.

More have tried but are not able to replicate Green and Bavelier (2003). Tsai, Cherng and Chen (2013) cannot see any significant group difference for participants given the same tasks as participants in Green and Bavelier (2003), i.e. Enumeration task, Multiple Object Tracking, Attentional blink and, an additional test, Attentional Network Test.

These results from Jacques and Seitz (2020), Boot et al., (2008) and Tsai et al., (2013) seem quite contrary to what has been discussed earlier on in this paper, where clear results are shown. An answer to this irregularity of results could be answered in Moisala et al. (2017) where a clear difference can be seen in how the behavioural and the neural correlates/areas in the brain react within the task performance. Video game players or participants who have undergone video game practice show different/higher activation in attention and working memory related areas when the difficulty or load of the task increases.

Common for studies mentioned above is the higher performance results for the participants depending on difficulty of task, or amount of load. For instance, Strobach, Frensch, and Schubert (2012) can see this in the higher performance for video game players in dual-task and task switching, but during single task performance no advantage in performance was seen in comparison with the control group. Moisala et al. (2017), Bavelier et al. (2012) and Green and Bavelier (2003) all contain certain forms of load conditions where clear advantage could be seen the more difficult the task became. None of the articles mentioned in this paper except one have brought up the subject of game difficulty. For Anguera et al. (2013) the video game NeuroRacer is used and the game contains in game features like an adaptable game difficulty. This is because the participants might be at different levels of proficiency with the game, an adjustment of the difficulty so that the gameplay always is at a challenging level for the participant could be an important key feature to why we see irregularities between performances.

Importance for Consistency and Standardization

It might also be that the differences in results (for example Moisala et al. (2017) cannot see an difference between video game genres in performance, Green and Bavelier (2003) see a larger effect in performance in action video game players and, Jacques and Seitz (2020) see no effect of action video games on attention) occur because of a lack of standardization in how video games should be studied and classified. Often the phrase video game, as mentioned in the introduction, refers to the different aspects of video games. The term video games can include commercial and non-commercial games, differences in genres and in intensity. An simple example of how easy it is to confuse the description of what one is measuring is can be seen in Bavelier et al. (2012) where it is described as an criteria of action video games that it is played from a first-person perspective, but one game in the abbreviated list is Gears of War, a third-person perspective game. This simple mistake will have no impact on the results in the presented article but in the long run mistakes like this can confuse and/or misguide the reader to which aspects of video games one is measuring. The reasoning for this is that we do not yet know the different challenges of going from a virtual third dimensional space from a first-person perspective to a third-person perspective. First-person perspectives are narrower whilst usually a third-person perspective gives a broader field of vision. Bediou et al. (2018) to clarify and create a standardization of action video games suggests four aspects that should be considered in describing an action video game. Qualitative features that are shared between all action video games: 1) they are fast paced, 2) high degree of load, 3) switching between high focused state of attention and a distributed state of attention and, 4) high number of degrees of distractors. This is a good start but the qualitative features of what kind of game this entail are not clear enough. Contra (1987) is a two-dimensional run and gun, shoot 'em up kind of game. Contra is seen as a difficult game with a high number of attend-to stimuli. It might be possible that this video game lives up to the description above but usually the description Bediou et al. (2018) puts forward of what an action video game is describes a first-person shooter or a third-person shooter. A two-dimensional video game would have a different set of mechanics and one might not fully understand the difficult step from two dimensions to three dimensions. Also, video games evolve at a quick rate, since the start of its introduction into cognitive psychology video games have diversified and a significant cross-pollination has occurred within video games genres. Whilst one could easily distinguish between the different genres 30 years ago (based on the small sets of common mechanics in the different genres) today there have been an increase in the amount of genres that a video game can entail, furthermore video games are using several of these genres and blending the mechanics between them to create hybrids, intertwining the different genres and mechanics. For instance, a popular combination has been between the role-playing game mechanics and the shooter game mechanic (see Mass Effect or Borderlands). With research often using the classically named game genres as an indication on how to classify a game the impact the broadening and complex nature of video games will have will be severe. How would one compare an action video game 30 years ago with a simple small set of mechanics with a current complicated large set of mechanics in a video game where some of the mechanics are reminiscent of the mechanics determined by the Action genre? Even further, how would we set apart the different parts without creating a game by game basis of the effects on human cognition.

It is also important to note that the characteristics of what constitutes a video game player is seen differently depending on which study one explores. Most often a questionnaire that establishes the amount and duration and participant plays video games. This questionnaire might, as in Bavelier et al. (2012) be specifically designed to measure action video game use in the participant. For Bavelier et al. (2012) participant questionnaires only determined action video fame play thus in the non-video game player group there might have been participants that did play other genres of video games. It might be a reason to why a lack of decreased reaction time effect can be seen (i.e. that for Moisala et al. (2017) one could see that reaction time between high and low condition did not affect reaction time as much as for non-video game player groups).

EEG Studies of Video Games and Attention

When comparing video game players with non-video game players, in a targeted spatial and temporal selective attention demanding task, video game players had better performance in speed and accuracy in comparison with non-video game players (Mishra, Zinni, Bavelier, & Hillyard, 2011), both in central and in the peripheral visual field. Also, video game players showed greater suppression in comparison to non-video game players when measuring SSVEPs of rapidly flashing distractors (Mishra et al., 2011). Attending to distractors cause larger SSVEPs but these were smaller in video game players than in non-video game players, showing that video game players better can suppress peripheral stimuli. The attention related SSVEPs is determined to lie in the ventral lateral extrastriate visual cortex and the amplitude of the SSVEP correlates strongly with participants reaction time to target stimuli (Mishra et al., 2011). This suggests that video game players have an advantage with detecting targets when under high load meaning that video game players can more easily suppress irrelevant distractors already in the extrastriate visual cortex.

When target was attended to and task is under high load, video game players ERP component P300 was larger than in non-video game players (Mishra et al., 2011). Video game players therefore seem to have ease of stimuli discriminating and making decisions. Seemingly giving the person more confidence in their decision making.

When compared with non-video game players a first-person shooter action video game group improved both in 20^{o} and 30^{o} eccentricity (Wu et al., 2012). However, a difference could be seen within the group itself. Some of the participants showed to have a different P200 and P300 wave then other first-person shooter action video game players, these participants (named FPS+) also showed a higher improvement in the more difficult 30^{o} condition (Wu et al., 2012).

In Smith, Mcevoy and Gevins (1999) participants, 22-28 year olds, were asked in an first experiment, to perform working memory tasks where they were asked to identify stimulus position (spatial condition) or identity (verbal condition) and compare with the stimulus presented to them three trials earlier. In a second experiment subjects were asked to train in a non-commercial video game called Space Fortress, playing a total of 280 minutes. In both experiments an EEG measurement was made as tasks were performed. As the time on the tasks went on a significant increase could be seen in the frontal midline theta component in both experiments suggesting that the ability for conscious control necessary to attend to tasks and sustain performance was increased (Smith et al., 1999). Activity in the alpha band increased as well with alpha amplitude showing big changes in and between sessions, which suggests that as skill of task develops less cortical neurons are necessary to activate to perform the task (Smith et al., 1999).

In West et al. (2015) study participants were given an questionnaire dividing the participants into two groups action video game players and non-video game players, with participants in the action video game playing group reporting a minimum of six hours of action video game play per week (averaging almost 18 hours of video game play per week). They then performed a 4-on-8 Virtual Maze. A 4-on-8 Virtual Maze is a virtual maze with several landmarks in it designed to indirectly measure volume and function of the hippocampus and striatum. Based on participants' performance and reported description of how they handled the task, the subjects were categorised into using spatial strategy and response strategy to solve the maze task. Whilst recording an EEG, specifically the N2pc component, participants also performed a visual spatial attention task (West et al., 2015). The 4-on-8 virtual maze task showed that 80.76% of action video game players used a response strategy to complete the task whilst in the non-video game player group 42.42% of participants used response strategy (West et al., 2015). Response strategy is a strategy an individual use when navigating an environment using specific movements and in which order these movements were. The response strategy is striatum dependent (Bohbot, Lerch, Thorndycraft, Iaria, & Zijdenbos, 2007). Other participants (19,24% of action video game players and 57,58% of non-video game players) used spatial strategy to perform the task. With spatial strategy the individual learns to navigate an environment by creating a cognitive map of the area using landmarks as reference points (West et al., 2015). This strategy is hippocampus-dependent (Bohbot et al., 2007). The EEG showed that during visual spatial attention task N2pc component showed a large amplitude for non-video game players in comparison with action video game players when measuring targets near fixation (an easier, less demanding condition) (West et al., 2015). When the target was in a far condition (harder, more demanding condition) action video game players produced a larger N2pc (West et al., 2015). This seems to coincide with Bavelier et al., (2012) where the amount of activation is lower in action video game players because of the more efficient processes and connectivity in attentional fronto-parietal networks.

Further EEG results can be seen when participants played a competitive video game (Mario Power Tennis) (participants had not played this game before however no information about participants habitual use of video games was investigated) continuously for 65 minutes (Sheikholeslami et al., 2007). During which five 10-minute EEG recordings were made. The Regions of interest were Theta-wave (4-8 Hz) powers in the frontal cortex and Alpha-wave (8-13 Hz) powers in the parietal cortex. Analysis of the EEG recordings show that frontal midline theta-wave increases the longer the participant plays the video game. Activity in parietal alpha-wave initially decreases but rebounds and increases as the participant continually plays the video game. Both the increase in theta-wave and attenuated alpha-wave indicates with continued play the video game player should see an increase in mental load (Sheikholeslami et al., 2007).

These EEG findings suggests that video game players better can forgo distracting stimuli in central and peripheral view and discriminating stimuli giving video game players more confidence when making decisions. Video game players also seem to have more efficient processes and functional connectivity in attentional networks but utilizing these networks more as non-video game players as mental load increases.

Attention can Improve with Video Game Training

As mentioned earlier action video game training for one hour per day, ten days in a row makes non-video game players outperformed on post-test enumeration task, UFOV task and, attentional blink task in comparison to puzzle game trained subjects (Green & Bavelier, 2003). High pace video game training with multiple distractors would help participants with attentional performance. With superior video game player performance seen at earlier ages as well as with adults (Anguera et al., 2013; Antzaka et al., 2017; Bavelier et al., 2012; Green & Bavelier, 2003; Moisala et al., 2017; Zhang et al., 2020). This would suggest that playing video games would improve performance of attentional networks no matter age. Anguera et al. (2013) investigated if training in the video game NeuroRacer would improve performance for participants at an older age, 60-85 years. Participants were divided into three groups, a multitasking group in which the group trained with the NeuroRacer video game in two tasks simultaneously, a single task group were the group trained in the same two tasks as the multitasking group but the two tasks were trained separately and, a control group that did not receive any training. The subjects in the training groups trained for 12 hours over four weeks. After four weeks the multitasking group showed significant improvement between pre- and post-training, not only that a performance gain could be seen after six months (Anguera et al., 2013). Whilst the single task group showed improved performance after one month this improvement was greater in the multitask group and after six months there were no visible gains from training sessions. Cognitive tests performed pre- and post-training also revealed improvements in working memory, sustained attention and improvements in an untrained delayed-recognition task with distractors, a task used to measure cognitive control.

Anguera et al. (2013) also evaluated pre- and post-training with an electroencephalography (EEG), measuring long-range phase coherence and event-related spectral perturbations (ERSP). Long-ranged theta coherence between posterior and frontal regions of the brain (an area associated with for instance sustained attention and working memory) and midline frontal theta (4-7 Hz) (associated with working memory, sustained attention and interference resolution) showed enhancement and performance benefits. Finally, trained participants midline frontal theta and long-ranged theta coherence was compared with younger adults (20-29 years). For the multitask group results in neural activity patterns were comparable with the younger adults (Anguera et al., 2013). It therefore seems as if older populations could benefit from video game training.

Interestingly, whilst older participants rely more on endogenous attentional networks (Madden, 2007) Video game players have less activation in endogenous attentional networks. (Bavelier et al., 2012; Green & Bavelier, 2003; Moisala et al., 2017; West et al., 2015; Zhang et al., 2020). It would therefore be interesting for future research to further investigate if training with video games would decrease activity and/or reliance on endogenous attentional networks and how this would affect older participants exogenous attentional network.

Discussion

Above I have investigated video game play and how it can affect our attentional networks and if it is possible to train attention with the use of video games. When investigating video games (commercial or non-commercial) one can see that performance in reaction time and in accuracy surpasses those who do not play video games (Anguera et al., 2013; Antzaka et al., 2017; Bavelier et al., 2012; Green & Bavelier, 2003; Moisala et al., 2017; Zhang et al., 2020), it also seems that those who play action video games are prone to better performance than the video game players (Green & Bavelier, 2003). This performance can be seen when testing participants on attentional, working memory and cognitive control tasks. During these tasks, as load (or difficulty of task) increases, video game players seem to use attentional networks more efficiently (Bavelier et al., 2012; Green & Bavelier, 2003; Moisala et al., 2017; West et al., 2015; Zhang et al., 2020), better locate target stimuli (Green & Bavelier, 2003) and better utilize systems designed to forego distractors and successfully ignore irrelevant stimuli (Green & Bavelier, 2003; Moisala et al., 2017; Zhang et al., 2020). Also, this effect can be seen in video game players but non-video game players who train for more than 10 hours with a video game seem to be able to adopt these performance benefits (Anguera et al., 2013; Green & Bavelier, 2003). This effect can be seen in different age groups as from adolescent, young adult, adults and older adults as well (Anguera et al., 2013; Antzaka et al., 2017; Bavelier et al., 2012; Green & Bavelier, 2003; Moisala et al., 2017; Zhang et al., 2020).

Neural correlates of video game attention show that the P200 and P300 component is higher in video game players than in non-video game players (Wu et al., 2012), SSVEP component was smaller in video game players than non-video game players for flashing distractors (Mishra et al., 2011), and N2pc component showed smaller amplitude for action video game players when compared with non-video game players when target was near fixation but higher for action video game players during the more demanding far condition (West et al., 2015). Theta-wave form in the frontal cortex increases during participants video game play and alpha-wave form in the parietal cortex first decreases but as participants continue video game play the alpha-wave form increases (Anguera et al., 2013; Sheikholeslami et al., 2007; Smith et al., 1999).

Even though not all studies find evidence for superior performance with video game players or action video game players this deviation could be because of lacking standardization and classification of video game research. With video game research still in its infancy researchers have an opportunity to create schemas for how video games can be studied. I would suggest that for future research a more robust paradigm describing facets of how to use and classify video games to be made. It would be beneficial if research also focused on differences between different genres of video games and within the same genre of game. The reasoning behind this is that worries over different aspects of games and genres might get calmed if research could see the impact of different mechanical features of video games. I would also suggest using non-commercial games as experimental parts in video game research. Often these video game have had several research paradigms built around them and the adaptability of those video game could be more useful in a scientific setting. However, closer relations and take-aways from the overall video game entertainment industry could benefit further research into video game effects on attention.

In conclusion, these findings suggest that as load increases for those who play video games attentional networks are working in a more automatic, efficient manner thus faster and better performance can be seen without sacrificing accuracy, and less activation is needed, and better allocation of resources can be seen as a result. Importantly this more efficient performance of attention can be trained no matter the age of the participant meaning that older populations could use video games in ways to battle attentional decline as individuals grow older.

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