EXTENDED ESSAY
Action Video Games and Cognition

Research Question: How do action video games influence the cognitive processes of memory and attention?

Subject: Psychology

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1. Introduction

In today's world of the evolving media, we see a growing ubiquity of digital technologies, in particular video games (VGs); visual interactive forms of entertainment which are available across a wide variety of platforms, from consoles to computers to mobile phones. VGs are exponentially becoming more popular and prevailing as a mainstream entertainment option among a large variety of age and ethnical groups. This has certainly impacted how people spend their time, and possibly changed the way in which they interact during everyday situations. Recent statistics showed that there are more than 2.3 billion active gamers in the world (Wijman, 2018), about 30% of the population, consequently leading researchers to investigate the impacts of this new technology on our brains and our behavior. In fact, the number of VG-related articles being published has been increasing at a constant rate of 20% annually since 2005, as illustrated in Figure 1 (Palaus et al., 2017).

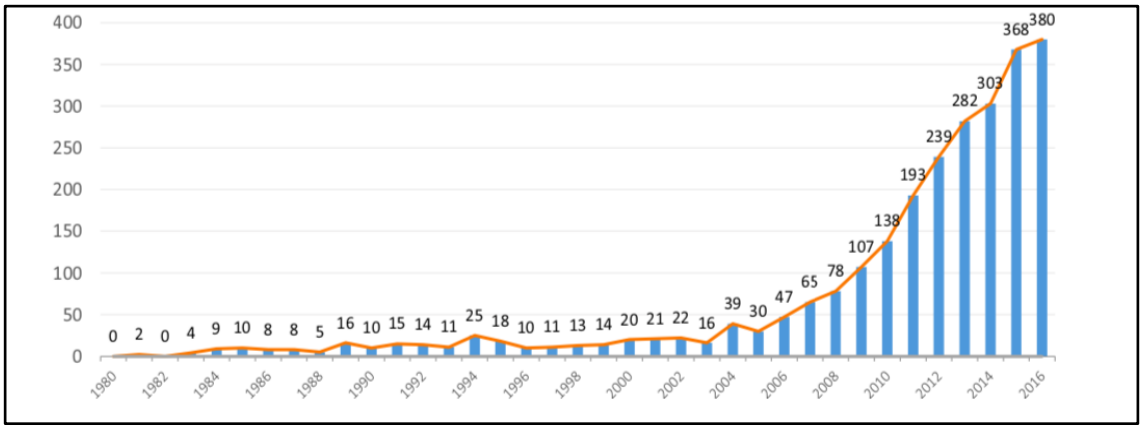

Figure 1: Increasing trend in VG-related articles from 1980 to 2016 (Palaus et al., 2017).

Questioning the impacts of playing these games on cognition is not unusual, nor is it uncommon to hear unsubstantiated positive or negative cognitive claims in the media such as VGs improve decision-making skills or that they hinder learning abilities. In order to assess such cognitive claims, we must first begin by expanding on the definitions of VGs. Due to the diversity of existing VG genres—all of which possess different features, themes and goals—

creating a unified general definition for all these categories would not be useful, as they are heterogenous i.e. hardly comparable (Palaus et al., 2017). In fact, Bavelier et al (2011) argue that "One can no more say what the effects of video games are, than one can say what the effects of food are". As such, this essay focuses only on action video games (AVGs), as according to Bavelier et al (2011), not only are they extremely popular among players, but also seem to result in a wide range of cognitive effects, thus deeming them worthy of investigation. AVGs are usually violent, visually rich three-dimensional games that impose fast-paced demands on the player and challenge their reflexes, hand-eye coordination, and reaction time (Oxford, 2018). Examples include, but are not limited to shooting, wrestling or martial arts, platforming, and tower defense games.

As with the case of VGs, there are many cognitive processes (decision-making, perception, learning) that could potentially be influenced as a result of playing AVGs. As such, in order to allow for a more focused investigation, this multiplicity will be limited by only considering the cognitive functions of memory and attention, as they play key roles in our daily lives and we heavily rely upon them; they are believed to be some of the most helpful factors leading to success in school or in the workplace, as they allow for greater productivity and efficiency when performing tasks (Hobbolog, 2017), so it is intriguing to examine how they are influenced as a result of playing AVGs. Furthermore, it is worth investigating both memory and attention due to the strong linkage that psychologists believe they have (Encyclopedia.com, 2020). As such, while investigating the effects of AVGs on memory, it would not be unlikely to observe (consequential) effects on attention, and vice versa. The arguments to be presented in this essay are thus encapsulated by the research question: 'How do action video games influence the cognitive processes of memory and attention?'. Sources featuring a wide variety of research studies from recently published, peer-reviewed journal articles written by known authors were

utilised to help determine the extent to which AVGs influence these cognitive processes, and further, to look at relevant real-life implications. These include experiments, correlational studies, and meta-analyses, which were selected due to the plausible interpretations and information that they shed light on. Furthermore, methodological and research approaches were discussed in order to identify strengths and limitations, as well as to evaluate the validity and reliability of these sources.

2. About Cognition

2.1 What are Cognitive Processes?

The term cognition appears everywhere in psychology. One of the earliest and most influential definitions was by Neisser (1976, p.1): "cognition is the activity of knowing: the acquisition, organization, and use of knowledge". More recently, it is a component of the mind which "encompasses all forms of knowing and awareness" (American Psychological Association, 2018). As such, anything that we engage in is related to cognition in some way or another (Neisser, 1976). Cognition relies on a variety of functions, or cognitive processes, such as perception, memory, attention and decision-making (Brandimonte, Bruno and Collina, 2006).

2.2 Memory and Attention

What we remember more or less shapes who we are. Memory is a complex cognitive process responsible for encoding, storing and retrieving information (Popov, Parker and Seath, 2017). Cognitive psychologists develop memory models in order to conceptualize the architecture of this complex memory system. One example is the Multi-Store Model, which suggests a unidirectional flow of information through three unitary stores: sensory memory, short-term memory and long-term memory (Atkinson and Shiffrin, 1968).

In his book, 'The Principles of Psychology', James (1890, p.917) defines attention as "the taking possession by the mind, in clear and vivid form, of one out of what may seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others". In simple terms, it refers to how we actively process information in our surroundings. Being able to attend to an internal or external stimulus requires our ability to allocate attentional resources efficiently.

Memory and attention are closely related; for instance, in the Multi-Store Model of memory, in order for a transfer to occur from sensory memory to short-term memory, the sensory information needs to be attended to (Encyclopedia.com, 2020). Without attention, it will be difficult to form and retain memories. Furthermore, although cognitive functions are still being mapped out in the brain, research has identified common brain areas that have been correlated with both memory and attention, namely the hippocampus and the medial temporal lobe (Chun and Turk-Browne, 2007). This information suggests a connectedness between memory and attention, which could enhance our understanding of how AVGs influence this linkage.

2.4 Operationalising Cognition

For psychologists to be able to measure the effects of AVGs on cognition, they first need to operationalise this construct. This can be achieved by designing cognitive tests to quantify participants' cognitive abilities. For instance, a digit span test would measure how well participants can store numbers in their memory; better performance in the test would indicate greater memory. Alternatively, researchers could use brain imaging technologies such as magnetic resonance imaging (MRI) or electroencephalography (EEG) to observe brain areas associated with a certain cognitive process while participants are undergoing a task (e.g. playing AVGs). A structural change in a brain area overtime—determined by taking multiple

scans across time intervals and comparing grey matter volumes of brain regions—may be indicative of changes in cognitive abilities. These cognitive tools are very useful to researchers because they allow them to investigate the influence of AVGs on memory or attention, and consequently determine the causality or the correlational nature between these variables.

3. The Influence of AVGs on Memory and Attention

Palaus et al (2017) conducted a meta-analysis reviewing a comprehensive compilation of 116 scientific publications which looked at structural and functional brain changes as a result of VGs, as well as their corresponding effects on a wide variety of behaviours, including cognition. The authors analysed both experimental and correlational studies, consisting of a cumulative sample of 3880 healthy participants, with no age or gender restrictions. Information extracted from the studies covered the type of VGs used, design, and the neuroimaging technique used to measure brain activity. Although the meta-analysis considered a myriad of different VG genres, the studies mentioned here are ones which utilized AVGs, therefore addressing the research question. Frontal and prefrontal regions of the brain were the most common areas studied, and they are associated with high-order cognitive processes. The authors classified cognition into six categories, some of which include attention, cognitive workload and cognitive control—the latter two being closely related to memory. Evidence within the meta-analysis suggested that selective attention, divided attention and sustained attention are all enhanced in AVG players (Bavelier et al., 2012b) compared to non-VG players, as indicated by the more active brain regions associated with attention. In fact, the authors mention that "the attentional benefits resulting from the use of VG seem to be the most evidence-supported aspect". Additionally, training with an AVG ('space fortress') enhanced working memory (Nikolaidis et al., 2014). As such, it could be seen that there are positive

neurological correlations or impacts (depending on the study being correlational/causational) between AVGs and brain areas associated with types of memory and attention. However, it is essential to understand that these changes in the brain do not necessarily reflect cognitive changes. For researchers to detect cognitive changes directly, certain research designs are required, such as the use of cognitive tests.

The meta-analysis provided useful findings as it compiled a large number of studies consisting of a large sample. It also based the findings of cognitive changes on scientific research of functional and structural brain changes. However, as with most meta-analyses, there are a few areas of uncertainty. The individual studies were heterogenous in some cases, in factors such as participants' onset age of playing, lifetime VG experience, and VG dedication. This made it difficult to compare the findings in an objective sense, possibly hindering the generalisability of the inferred conclusions. Moreover, the classification of VGs in the studies could have affected the generalisability too. Even with only AVGs, different categories might contain different variables. For instance, both shooting and fighting games are action as both demand focus and quick reaction time; however, shooting games require higher visuospatial skills compared to fighting games. The authors, Palaus et al (2017), suggest that "efforts should be made to determine which aspects of each VG genre are related with each cognitive process". Nevertheless, this meta-analysis showed that AVGs could be positively influencing memory and attention. Not to mention that these limitations are diminished due to other recent meta-analyses drawing similar conclusions that AVG training may serve as an efficient way of improving attention and memory in adults (Wang et al., 2016; Toril, Reales and Ballesteros., 2014), Although this meta-analysis provides useful information regarding AVGs and their influence on memory and attention, it fails to provide insight into specific experimental methods regarding how these influences are measured in an experimental setting, therefore the

next two studies are examples that investigate the influence of specific AVGs on specific aspects of memory and attention in an experimental setting.

In order to investigate the effects of playing League of Legends (LOL)—a multiplayer action game whose objective is to destroy the opposing team's base—on visual selective attention (VSA), Qui et al (2018) conducted a quasi-experiment where they compared 'expert' gamers with 'non-expert' gamers, forming a sample of 29 male students. VSA refers to the brain's ability to focus on something while simultaneously ignoring less important information (Bavelier et al., 2012a). Focusing on relevant information requires cognitive control, so researchers believe that people who can allocate their attentional resources while ignoring other distractions use their brains more efficiently and effectively (Railton, 2018). The participants in the expert group had at least two years of experience playing AVGs and were ranked in the top 7% of LOL players; whereas the non-expert group had fewer than 6 months of experience and were ranked in the bottom 30 to 45%. The researchers employed a 'useful field of view' test to measure the participants' VSA before and after playing LOL, which involved displaying a square in the middle of the screen, followed by another square flashing in a different place before requiring the participants to identify the position of the second square relative to the first. While performing this attention-demanding task, the researchers used EEG to measure the brain activity. Needless to say, the expert participants were found to have greater VSA than the non-experts before playing, as the grey matter volume from the EEG indicated more attention-related brain activity. More interestingly, after playing LOL for one hour, both groups demonstrated improved VSA as the volume of grey matter had increased for both groups since the initial scan. Additionally, the brain activity of the non-experts increased to the extent where they were now comparable to that of the experts. Thus, the findings suggest that playing AVGs correlates with rapid improvement in VSA.

Although this study demonstrated that increased VSA is observable after a one-hour game training session, there were a few limitations which require us to be more critical while interpreting the results. Firstly, there is the sample to be considered, which was relatively small and only employed male students, sparking the question of population validity. The findings cannot be said to be applicable to a wider population such as adults, due to the sample not consisting of any. Assuming that the effects are the same for these groups of people will require evidence since they are inherently different in terms of biology or their cognitive abilities. For example, adults could have experienced more brain plasticity throughout their lifetime, which means there could be more or less capacity for cognitive abilities (attention), hence, there is a lack of population validity. Additionally, since the experiment was conducted in a laboratory setting, it is unlikely for the participants to have performed similarly on the tests in different settings that they are used to, such as their homes or a gaming center, since these are common places where video games are usually played, hence there is a lack of ecological validity too. Furthermore, the experimental design does not take into consideration the retention of the improvements in VSA. This means that the effects observed are not necessarily stable, but rather transient. Further research is required to investigate whether the improved VSA is maintained for a certain amount of time after playing, for example, a few weeks. This, in turn, reflects the findings' applicability to real-life, as one cannot be certain whether these positive impacts are temporary or long-lasting. Finally, it is important to emphasize that this experiment was correlational in nature due to the reliance on brain imaging technology, which cannot infer causality. This means that it cannot be inferred from the findings that playing AVGs directly influences visual selective attention. It could be, for instance, that people with higher VSA excel more in gaming than those with lower VSA, not the other way around; it is simply an association between the two.

Building upon the argument that playing AVGs yields a positive influence on memory and attention, Kühn et al (2014) conducted a quasi-experiment to investigate whether AVG training induces structural brain plasticity. The sample consisted of 48 participants (mean age 24), and they had little VG usage in the past six months. They were randomly assigned to one of two groups: an AVG training group, who were instructed to play 'Super Mario 64' for at least 30 minutes per day for two months; and a control group, who did not play the game but underwent the same testing procedure following the training period. Super Mario 64 is a 3D action game where the player has to reach higher levels and save a princess by defeating enemies. The participants were taught the rules and how to play the game before the training phase, as well as informed that the best players would receive a monetary award. The researchers used MRIs to scan the participants' brains before and after the training phase. These findings are summarized in Figure 2.

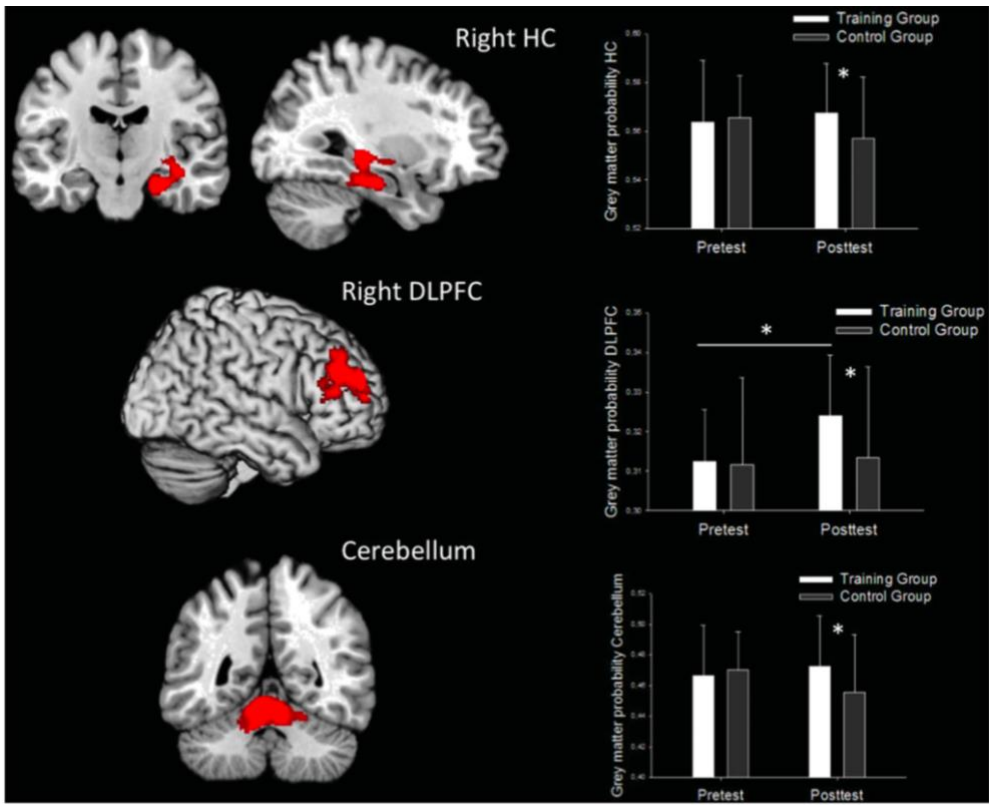

Figure 2: Gray matter volume in brain areas of participants in both groups, pre and post the training phase. (Kühn et al, 2014)

Compared to the control group, the training group experienced increased gray matter in the right hippocampus, right prefrontal cortex and the cerebellum—brain regions which are associated with memory formation—as seen from the figure, suggesting that there is a correlation between AVG training and improved memory formation.

The design was experimental and thus managed to eliminate many extraneous variables, which ensured that the link between AVGs and the three brain areas was causational. However, the idea that the increase in gray matter volume strengthened memory formation in of itself is merely an assumption; simply because there exists a correlation between a brain area and a cognitive process does not entail that a structural change in that area will cause a change in cognition. In other words, despite the study demonstrating that there is a causational link between AVGs and increased gray matter in the three brain areas, the link between this increase in gray matter and enhanced memory formation is simply a correlation, thus limiting the conclusions that could be drawn from this experiment. Still, the study had a few strengths: participants were randomly allocated to each condition, reducing bias; standardised instructions on how to play meant that all participants understood the game similarly; and giving monetary rewards boosted participants' motivation to game, ensuring that participants' level of interest was not a confounding variable. All these strengths confirm that Kühn et al's study contributes to the argument that AVGs potentially improve the cognitive process of memory.

Sala, Tatlidil, and Gobet (2018) arrived at conclusions contrary to the positive influences discussed thus far in the essay when they examined the relationships between VGs and five cognitive functions, two of which were memory and visual attention. 3 large meta-analyses were conducted in order to investigate these relationships: the first assessed the correlation

between VG skill and cognition (66 studies, 8141 participants); the second tested and compared VG players to non-players in terms of cognitive abilities (98 studies, 6166 participants); and finally, one which examined the causal effects of VG training on cognitive ability (63 studies, 3286 participants). In addition to these classifications, the authors further divided VG genres into action, non-action and mixed. The findings showed that in the first meta-analysis, there was a near-zero correlation between participants' skill level in AVGs and memory ($r = 0.01$), and visual attention ($r = 0.05$). The second meta-analysis found that gamers outperformed non-gamers in the cognitive functions, however this difference was substantially smaller than what previous research has alluded to. Unsurprisingly, the final meta-analysis showed that AVG training had negligible effects on participants' cognitive abilities. The authors concluded that this meta-analytical investigation demonstrated that playing AVGs has very little influence on memory and visual attention, which seems to contradict and perhaps even negate aforementioned benefits from meta-analyses and experiments.

The authors attempt to explain these contradictions as a result of their "more restrictive inclusion criteria" and "more accurate procedure for calculating the effect sizes and correcting for statistical dependence". Furthermore, they scrutinized previous research and pointed out flaws in an attempt of explaining their own findings. In fact, they believe that conducting further research into this field is "pointless". As to whether this evidence is conclusive or not, this cannot be determined without very thorough analysis of the methodology. However, the article provides a full list of the individual studies that have been analysed, including descriptive and inferential statistics, which increases the validity of the researchers' analysis and ensures that the accuracy is verifiable. It is also evident that the findings display a high degree of reliability due to the comprehensive nature of the meta-analyses conducted, which

looked at correlational, causational and comparative relationships, all having led to the same conclusion.

4. Discussion

There have been some contradictions in the research presented. The fact that even meta-analyses differed in terms of conclusions goes to show how the interaction between AVGs and cognitive processing is exceedingly complex. This is perhaps due to the fact that cognition is not the only factor which AVGs has an influence on. Other affected factors include violence or living a sedentary lifestyle, both of which are social factors. This is relevant because it allows us to understand that there exists a diverse, complicated set of interactions which would be difficult to account for in research. Perhaps playing AVGs increases violence and consequently, this somehow improves attention; or it could indirectly hinder memory function, for example, as a result of neglecting important duties. These claims are thought-provoking possibilities which could suggest a complex chain of relationships. As such, this approach to AVGs is somewhat reductionist and only considers few aspects and small perspectives.

The research aforementioned allows us to possibly draw a number of conclusions which are important and relevant to real-life. Firstly, assuming that playing AVGs does indeed yield positive effects on memory and attention as some of the previous research has alluded to, VG developers could take this into consideration when designing AVGs to maximize these cognitive benefits. Furthermore, education systems could utilise this in order to improve students' learning. Having an educational resource which matches students' interests could be very powerful, helping them pay more attention and retain more information. However, this claim about AVGs enhancing learning cannot be said without uncertainty, partly due to the fact

that spending time playing AVGs could be an opportunity cost for spending time doing something more useful and efficient, for example studying. Another reason for this uncertainty is that greater cognitive performance in a study does not directly translate into greater performance in real-life situations, as previously discussed with the problem of ecological validity. Even if AVGs may result in improved attention, that does not mean that a student will pay more attention while hearing biology facts or to a teacher explaining algebra. Therefore, it is difficult to conclude whether AVGs help with learning or not; although this is an intriguing example of an unresolved question which requires further research.

Another implication stems from Kühn et al's aforementioned findings; that playing AVGs possibly increases hippocampal volume, thus could help in reducing symptoms of malaises related to low hippocampal volume. As such, playing AVGs could possibly counteract mental disorders such as post-traumatic stress disorder, as well as diseases such as dementia and Alzheimer's—especially in order adults—as they have consistently been associated with decreased hippocampal volume (Kühn et al., 2014); however, further research is required to confirm this, as hippocampal volume is only one amongst many other factors which plays a role in degenerative diseases.

Finally, it is vital to emphasise the need for longitudinal research, as touched upon previously. VGs as a digital technology are relatively modern and as such, it is natural to question whether the influences they have on memory and attention are maintained following years of exposure to the AVGs. Although some of the research presented suggested positive effects, it does not take into consideration any observed changes or effects beyond what had been measured in the short-term. This might not be relevant to regular AVG players, as they are constantly engaging in gaming; however, in cases such as AVG training, longitudinal research could be useful in

providing insight as to whether one gaming session could provide long-lasting effects or if continuous periodic sessions are required.

5. Conclusion

In response to the research question "How do action video games influence the cognitive processes of memory and attention?", a number of studies have suggested that there is a positive relationship between AVGs and the cognitive processes of memory and attention. However, the credibility of this statement is hindered due to the limitations of the studies mentioned and the findings from Sala et al (2018), which stated that there are no cognitive benefits. However, the lack of research suggesting negative effects allows us to infer that there are no significant risks to memory and attention.

In addition to these cognitive benefits, there seems to be a number of interesting side effects and implications. Playing AVGs may help with learning as a result of enhanced memory and attention abilities. Moreover, they could structurally change certain brain regions like the hippocampus, which may help counteract diseases such as Alzheimer's.

In conclusion, it is important to be mindful of the fact that this research field is still in its infancy, and considering this, the contradictions in the findings make sense. AVGs are very complex and there are many aspects to them which makes conducting objective research difficult. Further research is required in order to resolve any conflicts, particularly longitudinal research. However, what can be said based on the research presented in this essay is that a few hours of playing AVGs weekly in moderate amounts can be beneficial to our memory and attention, although there is no conclusive evidence to suggest so.

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