The Effects of Video Games in Memory and Attention

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Abstract—The use of Information and Communication Technologies (ICT) is ubiquitous. Technologies like video games have become very popular not only with the young generation but also with older people. The video game industry has seen rapid growth over recent years, as has the interest in the influence of video game experience on people's daily life. The study focuses on a novel approach to training Visual Working Memory (VWM) through the use of video games and examines research evidence concerning whether video games can serve as a vehicle for promoting the development of cognitive skills and especially memory and attention.

Keywords—Video games, memory, attention.

1 Introduction

We live in the era of information and technology. The use of Information and Communication Technologies (ICT) is ubiquitous. The role of ICTs in education is a field that has been discussed in literature[1] [2] [3] [4] [5]. Technologies like video games have become very popular not only with the young generation but also with older people. The video game industry has seen a rapid growth over recent years, as has the interest in the influence of video game experience on people's daily life. Recently, there has been an increasing interest in the cognitive benefits that playing video games may have for players[6] [7] [8]. Recent research suggests that playing video games, even for a relatively short period of time, improves the performance on a number of tasks that measure visual and attentional abilities [9] [10].

The study focuses on a novel approach to training Visual Working Memory (VWM) through the use of video games. There are two main areas of literature that support this approach. Firstly, there is vast literature regarding individual differences in VWM and how these individual differences are linked to various aspects of visual attention. Secondly, the last decades have developed a body of research which supports that video games experience enhances a range of cognitive abilities like perceptual and attentional skills.

The goal of this review is to examine research evidence concerning whether video games can serve as a vehicle for promoting the development of cognitive skills. In this paper, we focus on the effects of video game training on memory and attention.

2 Non - Action Video Games

Deveau et. al. (2015) at the University of California Riverside (UCR), Brain Game Center developed a 3D space-themed video game. By taking into account that two relevant lines of research have made significant breakthroughs in brain training:

- Studying incidental benefits of off-the-shelf video games
- Transforming standard cognitive tasks into training tasks

They suggested that the utmost success will come from integrating knowledge of memory systems with that of brain plasticity and modern game-design principles. They have incorporated design principles from Perceptual Learning (PL) and Computer Science in order to increase the effectiveness of the game in practicing working memory. They have done so by integrating n-back tasks into the game mechanics. Levels are designed to get progressively harder through increasing cognitive challenge (n-level) and other game challenges (such as obstacles). While the game is getting more difficult and attention is spread over more elements than the conventional n-back, participant's control over their environment is anticipated to increase their engagement with the game. The game also incorporates principles from PL, where participants are trained on multisensory (auditory and visual) features, where sounds and visuals are designed to facilitate each other, and where attention and reinforcement are carefully sculpted to lead to the best learning [11].

The study of Ballesteros et al. (2014) investigated the effects of 20 1-h non action video games training session with games selected from the Lumosity, a web-based cognitive training platform, on a series of age-declined cognitive functions and subjective wellbeing. Forty healthy older volunteers participated in the study. They were randomly separated either to experimental group or the control group. All the participants, before and after the intervention, underwent neuropsychological tests. The experimental group incurred 20 1-h training sessions over 10-12 weeks on 10 video games from Lumosity (speed match, memory matrix, rotation matrix, face memory, memory match, money comb, lost in migration, space junk, raindrops, chalkboard). Assessment measured: processing, speed, attention, executive control, spatial working memory, episodic memory and subjective wellbeing. The results showed that the experimental group enhancement compared to the control group in controlled processing, attention, immediate and delayed recall memory [12].

Boot et al. (2011) conducted a research examining the effects of video-games playing on cognitive abilities, including memory between expert players and no-gamers. In the survey participated 11 expert video games players, who played seven or more hours per week for the past two years and 10 non-video games players, who played video games one hour per week or less. The result of the research showed that experts had better basic cognitive skills and in particular they could detect better changes to items stored in visual short-term memory and they performed more accurately in visual short- term memory tests [13].

Nouchi et. al. (2013) conducted a double-blind randomized controlled trial using a popular brain training game (Brain Age) and a popular puzzle game (Tetris), in order to determine if playing video games would improve cognitive functions and the beneficial effects of video games on cognitive functions would differ according to the types of video games. 32 participants took part in the study and were randomly assigned to either of two game groups (Brain Age, Tetris). Brain age is one of the most popular brain games designed, based on neuroscience evidence that is beneficial for cognitive functions. The participants were asked to perform each video game training (Brain Age or Tetris) over 4 weeks with at least 5 training days each week. On each training day, participants performed the video game for about 15 minutes. The measures of cognitive functions were conducted before and after training. On the first day of training (pre), all participants were tested on a series of neuropsychological and behavioral tests. After 4 weeks of training (post), all participants were re-examined to assess their performance on some neuropsychological and behavioral tests. According to the results of the study, brain age game improved executive functions, working memory, and processing speed while Tetris improved attention and visual-spatial ability [14].

Clemenson et al. (2015) investigated if virtual environmental enrichment through Video Games could improve Hippocampal-Associated memory. They assume that the visually stimulating virtual environments of video games could influence the hippocampal behavior. For participation in the study they needed 39 self-described video gamers and 29 self-described non-video gamers. The results from the experiment 1 showed that the video gamers who play 3D video games performed better on a demanding recognition memory task than video gamers who prefer easier 2D games. In experiment 2, they trained players for 2 weeks on 3D video game Super Mario 3D World and the results showed that they improved mnemonic discrimination ability. So the playing of video games is possible to provide meaning stimulation to the brain.[15]

Colzato et al. investigated if and to what extent video games could improve cognitive skills. The two groups composed of 26 experienced video game players (VGPs) and 26 with little or no video games experience (NVGPs). Participants transacted the stop-signal task, the N-back and the Standard Progressive Matrices (SPM). The results showed that VGPs have faster reaction and were more accurate in working memory than NVGPs, but they have comparable stopping efficiency. [16]

West et. al. (2018) conducted three separate experiments in order to determine the impact of different learning strategies that deferent game genre demand on the episodic memory, in which hippocampus is involved and in caudate nucleus and involve memorizing a series of actions from a given starting point. All the participants were brain-scanned with an MRI. Their results suggest that experience-dependent changes in the hippocampus are dependent on the spontaneous navigation strategies that people employ. The participants who spontaneously encode the relationships between landmarks use spatial learning strategies, resulting in experience-dependent growth in the hippocampus. In contrast, response learners do not use the relationships between landmarks and they show a reduction in grey matter in the hippocampus when exposed to both the same gameplay demands and a similar number of environments as spatial learners [17]

Baniqued et al. (2014), in an effort to identify whether playing casual video games could improve cognition training, conducted this study by using active control groups, training tasks, and multiple tests. The participants were 209 young adults aged 18-30, who had no major medical conditions and could be playing video games and board games for 3 hours or less per week for the last six months. They belonged randomly to one of four groups: working memory and reasoning games, adaptive working memory and reasoning games, active control casual games and a no-contact control group. Moreover, they had training sessions two or three times per week, where they played games for 20minutes for ten sessions. The cognitive assessment was grouped into five categories: perceptual speed, reasoning/ fluid intelligence, working memory, episodic memory, and attentional control. The results showed that casual video games can improve cognition but transfer to untrained task was limited. However, working memory and attention improved. [18]

3 Action Video Games

Dobrowolski et. al. (2014) conducted a study to determine the role of video game genre in cognitive enhancement. In order to do so, they designed a study comparing the cognitive functioning of first-person shooter (FPS) and real-time strategy (RTS) players (action games). The study involved 90 people divided into three groups. FPS players, RTS players, and a control group of Non video game players (NVGP). According to their results, action video games of different genres may not have an equivalent enhancing effect on the shifting aspect of executive functions and visual attention. Real-time strategy players showed superior performance to non-video game players on task switching and at Multiple Object Tracking (MOT), and also showed a trend level advantage over first-person shooter players on overall MOT performance. FPS players held a trend level advantage of lower switch costs but did not outperform NVGP's at MOT.[19]

Baavelier et. al. (2012) used brain imaging to test the hypothesis that the aspects of attention enhanced in action game players are changes in the mechanisms that control attention allocation and its efficiency. They have done so by comparing recruitment of front-parietal networks between a group of action video games players and a group of non-video game players in a visual search paradigm. They have used an easy versus a more difficult search, while concurrently measuring the impact of search difficulty on the processing of irrelevant motion information. The participants were 26 males (18-26 years old) split into two groups depending on their prior video games experience. Results of the study suggest that the video game group was faster at performing the search task and that there was less recruitment of the front-parietal attentional network. These results are compatible with the proposal that action game players may allocate attentional resources more automatically, possibly allowing more efficient early filtering of irrelevant information.[20]

Krcmar et al. investigated (2011) the effects of video games realism, between Doom 1 vs Doom 3 and tested attention, retention and aggressive outcomes. The participants were 130 undergraduate students, 76 males, and 54 females with mean age 19.6. They were randomly assigned to Doom 1 [n=41], Doom 3 [n=44] or control [n=45] gameplay conditions. The hypothesis was that players in Doom 3 would report higher levels of attention than Doom 1. Attention was measured by three items; the items were measured on a 7-point scale with a higher score indicating greater attention. The results showed that the hypothesis was supported. Those who played Doom 3 realized more realistic than those who played Doom 1. Moreover, those who played Doom 3 were more attentive and experienced more presence than those who played Doom 1. To sum up, playing a more graphically realistic video game the players have more attention, retention and aggressive outcomes.[21]

Green et. al. (2014) investigated the effect of action video game experience on task-switching. Task switching, or set-shifting, is an executive function that involves the ability to unconsciously shift attention between one task and another. They have done so by demonstrating that the action video game players (AVGPs) switch cost advantage generalizes to:

- Vocal responses in addition to traditional manual responses
- Tasks that are more cognitive rather than perceptual in nature
- Goal switches as well as motor switches. They conducted four separate experiments.

According to their results:

- The AVGPs show exactly the same advantage when using a vocal method of response.
- Twitch-cost advantage was strong in a task that was more cognitive in nature.
- the AVGPs advantage was also roughly equivalent in a condition where in the switch was required a goal shift and, in a condition, where the switch involved only a change in the motor response set.
- Training on an action game did indeed result in reductions in switch-cost that were greater than training on a control game.[22]

McDermott et al. [11], in order to evaluate the way that playing action video games supports memory abilities, conducted an experiment using four tasks that victual into separate memory processing areas. In particular, they wanted to find out if the benefits from visual short-term memory extended to long-term memory. The participants were 28 male AVGPs and 25 male NVGPs. In the Posner, letter identify task AVGPs had faster well-learned memories than NVGPs. In the proactive interference task, AVGPs were faster than NVGPs, because NVGPs slowed down when the interference increased. In the N-back task that requires multiple memories abilities, AVGPs were faster again. In the visual short-term memory task, which used a visuospatial short-term memory task AVGPs were more precise than NVGPs. [23]

Chisholm and Kingstone (2015) investigated the specifics of how improved attentional control is realized by action video game players (AVGPs). 57 undergraduate males participated in the study, according to their video games experience, half of them were put in AVGPs group and the other half were put in NVGPs group. They tracked and recorded the eye movement of the participants while they were performing a simple search task in a monitor and then selection and response performance were compared between the two groups. Their results demonstrate that AVGPs are more efficient in selecting a target and are also better at making quick and accurate manual responses. Both processes are strongly associated with the availability of cognitive resources and the integrity of prefrontal cortical regions. [24]

Qiu et. al. (2018) tested whether cognitive and neural plasticity is observable after a brief Action Video Game session. They used behavioral and electrophysiological measures in order to examine the plasticity of visual selective attention (VSA) associated with a 1 hour AVG session. The participants were both experts and non-experts in AVG and were tested with a Useful Field of View (UFOV) assessment before and after the session. EEG data were collected while the subjects were playing the game. They finally compared a participant's performance before and after the AVG session. Results revealed:

- Improvements in response time in the experts and non-experts
- Neural plasticity in the non-experts as indicated by the amplitudes of certain EEG components. Thus, the findings suggested that AVG experience was associated with rapid improvement in VSA. [25]

Blacker et al. (2013) conducted a study to examine the visual short-term memory (VSTM) in action video game players. Experiment 1, using colored stimuli, tested a general processing speed advantage between AVGPs and NVGPs, without being limited to the time to encode the memory items. The participants were 121 Temple University undergraduates, 106 males, 15 females with mean age 21.6. The results showed a VSTM advantage among AVGPs. Experiment 2 using more challenging, complex shapes stimuli to increase the processing demand of the task, replicated the VSTM advantage among AVGPs independence of the encoding time. The participants were 47 individuals from Experiment 1 and were divided into a group of 23 AVGPs and in a group of 24 NVGPs. So, AVGPs keep their VSTM advantage and confirmed that the more complex shapes produced increased difficulty relative to the simplest.[26]

4 Special Learning Difficulties: Dyslexia and ADHD

Franceschini et. al. (2017) tested reading skills and phonological working memory, visuo-spatial attention, auditory, visual and audio-visual stimuli localization, and cross-sensory attentional shifting in two matched groups of English-speaking children with dyslexia before and after they played AVG or non-action video games. Twenty-eight dyslexic children (8 females and 20 males) mean age 10.1 years (range 7.8–14.3) were involved in the experiment. Participants were tested 3 to 5 days before starting the treatment and re-tested between one and three days after its end. They have observed an improvement in word reading and phonological decoding speed, without any cost in accuracy. AVG training improves reading skills without a direct targeting of phonological, orthographic or grapheme-to-phoneme decoding. [27]

Antzaka et. al. (2017) based on studies showing that Action Video Game-AVG training improves not only certain attentional components but also reading fluency in children with dyslexia, tried to identify the shared attentional components of AVG playing and reading. 38 French, right-handed adults (18–45 years old) with normal or corrected-to-normal vision, were recruited. Two groups were formed, AVG players and non-players (NVG). Two tasks of global and partial report were used to measure VA span together with a Single letter identification control task. According to their findings larger Visual Attention (VA) span was observed in AVG players compared to non-players. [28]

Franceschini et. al. (2013) tested reading, phonological, and attentional skills in two matched groups of children with dyslexia before and after they played action or nonaction video games for nine sessions of 80 minutes per day. They have relied on the fact that recent studies suggest that treatment of attentional deficits could be crucial in dyslexia remediation and all the existing treatments are controversial and demand high levels of resources. Taking that into account, they tested the hypothesis that since video game training has been proven to increase attention abilities, attentional action video game (AVG) training should produce learning that transfers well beyond the task domain, so they investigated the effects of video games on children with dyslexia. According to their results only playing action video games improved children’s reading speed, without any cost in accuracy, more so than 1 year of spontaneous reading development and more than or equal to highly demanding traditional reading treatments. Attentional skills also improved during action video game training.[29]

Blandón et al. (2016) conducted a pilot study using a custom-made neurofeedback video game called Harvest Challenge. The video game uses Brain Computer Interface to measure the attentional levels of players in order to use them as an input control in the video game. The participants were 9 diagnosed children ages 5 to 12 who played the video game in 30-minute-long sessions. Moreover, they recorded the EEG signals, which allow the post-processing signal in the time and frequency domains. The results showed improvements in the sustained attention levels of players and higher resting values in the power of alpha and beta bands rather than Delta and Theta [30].

Sonne et al. (2016) designed ChillFish, a breath-controlled biofeedback game for children with ADHD. ChillFish is controlled by the player breathing into a sensor-mounted LEGO fish. Breathing exercises can help children with ADHD control their stress level. For the pilot study, 16 adults aged between 25 and 41 were recruited. The result showed that the game challenge of balancing engagement and relaxation in physically controlled games for children with ADHD can make a game be calming and sustain their attention [31].

Chin-Ling Chen et al. (2017) designed a 3D game to improve the attention to children with ADHD. Neurofeedback training teaches them to focus, relax and control their attention and meditation. The participants were 10 and they lay theme to 14 games of the game training course at least twice a week. They were tested before and after each training. Moreover, the training included the following types of attention:

Vigilance Attention, Sustained Attention, Divided Attention, and Selective Attention. According to their results, the game training can give feedback and improve children attention and meditation significantly [32].

Cowley et al. (2016) at conducted a clinical trial of a novel design for neurofeedback (NFB) therapy in adult ADHD at the University of Helsinki. 54 adult Finnish participants aged 18-60 were recruited. 44 of them had been ADHD diagnosed and the other 10 ADD. Furthermore, participants were split between treatment and control groups. The intervention based on neurofeedback training regimes theta-beta and sensorimotor rhythm. In practice, the training consisted of 40 sessions during 2-4 months. The participants had a session 2-5 times a week and each session lasted 1hour. During each session, they played different game trials which got immediate visual reinforcement for classier matching states in their EEG. Their findings showed that the treatment group reported better improvements in ADHD/ADD than the control group [33].

Ochi et al. (2017) conducted a pilot study and they developed a neurofeedback game for attention training in adults. The participants were 17 adults separated into two groups of high risk and normal based on their initial assessment of ADHD symptoms. The game used a BCI system to detect the attention levels of players from their brain activity measured by a dry electrode played at the forehead in the right prefrontal lobe area. When the player had a low attention level the background of the game slowly dimmed to black and left the field of view only in the center of the screen. This strategy helps the player to focus on a small area of the game and regain his/her attention. Their finding suggests that neurofeedback training could be effective as an alternative treatment for ADHD, because the attention level, the time retained at elevated levels and the time user used to refocus has improved for the high risk group [34].

5 Conclusion

During the last few years an important number of studies have been addressing the effect of video game training in cognitive functions, and especially in visual working memory, attention and executive control. A great number of studies have shown that all ages could benefit from such treatments. Especially people with developmental dyslexia could benefit from simple and cost-effective treatments. The results are promising but the answer to the question 'Does video game training improve cognitive functions?' is not straightforward. We have to consider the genre of the game, the duration of the training and the fact that the way of playing the game can lead to different outcomes. More research is needed in order to determine specific characteristics of the video games that promote the development of cognitive functions, and the groups of the population for whom such education would be beneficial.

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