Effects and Applications of Video Games and Virtual Environments

by

Devon Brooke Allcoat

Thesis

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Abbreviations

ANT: Attention Network Task

AR: Augmented Reality

DES: Differential Emotions Scale

FEB: Full-Element Baseline condition

HEB: Half-Element Baseline condition

LDI: Lure Discrimination Index

MMO: Massively Multiplayer Online (Game)

MR: Mixed Reality

MST: Mnemonic Similarity Task

NVGP: Non-Video Game Player

PRE: Preview condition

RPG: Role-Playing Game

UTAUT: Unified Theory of Acceptance and Usage of Technology

VGP: Video Game Player

VR: Virtual Reality

WBLT: Web-Based Learning Tools

XR: Extended Reality

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Declaration

The thesis is my own work and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university. The thesis has been carried out and submitted as part of a Doctorate of Philosophy in Psychology from The University of Warwick. The thesis has only been submitted for this doctoral programme and has not been submitted at any other institution. The thesis does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, are clearly acknowledged. Contributions to research papers and presentations are found on the following page.

Inclusion of Published Work

Parts of this thesis have been published or submitted for publication.

Chapter 2:

- Allcoat, D., & von Mühlenen, A. (2019). Does the frequency of video game play affect performance in visual attention tasks? Poster presented at the TEAP 2019 Conference, London, UK.
- Allcoat, D., & von Mühlenen, A. (2020). *Do video game players perform better on visual attentional tasks than non-video game players?* Visual Cognition. Manuscript submitted for publication.

Chapter 3:

- The Video Game Experience Questionnaire developed in Chapter 3 will be published for use by other researchers.

Chapter 5:

- Allcoat, D., & von Mühlenen, A. (2020). *Impacts of Video Game Experience on Learning and Memory.* Psychological Research. Manuscript submitted for publication.

Chapter 6:

- Allcoat, D., & von Mühlenen, A. (2017). *Learning in a Virtual Environment: Effects on Performance, Mood, and Engagement.* Poster session presented at the 58th Annual Meeting of the Psychonomic Society, Vancouver, Canada.

- Allcoat, D., & von Mühlenen, A. (2018). Learning in virtual reality: Effects on performance, emotion and engagement. *Research in Learning Technology, 26*(0). doi:10.25304/rlt.v26.2140

Chapter 7:

- Data from the pilot study from Chapter 7 has been presented and published:
    - Allcoat, D., Azmat, F. & Stansfield, K. (2017, July). *Learning in Digital Reality Environments – Benefits of Virtual Reality and Mixed Reality.* Poster presented at the CONSTRUIT conference, Coventry, UK.
    - Stansfield, K., Azmat, F., Knowles, G., Evans, C., Allcoat, D., &. Mazur, G. (2018). *Improving Technology Enhanced Learning (TEL) Selection & Deployment Using Modern QFD: A Virtual Reality Case Study.* Paper presented at the 24th International Symposium on Quality Function Deployment 2018 in Hong Kong.
- Chapter 7 has also been submitted in its entirety as a paper:
    - Allcoat, D., Hatchard, T., Azmat, F., Stansfield, K., Watson, D. & von Mühlenen, A. (2020). *Education in the Digital Age: Learning Experience in Virtual and Mixed Realities.* Journal of Educational Computing Research. Manuscript submitted for publication.

Finally, Chapters 6 and 7 were presented in a World Bank Keynote speech:

- Allcoat, D. (2019). *Virtual Reality in Education: Emerging Lessons from Research.* Keynote presentation at the Education Global Practice Series at the World Bank, Washington, D.C.

Abstract

The widespread use of virtual environments in today's society leads to the importance of researching how using these virtual environments affect us, as well as how we can best use them. Video games are a very commonly used type of virtual environment/application of virtual environments. Video game research is rife with conflicting results, from studies into training, effects on emotion, to effects on visual attention. Chapter 2 considers the impacts of playing video games on visual attention and shows that the effects depend on the type of attentional process measured, and the video game genres played. Chapter 3 looks at how studies measure video game experience, and suggests a more sophisticated measure, including video game genres and platforms. This chapter also considers to what extent different video game genres are linked to different cognitive skills. Chapter 4 covers research between video game playing, task switching, and impulsivity. Chapter 5 shows that home video game playing (i.e. on home console platforms) affects both implicit memory and explicit memory, but mobile video game playing does not.

Recent technological advances allowed the development of a newer form of virtual environment, virtual reality. Virtual reality has become more popular over the last few years in manufacturing and entertainment industries. However, studies into applying virtual reality to educational settings are limited. Chapter 6 presents a study that tests the effects of virtual reality on learning. The results show increased motivation and engagement with learning materials, when compared to learning with textbook-style or video materials. Chapter 7 compares learning in virtual reality, mixed reality and traditional lecture style modalities, and finds that participants report higher levels of engagement in both Virtual Reality and Mixed Reality conditions, and higher levels of positive emotions in the Virtual Reality condition. Implications for how individuals are affected by both of these types of virtual environments is discussed, including how they can be applied to learning.

Chapter 1: The History of Virtual Environments and Video Games

Virtual environments: are they harmful, or helpful? This has long been a topic of debate, particularly in relation to video games. As this thesis is somewhat multidisciplinary, the purpose of this chapter is to provide an overview of the field, covering areas of psychology, technology, and education. My research covers different types of virtual environments, and as such, I will give an overview of each. With technology ever-changing and advancing, I believe it is important to consider its history and progression. Towards the end of the chapter, I will discuss research value and research motivation, and finally, an overview of each chapter in the thesis will be presented.

Virtual Environments

There are multiple different types of virtual environments, from simple environments displayed on a computer screen, to fully immersive environments such as virtual reality (VR). As such, virtual environments have existed in many forms over the past few decades, and have been used for many purposes, ranging from entertainment to military training.

There is not a single accepted definition of what exactly a virtual environment is (e.g., Ellis, 1994; Schroeder, 2008). Virtual environments, by some definitions, can be as simple as email or chat applications. However, other definitions are stricter, and require the environment to give the user a sense of being in the environment, a concept which is discussed as either a "sense of presence", "immersion", or both. This more specific definition can come under the term "immersive virtual environments". Blascovich (2002) stated that a virtual environment becomes an immersive virtual environment when it "creates a psychological state in which the individual perceives himself or herself as existing within the virtual environment" (Blascovich, 2002, p 129). This would often be accomplished with something such as an avatar, or some other representation of the self in the virtual environment. As such, video games and VR would typically be considered to be forms of more immersive virtual environments. Many factors can contribute to immersion, such as visuals, sound, embodiment, perspective, and haptic feedback. Whilst both video games and VR can be considered immersive, these factors can cause different levels of immersion.

Virtual environments, video games, and VR are distinct from one another. A virtual environment is commonly defined as "a computer-generated, three-dimensional representation of a setting in which the user of the technology perceives themselves to be and within which interaction takes place" (virtual environment, n.d.). Video games are electronic games which use interaction with a user interface to generate feedback on a two-dimensional (2D) or three-dimensional (3D) video display device (e.g., a computer monitor, a TV screen, or a VR headset). VR in its current form is typically known to be a computer-generated 3D environment, usually viewed via a headset, which replaces the real world.

The Origins of Video Games

Early examples of video games can be traced back to the 1950’s. It’s hard to pinpoint exactly what would be considered the first video game, as a few programs were developed in the early 1950’s which could be considered video games, but which were never widely publicised.

One of the earliest video games, which remains well-known today, is *Pong*. *Pong* is a 2D electronic game that simulates ping-pong. The design of the game itself is very simple, a black screen with a dashed white vertical line down the middle, representing the centre of the ping-pong table, and two controllable white rectangles representing the paddles, which could move vertically, at either side of the screen. A white “ball” moved horizontally and diagonally back and forth on the screen when hit by the paddles. The aim of the game was to have the ball reach the other side of the screen without being returned by the opponent in order to score points. This was released by Atari in 1972 and became widely distributed in 1973. As these early video games were 2D, not 3D, they would not be classed as virtual environments under some current definitions.

Pong was one of the first arcade games (Goldberg, 2011). Arcade games are games which are available to play in public businesses such as restaurants, bars and amusement arcades. Video arcade games are typically coin-operated machines in self-contained stands which include a screen, controllers, and hidden hardware. Video games were first commonly available to members of the public, and rose in popularity, as arcade games (Kline, Dyer-Witheford & De Peuter, 2003). Just before *Pong* was fully announced in November 1972, the first home console, the Magnavox Odyssey[1], was released in the United States in September of that year (released later overseas). It also featured a ping-pong game called Table Tennis. With *Pong* being the first commercially successful video game, and with it doing so well in arcades, this also helped drive sales for the Magnavox Odyssey (Wolf, 2008).

The Magnavox Odyssey, as the first commercial home video game console (Hosch, 2008), was very basic compared to consoles as we know them today. Wolf (2008) describes this system. It was only capable of displaying three black and white square dots on the screen and had no sound capabilities. To create visuals, players had to place plastic overlays onto their television screen. One to two players in each game could control their dots with the controller (which featured three knobs and one button), depending on the rules of the game being played. The console was sold with dice, paper money, and other board game items to accompany the video games, while a peripheral controller - a light gun - was sold separately. A total of 28 games were released for this console, some of which were available on the same game card.

Many video games produced today have ever-increasingly realistic graphics. However, some of the early examples had no graphics beyond basic

[1] For an image of the Magnavox Odyssey, and other home gaming consoles released until 2011, please see https://www.hongkiat.com/blog/evolution-of-home-video-game-consoles-1967-2011/

text displays and inputs. An early, well-known and influential example of a text-based adventure is *Zork*[2] (e.g., Egenfeldt-Nielsen, Smith & Tosca, 2013; Goldberg, 2011). *Zork*, released in 1977, is an interactive fiction story, set in ancient underground ruins. Players took the role of an adventurer, aiming to explore the "Great Underground Empire" and to leave alive with its treasures. It is played by reading the story presented on a screen, and inputting text commands for actions to be taken.

Another early influential video game was *Space Invaders*. This was released in 1978 and is considered to have been key in the movement which helped to usher in the “Golden Age” of arcade video games (e.g., Kent, 2001), alongside games like *Pac Man* (Wolf, 2008). These 2D single-screen or flip-screen games with static backgrounds such as *Space Invaders*, *Pac Man*, *Frogger* and *Donkey Kong*, became common in arcades in the 1970’s and early 1980’s (the “Golden Age”), leading to a huge increase in the popularity of video games, which had originated with *Pong*.

Video games evolved from these early examples towards the types of video games we see today. One big jump was the development of 2D side-scrolling games, which used scrolling computer display technology, allowing for larger and more dynamic game worlds. Examples include *Battletoads*, and the archetypal *Super Mario Bros.*, a side-scrolling platform game. A platform game is

[2] For images of early video games, including *Zork*, *Space Invaders*, *Pac Man* and *Frogger*, please see http://www.movingimage.us/files/exhibitions/minisites/expandedentertainment/78-82/78-82.html

a type of game genre, with gameplay typically requiring jumping or traversing between platforms. When side-scrolling capabilities were developed, this game genre evolved from single-screen settings to dynamic game environments, as seen in the differences between *Mario Bros.* (1983) and its 1985 successor *Super Mario Bros.* (Kent, 2001).

A genre is a particular style or category, and genres have been used to define categories of many types of media, such as books, film, music etc. Distinguishing between genres is often important for video games because the style of gameplay and the actions you take differ in each genre, so it is suggested that player experiences differ depending on the genre (e.g., Johnson, Nacke & Wyeth, 2015; Johnson, Wyeth, Sweetser & Gardner, 2012). Whilst action games tend to be fast-paced, with the ultimate goal to defeat an enemy, puzzle games are often slower-paced with the only tangible goal being to solve the puzzles, for example. Generalising all video games as the same, regardless of genre, would be like saying that a romantic comedy film is the same as a horror film and has the same impact on the audience watching it. As the technologies used to create video games developed, so did the video game genres.

From these developing 2D virtual environments, video games further evolved to use the 3D environments we are most familiar with in today's games. This was in part due to advances in processing power and storage space (Wolf, 2008). Examples of early 3D games include *Wolfenstein 3D*, *Doom*, *Super Mario Kart* (1992) and *Duke Nukem 3D*. These games used 2D techniques to simulate the appearance of a 3D environment. This type of environment is often referred to as 2.5D, or sometimes pseudo-3D, as they were limited in their 3D presentations; appearing 3D but not having 3D interactivity (e.g., Perron & Wolf, 2008). *Quake*, the successor to the popular *Doom* (Kline, Dyer-Witheford & De Peuter, 2003), was released in 1996 and did not have these limitations, and as such was considered to be "true 3D". While this was not the first "true" 3D game, with *Battlezone* being the first game to use a 3D polygon-based environment (Wolf, 2008), it was another influential game which helped progress the industry in the direction it continues towards today.

These types of games were increasingly released on PCs, home consoles, and the newer handheld video game consoles, rather than arcade consoles (Kline, Dyer-Witheford & De Peuter, 2003). Although the oldest "true" handheld game console (with interchangeable cartridges) was the Microvision released in 1979, the handheld game console concept was arguably popularised by the Game Boy, released by Nintendo in 1989 (Amos, 2019). Handheld consoles became popular for being fun, portable and convenient. *Tetris*, created in 1984, is a very well-known game which was initially released for arcades, personal computers (PCs), and home consoles (Wolf, 2008). Handheld versions which came later, such as the Game Boy release (Wolf, 2008), solidified its popularity.

Although *Tetris* is an example of a game released across arcade, home console and handheld platforms (Wolf, 2008), handheld consoles differed significantly in terms of computing power compared to home consoles, meaning generally the games that could be played on them were different. In order to make these consoles mobile, the hardware was not as sophisticated as that of home consoles due to space and weight limitations. Whilst having success with the Game Boy, Nintendo released a home console, the Super Nintendo Entertainment System (also known as the SNES) in 1990, a follow-up to the previously popular Nintendo Entertainment System (also known as the NES) from 1983 (Amos, 2019).

Nintendo has since dominated the mobile handheld market, moving through various iterations of the Game Boy, to the DS, and currently the Switch (Hutsko, 2000; Sun, 2019). Sony, on the other hand, took over much of the success from home consoles when they released the PlayStation in 1994, which became the first "computer entertainment platform" to ship over 100 million units (Sony Computer Entertainment, 2005). Microsoft also entered the home console market as a true competitor with the release of the Xbox in 2001, with a stronger focus on action video games, with first-person shooters such as *Halo: Combat Evolved* (Glenday, 2008). Today, video games are commonly played on mobile phones as well as home consoles and handheld game consoles, and this mobile experience is becoming increasingly popular (Limelight Networks, 2019).

Over time, graphics have been improved to become progressively more realistic and, as hardware has improved, gameplay has become more dynamic. The next big jump in the video game industry which increases the sense of realism is virtual reality.

The Origin of Virtual Reality

One of the most recent developments for virtual environments is the addition of virtual reality headsets, which are now commercially available for video games. As home and mobile consoles have become standard household objects, VR technology was developed to be a similarly affordable piece of hardware and commercial VR headsets are now being released. At the time of writing, the main examples of these are the Oculus Rift, the HTC Vive and Sony's Playstation Virtual Reality (PSVR)[3]. Although currently these specific products are relatively new to the market, virtual reality has been around in other forms for a number of decades.

Early work done towards creating virtual reality environments can be found as far back as the late 1920's, through work done by Edwin Link (Rolfe & Staples, 1986). Virtual reality then became more developed in the 1960's. In particular, two head-mounted displays were developed (Comeau & Bryan, 1961; Goertz, Mingesz, Potts & Lindberg, 1965) which resemble the virtual reality headsets we see today. Originally developed for use in the motor industry for vehicle simulations, this technology was quickly adapted for a wide variety of areas, including planetary surface exploration, interactive art, tele-robotics and scientific data visualisation (Ellis, 1994). The application of VR for entertainment is quite different to the original applications for aviation training (Vince, 2004).

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[3] For images of these VR headsets, please see https://www.theguardian.com/technology/2016/nov/10/virtual-reality-guide-headsets-apps-games-vr

Virtual reality did not take off as people expected in the 1980’s and 1990’s, with many products being a commercial failure and quite quickly discontinued, as discussed by King and Krzywinska (2006). This was due in part to hardware and software limitations and the expense of the equipment. In 1995, Nintendo, one of the biggest gaming companies of the time, released a table-top video game console called the Virtual Boy, firstly in Japan and then soon after in North America. This is considered as one of the early examples of a video game VR headset (King & Krzywinska, 2006). It consisted of a headset display mounted on a tripod, connected to a controller. The headset was open and not head-mounted, so players had to simply lean forward and place their face into the headset. However, the Virtual Boy, like so many others, was a commercial failure and was discontinued within a year of its release. This was said to be due to its high price, low-quality games, health concerns (such as eyestrain), poor portability, monochromatic display, and its poor attempt at a "3D" effect (King & Krzywinska, 2006).

However, VR has been revitalised in the last few years, and has emerged as a popular platform for video games and other entertainment. Entertainment companies commonly advertise the technology for recreational purposes. Even in industry, the technology is used for marketing and advertising purposes. As a result, many of the applications equipment available are entertainment based. Examples include popular video games which were adapted to VR such as Fallout 4 and Skyrim, as well as games developed specifically for VR such as *Space Pirate*

Trainer, *Beat Saber*, *Tilt Brush*, and *RIGS*. Commercially, much less focus has been given to developing software for industry or commerce. Often companies and institutions must contract the creation of specific software, or create it in-house, as off-the-shelf alternatives are rarely readily available.

Similar to virtual environments, virtual reality has varying definitions. These definitions have changed between the early forms of VR to modern VR. For example, many consider virtual reality to be purely headset-based. However, in automotive and other industries, cave automatic virtual environments (CAVEs) are used, utilising wall projectors, which are often referred to as being virtual reality (e.g., Cruz-Neira, Sandin, DeFanti, Kenyon & Hart, 1992), since they also create immersive virtual environments.

Modern VR, as mentioned above, is typically considered to be a computer-generated 3D environment, usually viewed via a headset, which replaces the real world. Sales figures for two of the most popular VR headsets (Oculus Rift and HTC Vive) are now reported to be in the millions (SuperData, 2020). However, other approaches have been introduced in which 'virtual objects' are overlaid onto the real world; Augmented Reality (AR) and Mixed Reality (MR) systems. The difference between MR and AR is not clearly defined, but it is commonly considered to be that MR allows real and virtual objects to interact, whereas AR doesn't. MR combines the real and virtual worlds, with physical and digital objects co-existing and interacting in real-time. Extended Realities (a term used here to encapsulate VR, AR and MR) are often treated as the same, but they offer very different experiences and possibilities; therefore, their advantages and disadvantages need to be matched to any given application.

Psychological Research

Negative Effects of Video Game Playing

Video games have been widely used for some years now, and as such their use has often been discussed and debated by the public, researchers, and the media. These games have found themselves as a topic of debate over concerns about how they affect well-being, particularly in relation to children.

One of the most prominent and well-known debates regarding video games is whether violent games influence violent behaviours. A common theory is that playing violent video games increases aggression in young people. Various studies claim to support this hypothesis (e.g., Anderson et al., 2004, Barlett & Rodeheffer, 2009; Moller & Krahe, 2009). However, other studies find no link between violent video games and increased aggression (Adachi & Willoughby, 2011; Drummond & Sauer, 2019; Ferguson et al., 2008; Przybylski & Weinstein, 2019; Williams & Skoric, 2005) or even find that playing games reduces aggression (e.g., Barnett, Coulson & Foreman, 2009; Colwell & Kato, 2003; Ferguson & Rueda, 2010; Sherry, 2007).

More recently the media in the US has returned to discuss video games as being a contributing factor to shootings, such as the one in Walmart in El Paso on August 3rd, 2019. In response to the shooting, Walmart removed certain video games from display, as well as references to specific types of action games (Fortin, 2019). The fact that the media's occasional condemnation of video games can drive commercial decisions demonstrates how important evidence-based research is for this form of entertainment.

Another issue which has only been researched more recently, is the addiction to video games (Gunuc, 2015). The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), introduces "Internet Gaming Disorder", identifying it as a condition which requires further clinical research. As well as concerns about addiction (e.g., Wood, 2008), other mental health concerns regarding video game playing include social isolation and self-esteem (e.g., Colwell & Payne, 2000).

There are a large number of other controversies surrounding both video games in general, as well as specific games. These include issues with sexual themes, portrayal of gender, LGBT characters, portrayal of cultures and countries, religious symbols, and online harassment. Some of these issues have even caused particular games to be banned in some countries (e.g., Call of Duty games, Custer's Revenge, Bully, Command & Conquer: Generals). These issues are talked about in the media, and often prompt academic research. For example, Dill, Brown and Collins (2008) investigated the effects of exposure to sex-stereotyped video game characters on an individual's judgement of sexual harassment. They found that men exposed to stereotypical media content made more tolerant judgments of real-life instances of sexual harassment when compared to controls.

Positive Effects of Video Game Playing

Not all potential effects of video game playing are negative. A variety of possible benefits of playing video games have been studied, including spatial skill improvements (e.g., Uttal et al., 2013), emotional benefits (e.g., Granic, Lobel & Engels, 2014), improved problem-solving skills (Prensky, 2012), and increases in cooperation and helping (Ewoldsen et al., 2012; Velez, Mahood, Ewoldsen & Moyer-Gusé, 2012).

To date, much of the video game research has been focused on cognition. Boot, Kramer, Simons, Fabiani and Gratton (2008) studied a variety of different cognitive abilities, which included memory, executive control and attention. They found that ‘expert gamers’ showed improved performance on these tasks in comparison to ‘non-gamers’. Researchers have attempted to see if these benefits can be brought about with training, and although some have found positive training results (e.g., Green & Bavelier, 2003; Green & Bavelier, 2006; Green & Bavelier 2007; Kozhevnikov et al., 2018), others have failed (e.g., Boot, Kramer, Simons, Fabiani & Gratton, 2008; Oei and Patterson, 2013). Oei and Patterson (2014) provide a literature review focused on training gains and suggest that previous research differs because any training gains are very specific, rather than reflecting a general skills improvement.

Effects of video game playing on cognition are widely debated, similar to the debates of the impact of video games on aggression. Evidence is available supporting positive, negative, and negligible effects of video game play and cognition. In some cases, this is due to the types of cognition studied. Video game studies into cognitive skills typically include perception and visual attention. Visual attention is a broad term which encompasses many specific types of attentional processes. These are cognitive operations that facilitate the selection of relevant information and help to filter out irrelevant information. Not all of these processes use the same cognitive mechanisms, which may account for why some appear to be improved through video game play, but not others, as video game playing may use and train some of these mechanisms, but not all.

Dye, Green and Bavelier (2009) ran a study with the attention network task (ANT), a complex task which considers three factors of visual attention which are cognitively different: alerting, orienting and congruency. They found that action video game players (VGPs) make faster and more accurate responses to targets, suggesting that they have improved attentional skills compared to non-video game players (NVGPs). Specifically, they found that action VGPs had a larger orienting effect than NVGPs, and a larger congruency effect. Obana and Kozhevnikov (2012) found a very short-term performance improvement in the congruency portion of the ANT after playing an action video game (lasting about 10-30 minutes after playing). However, Irons, Remington and McLean (2011) used a flanker compatibility task (testing congruency) and found that action VGPs did not have larger interference from distractors.

Enumeration tasks have also previously been used to study the differences between VGPs and NVGPs by Green and Bavelier (2003; 2006). This task requires participants to count the number of objects on display. Green and Bavelier found that response time for VGPs and NVGPs are similar for up to 5 or 6 items, and then up to 12 items it is slower for VGPs relative to NVGPs. Response time is typically faster for action VGPs than NVGPs (e.g., Castel, Pratt and Drummond, 2005; Dye., Green & Bavelier, 2009). However, Green and Bavelier found that VGPs had increased performance as they were more accurate and, on average, were able to successfully track two more items than NVGPs. Green and Bavelier (2003) also found that just 10 hours of action video game training improved performance in this task by increasing accuracy.

There are many studies which show performance improvements for VGPs over NVGPs for a multitude of visual attention tasks. However, other studies have attempted to replicate these effects and failed. Murphy and Spencer (2009) conducted a replication of Green and Bavelier (2003). They ran 65 participants on the Attentional Blink task (temporal attention), a Useful Field of View task (spatial distribution of attention), an Inattentional Blindness task (attentional capacity) and a Repetition Blindness task (attentional processing ability). They failed to replicate Green and Bavelier's findings, instead finding no indication that VGPs have better visual attention skills (see also Kozhevnikov et al., 2018).

Boot, Kramer, Simons, Fabiani and Gratton (2008) studied memory, executive control and attention, and found that expert gamers could switch between tasks more quickly, could track faster moving objects, were better at detecting changes to objects in visual short-term memory, and were more efficient at mentally rotating objects, than non-gamers. However, they were unable to replicate the action video game training and individual difference effects seen by Green and Bavelier (2003, 2006). Meanwhile, Collins and Freeman (2014) tested 66 participants for task switching ability, visual short-term memory, mental rotation, enumeration, and flanker interference and they found no significant differences between action VGPs and NVGPs.

Many VGP studies also focus solely on action VGPs, whereas others consider VGPs more broadly, regardless of genre. A recent report (Limelight Networks, 2019) found that 18-25-year-olds prefer First-Person Shooter (e.g., Call of Duty) and Battle Royale games (e.g., Fortnite). However, globally across all age groups “Casual Single-Player” games were found to be the most popular – these are described as games such as Candy Crush, Angry Birds, and Spider Solitaire, all of which are non-action games. As non-action games are played the most, it is important to consider both action and non-action games. Oei and Patterson (2013) found visual search enhancement through video game training. However, it was not dependent on the game being an action video game, as visual search time was significantly decreased after training with a hidden object game and a match-3 game (games which require searching a display for specific or matching shapes).

Overall, there is much contention in current VGP studies. It is important to understand why this might be, to accurately gauge the realistic impacts and effects of playing video games. As technology improves and becomes more and more important in everyday life, it is vital to understand not only its possible effects, but also its possible uses and applications

Technology and Pedagogy

Education is often slow to adopt technological improvements (e.g., Cuban, 1986; Selwyn, 2017). However, learning with electronic media (e-learning) has been shown to be effective in numerous studies (e.g., Rosenberg, 2001; Zhang, Zhao, Zhou & Nunamaker, 2004). In a meta-analysis including 1105 papers, Schmid et al. (2014) found a small but reliable advantage for non-Internet computer-assisted instruction compared with classroom instruction.

According to the constructivist learning theory (e.g., Duffy, 2013; Fosnot, 1996) learning is an active process, whereby learners construct knowledge for themselves (as opposed to passively receiving information). This theory builds on ideas and suggestions from Piaget’s theory of cognitive development (e.g., Piaget, 1937; 1950), Dewey’s functional psychology (Dewey, 1938) and Vygotsky’s social development theory (Vygotsky, 1980), which have been expanded and researched within cognitive psychology.

E-learning generally promotes active learning through interactive technology tools, which constructivism would claim as beneficial. Kay (2011) developed an evaluation scale for Web-Based Learning Tools (WBLT) which focuses on three key constructs: learning, design, and engagement. Kay found an improvement in pre-versus post-test scores on remembering, understanding, application, and analysis when using WBLT compared to standard methods of teaching. These categories were derived from the revised Bloom's Taxonomy (Bloom, Englehard, Furst, Hill & Krathwohl, 1956; see also Anderson et al., 2001), which suggests that there is not simply one way in which information is processed and learnt. The taxonomy is a model used to classify educational learning objectives based on cognitive principles, and it presents learning as a hierarchy of learning, consisting of six stages that involve cognitive processes from simplest to most complex (from remember, understand, apply, analyse, evaluate, to create).

Technologies can complement classroom teaching rather than replace it, with technologies like VR being particularly useful for teaching practical tasks, while virtual laboratories can offer advantages over traditional methods, such as providing greater flexibility for conducting experiments (Valdez, Ferreira, Martins & Barbosa, 2015; for reviews see Albidewi & Tulb, 2014; Hilgarth, 2010; Welsh, Wanberg, Brown & Simmering, 2003). VR boasts a number of features that could be useful for education: they present environments in 3D, they are interactive, and they are able to give audio, visual and even haptic feedback. Presenting learning materials in 3D can be especially beneficial for teaching subjects where it is important to visualise the learning materials (e.g., in chemistry or in engineering).

Simulations can be used to mimic real experiments which are important in Higher-level education for many subjects (e.g., Davies, 2008), and understanding has been shown to be equivalent for both physical and virtual experiments (Zacharia & Olympiou, 2011). Experiments and practicals are often important interactive learning approaches, and XR can be beneficial when physical experiments are not practical. Indeed, interactivity and feedback enhance learning by promoting active rather than passive learning. Active learners are more engaged, motivated, and show better learning than passive learners (Benware & Deci, 1984), leading to better student outcomes (Chi, & Wylie, 2014; Cui, 2013).

Markant and Gureckis (2014) noted that according to one explanation active learning improves performance by enhancing cognitive processes related to motivation, attention, and engagement (see also Chi & Wylie, 2014). However, they theorised that the difference between active learning and passive learning comes from a hypothesis-dependent sampling bias which happens when an individual collects data to test their own hypotheses. This explanation is in line with constructivism, which also focuses on the importance of the interaction between experiences and ideas. Thus, VR and MR, which enable active learning, might be more effective compared with traditional learning methods because they allow one to experience and test such learner-generated hypotheses, when compared with traditional passive learning methods (e.g., lectures, textbooks).

Freeman et al. (2014) conduced a meta-analysis of 225 studies which compared student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning conditions. They found that students in classes with traditional lecturing performed worse in the examination and were 1.5 times more likely to fail than students in classes with active learning methods. Similarly, another meta-analysis also found a benefit of using computer simulations for STEM learning (D'Angelo, Rutstein, Harris, Bernard, Borokhovski & Haertel, 2014).

Pan, Cheok, Yang, Zhu, and Shi (2006) noted that the use of extended realities can help enhance, motivate and stimulate learners' understanding, as well as improve their overall mood. Being in a positive mood can also have reciprocal effects on learning, for example by enabling increased cognitive flexibility (Nadler, Rabi, & Minda, 2010), or simply by creating a positive academic climate (Seligman, Ernst, Gillham, Reivich, & Linkins, 2009). Indeed, Olmos-Raya et al. (2018) found a significant effect of both positive emotion and high immersion on knowledge acquisition.

In VR the user is totally immersed in the virtual environment, as it replaces the physical environment around them. Immersion and engagement can be considered intrinsically linked in virtual environments (McMahan, 2003). Mount, Chambers, Weaver and Priestnall (2009) discussed the relationship between immersion, presence and engagement. They explored what it means for a learner to be immersed, and considered immersion and engagement in 3D virtual environments, in order to outline how 3D virtual environments can be used to enhance learner engagement.

Educational research and theories therefore suggest that virtual reality, and other forms of XR, may be well suited to education as well as entertainment and industry.

Research Value

It is important to conduct further research into video games and other virtual environments because of how prevalent they are in today's society. The Entertainment Software Association regularly reviews data about the video game industry. Although video games are often considered to be primarily for children, under 18's only make up 26% of the video game playing populations (Entertainment Software Association, 2015). 30% of video game players are 18-35 years old, 17% are aged 36-49, and 27% are 50 years old and over.

Video gaming is usually considered to be a male-dominated environment, but it has been found that it is a much more even split between male (54%) and female (46%) than might be expected (Statista, 2017). In total, estimates show that there are over 2.3 billion gamers playing worldwide (Newzoo, 2018).

The data shows that video games, a subset of virtual environments, are played by millions of people across all ages, gender and socioeconomic statuses. Therefore, as something which is used by so many people, they should be studied in-depth to understand just how they affect people. It is also important to consider possible applications of virtual environments and video games, as any beneficial uses can reach a wide audience.

Similarly, virtual reality statistics show the increasing use of this technology. A report from Greenlight Insights (2017) predicts continued growth for VR with global revenues expected to increase from $29.1 billion in 2019 to $74.8 billion in 2021.

The findings of this research could potentially impact home, professional and educational settings, as virtual environments are used in all of these situations.

Research Motivation

The aim of this thesis is to critically examine these types of virtual environments, and to provide further understanding into how we may benefit from utilising them.

Some of the current research into virtual reality is either not very rigorous (e.g., educational reports), doesn't consider human-technology interaction (such as simulator sickness), or doesn't include enough pedagogic information (e.g., technology studies). As such, there is a gap in the field for research that covers all of these bases. Video game research, on the other hand, is often very conflicting, with opposing results found across studies.

My motivation for studying this topic is twofold. Firstly, with such great controversy surrounding video games, I am interested in further examining the true cognitive effects of using them. Video games are often vilified in the media, even though many individuals report a positive experience with them and gaming is on the rise. Literature, on the other hand, is varied, with some studies denouncing them as a harmful form of entertainment, and others praising them as a great way to train your brain. I believe it is important to understand why there is such a disparity in results, and where the truth lies.

Secondly, I believe it is important to keep education up to date with other areas, such as entertainment and industry. When it comes to new technology, education is often lagging behind these other fields albeit due to lack of funding, traditional mindsets, or other reasons. I am motivated to help study how these technologies may be of benefit to education. In particular, not just whether the equipment can be used for education, but whether it should be used. As opposed to just using new technology for the sake of it, I want to examine if it offers any real benefits. Beyond this, taking into account any practical considerations, I would like to then demonstrate how these technologies might be integrated into education.

Thesis Structure

Chapter 2 considers video games and visual attention. Many previous studies show conflicting evidence for the impact that video games have on attention. An experiment is conducted investigating these conflicting results, considering multiple different types of attention, and how these different types are affected by both frequency of video game play, and video game genre. The attention network task was used to measure alerting, orienting, and congruency. A preview search task was used to measure searching and filtering. Finally, an enumeration task was used to measure executive control and visual short-term memory.

Chapter 3 looks more in-depth at the ways that video game experiences are measured, and how video game genre might impact on results. A new questionnaire (the Video Game Experience Questionnaire) was developed in order to more accurately gain an understanding of participants' video game playing history, considering potentially important factors such as genre and platform. Furthermore, a questionnaire was put to professionals in the video game industry regarding the cognitive skills relevant to different video game genres, in order to further understand the impacts of these genres.

Chapter 4 uses the new questionnaire developed in the previous chapter to compare participants in a task switching study, where participants switched between parity (odd or even) and magnitude (smaller or greater than five) tasks. A further area of interest which was included was personality, to consider whether video game players tend towards any of the Big Five Personality Factors, which was measured with a brief 10-item personality scale. Impulsivity was also measured using the Barratt Impulsiveness Scale, to see if this links to video game play experience or personality.

Chapter 5 presents research into the impact of video game playing experience and learning. The experiment discussed in this chapter grouped participants based on their video game experience by using the Video Game Experience Questionnaire created in Chapter 3. Participants took part in three different learning tasks and performance on these tasks was compared based on participants' video game experience. Contextual cueing was used to measure implicit memory, colour sequences were used to test working memory, and word recall was used to test explicit memory.

Chapter 6 investigates learning in virtual environments, specifically virtual reality (VR). In this chapter’s experiment, virtual reality is compared to both traditional textbook style materials, and video. Learning is measured by participants taking a test before and after studying learning materials (Biology - plant cells) from one of the three conditions. Learning is split into remembering and understanding, which are two aspects of Bloom’s taxonomy. Emotional impact was also considered, and students rated the learning environments with a web-based learning tool evaluation scale.

Chapter 7 examines more in-depth learning in virtual environments, including comparisons between VR and mixed reality (MR). In this experiment, VR is compared to MR, and traditional learning, again comparing pre-test and post-test scores across conditions. Learning materials used were from a university engineering course, and the subject was solar panels. The traditional learning condition in this experiment is comprised of lecture slides. User experience factors are also considered, such as presence, user acceptance, and simulator sickness.

Chapter 8 brings together the findings of the previous chapters, and gives conclusions based on these and pre-existing literature. Implications of these findings are discussed, and suggestions for future research are made.

Chapter 2: Do video game players perform better on visual attentional tasks than non-video game players?

Abstract

Research has shown that video game players perform better on a multitude of visual attention tasks than non-video game players. However, more recent research questions these findings, showing limited or no benefit of video game playing. The aim of this study was to further investigate this discrepancy by considering multiple attentional processes, including alerting, orienting, executive control, searching/filtering and visual short-term memory. Three different attention tasks were selected to measure these processes: The Attention Network Task (ANT), the preview search task, and the enumeration task. A total of eighty participants completed the tasks and filled out a questionnaire about their past video game experience. For the analysis, participants were divided into three groups depending on whether they played rarely/never, occasionally, or frequently. The groups were equivalent in terms of other control measures, such as personality. Those playing rarely/never had a stronger alerting effect in the ANT than those playing occasionally or frequently. All three groups had the same preview benefit in the preview search task. In the enumeration task, no difference was found between the three groups in the deflection points. Those who played occasionally or frequently were also further grouped into action and non-action players. Action video game players had a higher orienting effect than non-action players. We suggest that the conflicting

results in previous research can be partially attributed to the type of task used to measure visual attention, as well as to the genre of game played.

Introduction

Video games are a widely used form of entertainment, with over 2.3 billion gamers playing worldwide (Newzoo, 2018), spending an average of 7 hours playing every week (Limelight Networks, 2019). In context, UK adults spend 12 hours a week watching on-demand TV, and 12 hours a week on social media (ComRes, 2018). With such a frequency of play, the possible impacts of video game playing suggest further research is still required, as it is important to consider the various effects such a widespread medium may have on people. Since their inception, video games have been a matter of dispute in both the public and scientific communities. Both opinions and research are split, with arguments for both their negative and positive impacts.

Many aspects of video games have been studied, with one of the most well-known debates being whether violent video games cause aggression. Like much of video game research, arguments are split two ways, with some researchers arguing that violent video games do not cause aggression (e.g., Ferguson, 2007; Fleming & Rickwood, 2001; Kühn et al. 2019; Sherry, 2007), and others arguing that they do (e.g., Anderson et al., 2004; Barlett & Rodeheffer, 2009; Bushman & Anderson, 2002). As well as possible direct impacts of playing, such as aggression, there are possible links between other negative traits and video game playing that are debated, such as addiction (e.g., Wood, 2008), social isolation, social phobia and depression (Wei, Chen, Huang & Bai, 2012), and reduced self-esteem (e.g., Colwell & Payne, 2000). Video games can also sometimes impact on mood in positive ways. Casual video games were reported to improve mood and reduce stress (Russoniello, O'Brien & Parks, 2009). Playing video games can reduce rumination, which is a good predictor of depression, and may contribute to triggering depression (Kühn, Berna, Lüdtke, Gallinat & Moritz, 2018).

There are other potential effects of video game playing which are researched, such as possible benefits for medical training (e.g., Alnajjar & Virdi, 2009). A broad area which has been focused on is cognition. Boot, Kramer, Simons, Fabiani and Gratton (2008) studied a variety of different cognitive abilities, which included memory, executive control and attention in players and non-players. They found that 'expert gamers' showed improved performance on these tasks in comparison to 'non-gamers'. Researchers have attempted to see if these benefits can be brought about with training, and though some have found positive results to this effect (e.g., Green & Bavelier, 2003; Green & Bavelier, 2006; Green & Bavelier 2007), others have failed (e.g., Boot, Kramer, Simons, Fabiani & Gratton, 2008; Oei and Patterson, 2013).

Oei and Patterson (2014) found that training gains are specific, not general. They had non-gamer participants play a game on a mobile device for one hour a day for four weeks. They completed a battery of visual attention tasks (attentional blink task, spatial memory and visual search task, multiple object tracking and cognitive control, and a verbal span task) both before and after training. They found different cognitive improvements across various game genres (not just action games). They concluded that video game training does not improve general cognitive systems, but specific cognitive processes, such as spatial working memory with a memory matrix game, and those sharing common demands, accrediting cognitive improvements to near-transfer effects.

Another possible reason for the mixed results could be the issue of self-selection bias of participants, as people with superior perceptual, attentional, and cognitive skills might benefit and enjoy video game play more as these skills are required for successful gaming. This also includes other non-causal factors such as whether a video game system is available in the household (Boot, Kramer, Simons, Fabiani & Gratton, 2008).

Other areas within cognitive skills are perception and visual attention. This study aims to consider a variety of attentional processes, in order to better understand the previous disparity in results. Visual attention is a broad term which encompasses many specific types of attentional processes. These are cognitive operations that facilitate the selection of relevant information and help to filter out irrelevant information. Not all of these processes use the same cognitive mechanisms, which may account for why some appear to be improved through video game play, but not others, as video game playing may use and train some of these mechanisms, but not all. In order to measure how video game playing affects attention, specific tasks were chosen which measured these different attentional processes.

The attention network task (ANT) is a paradigm (Fan, McCandliss, Sommer, Raz, & Posner, 2002), which considers three factors of visual attention: alerting, orienting and congruency. For alerting, a short alerting tone is either present at the beginning of the trial, or there is no tone. Orienting is tested with either a valid (on the same side of the screen) or invalid (on the other side of the screen) orienting cue which is briefly presented before the target. Flanker arrows on both sides of the target were either congruent, facing the same direction as the target, or incongruent, facing the opposite direction. This task measures these three types of attentional processes, which are cognitively different. Dye, Green and Bavelier (2009) showed that action video game players (VGPs) make faster and more accurate responses to targets, suggesting that they have improved attentional skills compared to non-video game players (NVGPs). Specifically, they found that action VGPs had a larger orienting effect than NVGPs, and a larger congruency effect. Obana and Kozhevnikov (2012) found a very short-term performance improvement in the congruency portion of the ANT after playing an action video game (lasting about 10-30 minutes after playing). However, Irons, Remington and McLean (2011) used a flanker compatibility task (testing congruency) and found that action VGPs did not have larger interference from distractors.

The preview search task requires participants to search for a target whilst filtering out irrelevant distractors. In this paradigm, participants are first shown a preview set (for 1s) with half of the distractors followed by the second set containing the target with the other half of distractors. Participants are able to ignore the previewed distractors, allowing them to search only through the second set, leading to better performance. The preview condition (PRE) is typically compared with a full-element baseline condition (FEB) in which all items appear together and with a half-element baseline condition (HEB) in which only the new items from the PRE condition are presented. The mechanism of filtering out the first set was called visual marking (Watson & Humphreys, 1997). This task was chosen as a measure for filtering and inhibitory processes in visual attention. Yan and El-Nasr (2006) state that action-adventure games and first-person shooter games tend to elicit a top-down visual search pattern, involving goal-oriented attention, in which an individual allocates attention to specific features, objects, or locations in space. This would suggest that they are better at visually searching for specific targets.

Finally, for visual short-term memory, the enumeration task was selected, which requires participants to count the number of objects on display. These objects, such as small circles or squares, are shown on screen for a brief period of time. Typically, response time and accuracy are constant for up to four items (e.g., Atkinson, Campbell, & Francis, 1976; Oyama, Kikuchi, & Ichihara, 1981; Trick & Pylyshyn, 1993) and then response time begins to increase from 5 to 12 items. These first few items which can be processed easily are the subitizing range, which does not require the use of visual short-term memory, and larger numbers of items which take longer to process are part of the counting range, where visual short-term memory is used. Although visual short-term memory is not needed for the subitizing range, it has been suggested that subitizing and visual short-term memory share a common system (Cutini & Bonato, 2012).

This task has previously been used to study the differences between VGPs and NVGPs by Green and Bavelier (2003; 2006). Green and Bavelier found that response time for VGPs and NVGPs are similar up to 5 or 6 items, and then up to 12 items it is slower for VGPs relative to NVGPs. Response time is typically faster for action VGPs than NVGPs (e.g., Castel, Pratt and Drummond, 2005; Dye, Green & Bavelier, 2009). However, despite being slower, VGPs demonstrated better performance as they were able to successfully track on average two more items than NVGPs. Green and Bavelier (2003) also found that just 10 hours of action video game training improved performance in this task by increasing accuracy.

There are many studies which show performance improvements for VGPs over NVGPs for a multitude of visual attention tasks. However, other studies have attempted to replicate these effects and failed. Murphy and Spencer (2009) conducted a replication of Green and Bavelier (2003). They ran 65 participants on the Attentional Blink task (temporal attention), a Useful Field of View task (spatial distribution of attention), an Inattentional Blindness task (attentional capacity) and a Repetition Blindness task (attentional processing ability). They failed to replicate Green and Bavelier's findings, instead finding no indication that VGPs have better visual attention skills.

Boot, Kramer, Simons, Fabiani and Gratton (2008) studied memory, executive control and attention, and found that in comparison to non-gamers, expert gamers could switch between tasks more quickly, could track faster-moving objects, were better at detecting changes to objects in visual short-term memory, and were more efficient at mentally rotating objects. However, they were unable to replicate action video game training and individual difference effects seen by Green and Bavelier (2003, 2006). In contrast, Collins and Freeman (2014) tested 66 participants for task-switching ability, visual short-term memory, mental rotation, enumeration, and flanker interference and they found no significant differences between action VGPs and NVGPs.

Many VGP studies focus solely on action VGPs, whereas others consider VGPs more broadly, regardless of genre. A recent report (Limelight Networks, 2019) found that 18-25-year-olds prefer First-Person Shooter (e.g., Call of Duty) and Battle Royale games (games in which players compete to be the last player standing; e.g., Fortnite), however, across all age groups Casual Single-Player games are the most popular. As non-action games are played the most, it is important to study both action and non-action games. Oei and Patterson (2013) found visual search enhancement through video game training. However, it was not dependent on the game being an action video game, as visual search time was significantly decreased after training with a hidden object game and a match-3 game (games which require searching a display for specific or matching shapes).

The present study looks at three different visual attention tasks in order to further explore if the type of attentional process has an impact on results, to attempt to see specifically what aspects of attention are affected by video game playing. The ANT, preview search, and enumeration tasks are used. Based on previous findings, the predictions for these tasks are as follows: 1) there will be a higher orienting effect for VGPs; 2) there will be a higher congruency effect for VGPs 3) VGPs will be more efficient at the preview search; 4) VGPs will be able to subitize a higher number of dots.

Method

Participants

81 participants took part in the study, but one was removed due to very high error rates across all tasks (51-91%), which indicated that they had not followed the instructions. Data was used from 80 participants, who took part to earn Psychology course credit at the University of Warwick. Participants (56 females, 24 males) had an estimated average age of 21.3 years (range 18-40), and all participants reported normal or corrected-to-normal vision. The study was approved by the University of Warwick Ethics Committee (Psychology), and each participant gave prior informed written consent.

Apparatus

Participants were tested in individual laboratory rooms with low lighting. Stimuli were presented on a 19” LCD monitor running with 60 Hz at a 1440x900-pixel resolution. The experiment was controlled by an IBM-PC compatible computer using custom-written software. Participants sat with their head approximately 57 cm away from the computer screen, and their responses were recorded using three navigation keys (left, right and down keys) of a standard computer keyboard. In the Enumeration task, the space bar and the 1-9 keys were also used for responses.

Procedure

Participants were given printed instructions detailing what they were required to do for each task. After giving consent, they completed the computer tasks in the following order: ANT, preview search, enumeration, this took 30-40 minutes depending on each participants' speed. This order was not counterbalanced as it was selected based on the task requirements (i.e. enumeration was completed last, as it would be less impacted by fatigue effects due to the nature of the subitizing process). The groups were not expected to have differing levels of fatigue resistance, as they were all equally likely to participate in on-screen activities of various kinds. At the end of the tasks, they were given the questionnaires, which they completed in 5-10 minutes.

Stimuli and Design

Attention Network Task (ANT)

This task measures three aspects of visual attention: alerting, orienting and congruency. For alerting, there was either a short tone presented at the beginning of the trial or the tone was absent. An orienting cue was displayed, which was either valid (correctly indicating the target location), or invalid (on the other half of the screen). Participants were tasked to report the direction of the target arrow (i.e., the middle arrow in a row of five arrows). The four flanker arrows on either side of the target were either congruent (facing the same direction as the target) or incongruent (facing the opposite direction). For an illustration of the sequence of events in the ANT see Figure 2.1.

A 2x2x2 mixed design was used with Alerting (tone, no tone), Orienting (valid, invalid) and Congruency (congruent, incongruent) as within-subject factors. There were 20 practice trials followed by 128 experimental trials, which were divided into four blocks, with short breaks between blocks. Stimuli were grey (RGB: 128, 128, 128) on a black background, five pixels thick (~0.2°). The fixation cross in the centre of the screen was 1.5° in size. The cue was a horizontal oval (1.6° × 0.8°) with no fill and was presented either 5.4° above or below fixation. The arrows (length of 1.5°) were comprised of a horizontal line (length of 1.0°) and a right-angled equilateral filled triangle (0.5° × 0.7°) pointing either left or right. Arrows were also presented either 5.4° above or below fixation. The target arrow was presented in the centre (horizontally aligned with fixation), with the adjacent flanker arrows 5.4° and 2.7° to the left and to the right of the target (see Figure 2.1). The alerting tone was a short auditory beep (~400 Hz) lasting 50 ms.

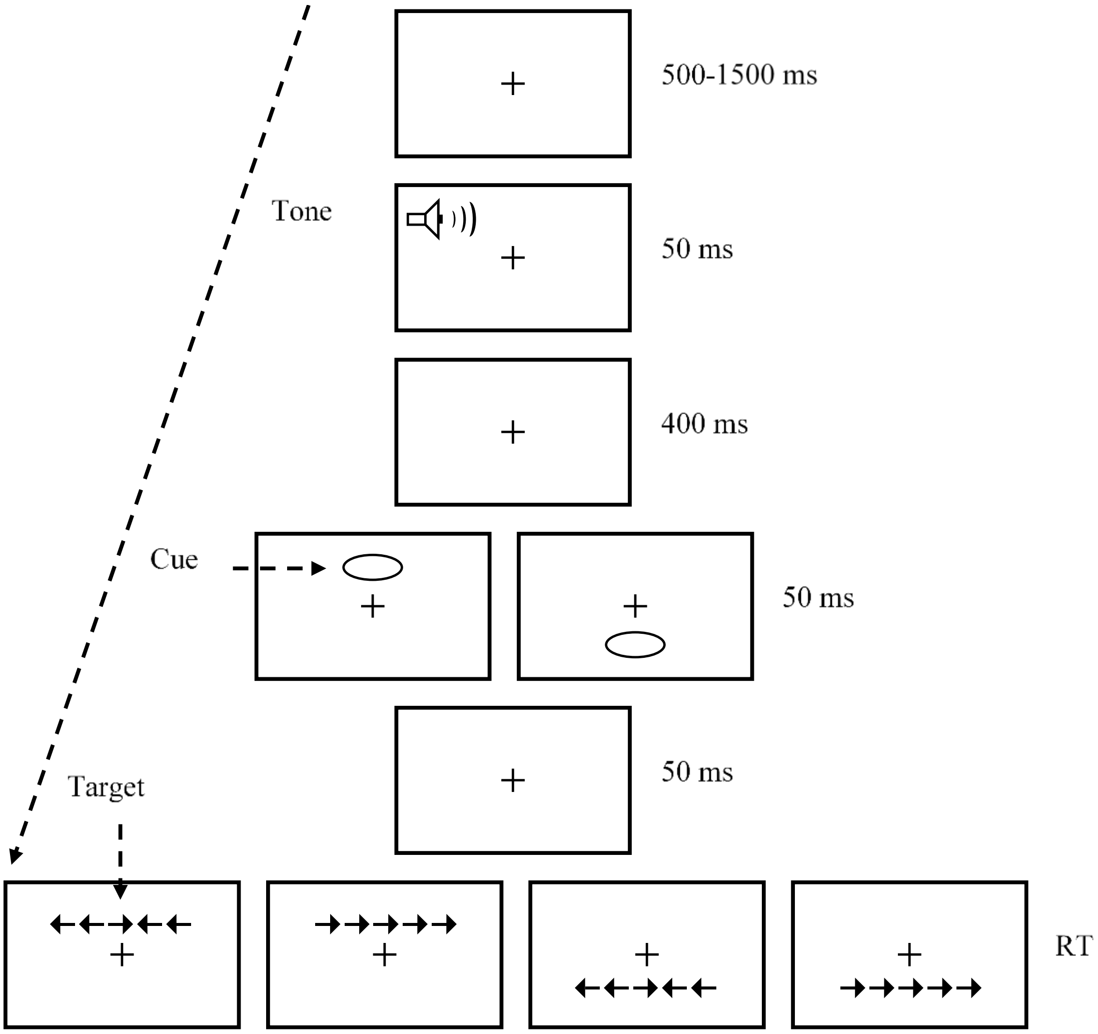

Figure 2.1. The sequence of events in an example trial of the ANT. A tone (either present or absent) was followed by a spatial cue (top or bottom of the screen), which in turn was followed by target arrow either in the cued or uncued location (i.e. valid or invalid). The target arrow also had surrounding flanker arrows (either congruent or incongruent to the target arrow). In this example, participants were required to give a right-arrow response.

Preview Search Task

In this task participants had to search for a target – in this case a blue H – among distractors – blue As and green Hs (see Figure 2.2). They had to press one of two arrow keys (left or right) to indicate whether the target was on the left or right side of the display. The display size was systematically varied from 4, 8, to 16 items. There were 3 different conditions for the preview search: half element baseline (HEB), full element baseline (FEB), and preview (PRE). The half element baseline condition showed half as many items in the visual search screen as the full element baseline. The preview condition had a brief display of half of the distractors before showing the full search screen.

A 3x3 within-subjects design was used looking at condition (HEB, FEB, PRE) and set size (4, 8, 16) as within-subjects factors. Each participant completed 20 practise trials followed by 252 experimental trials divided into 9 blocks, with short breaks between blocks. There were a total of 24 experimental trials for each combination of condition and set size. There were also 36 trials where no target was presented (catch trials). Stimuli comprised of a grey fixation dot (RGB: 128,128,128) with green (RGB: 11,193,126) or blue (RGB: 68,164,176) letters, on a black background. The fixation dot was a square subtending 0.4° of visual angle. The target was a blue letter H, and distractor letters were green Hs and blue As, all subtending 1.0° × 1.5° (thickness ∼ 0.16°). Letters were created via line segment subsets from a box-figure 8. Target and distractor letters were randomly placed within an 8 × 8 cell matrix, each cell 75 pixels high and wide (3°). The random placement had the constraint that the target could not be placed within the two central columns, to ensure that it was not ambiguous whether the target was in the left or right sections of the screen.

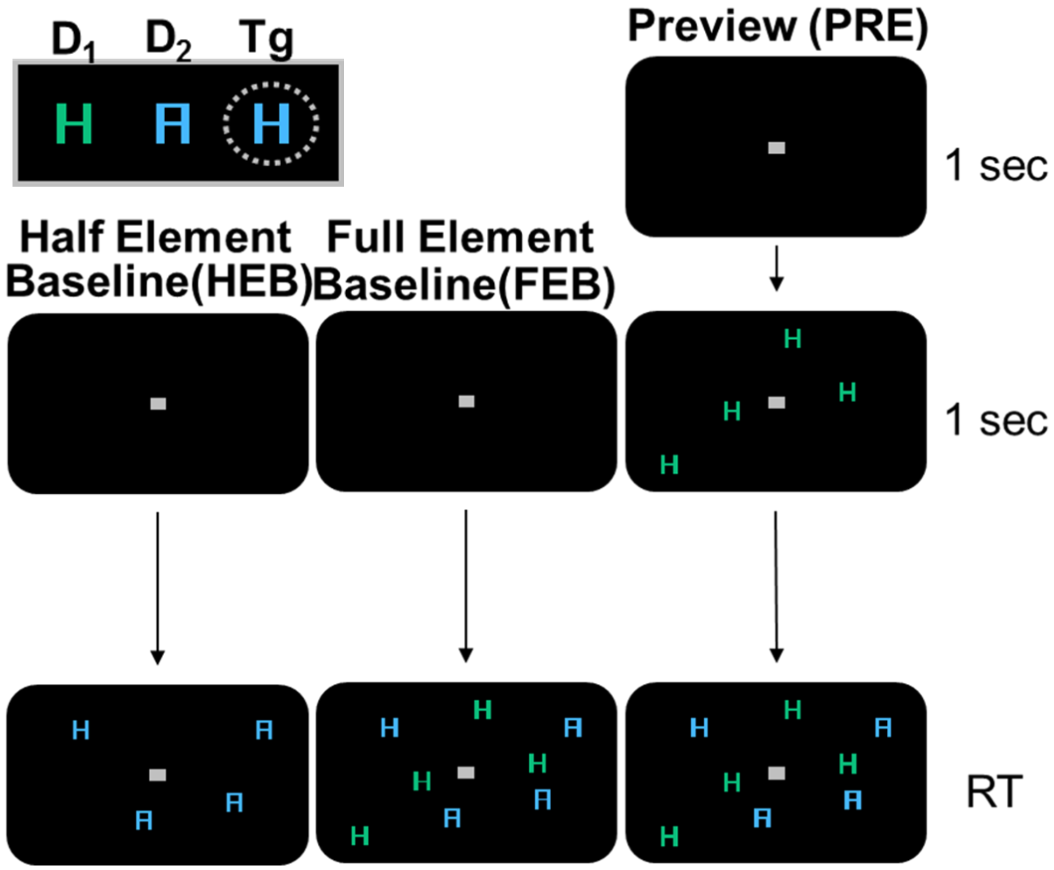

Figure 2.2 Illustration of the targets and distractors, as well as the sequence of events in the three conditions of the Preview Search task. Each trial starts with the presentation of a fixation dot for 1 s. In the preview (PRE) condition, the dot is first followed by the preview display for 1 s. Note that the stimuli were coloured blue and green, which may not be visible in when printed in black and white.

Enumeration Task

A varying number of dots between 1 and 9 were presented on the screen for 250 ms. Participants had to press the space bar as soon as they knew how many dots were displayed on the screen. Next, they had to enter the number of dots using the corresponding key (1-9) on the keyboard. Feedback was provided during the practice stage. There were 18 practise trials followed by 180 experimental trials in six blocks. The dots were filled circles 0.8° in diameter and they were placed in a matrix of 8 x 8 cells, each cell 3.0° high and wide. Dots were placed randomly in cells and were randomly jittered (shifted horizontally and vertically between -0.5° and +0.5°).

Questionnaires

The first part was an adapted version of the Video Game Play History Questionnaire (Gackenbach, 2006; Gackenbach & Bown, 2011), which included four main questions to score video game play experience, looking at the frequency of play, length of play, number of games played, at age video game playing began (Appendix 1). The question "How often do you typically play video games?" was used to group participants based on their frequency of play. Questions also included which platforms they played video games on, and which genre they played most frequently. The second part (Appendix 2) was a brief 10-item personality questionnaire (Gosling, Rentfrow & Swann, 2003). This scored each participant on each of the Big 5 Personality traits, using two items for each of the traits (Extraversion, Agreeableness, Conscientiousness, Emotional Stability, Openness to Experience), on a scale of 1-7 (from disagree strongly to agree strongly).

Results

Of the 80 participants, three did not complete the Enumeration task due to a technical fault. In total, data from 80 participants was used for ANT and Preview Search analysis, and from 77 participants for Enumeration analysis. Next, the Video Game Play History Questionnaire was used to place participants into one of three VGP Frequency groups, depending on whether they played video games rarely/never, occasionally, or frequently (see Table 2.1). As can be seen from Table 2.1, those playing action games (compared to non-action and "none of the above") tend to play more frequently, however, this difference was statistically not significant, χ^2 (4, N = 80) = 3.41, p = .491. However, frequency of play was significantly linked to platform, χ^2 (4, N = 80) = 16.87, p = .002, with those playing occasionally or frequently being more likely to play on both home and mobile platforms rather than on only home or only mobile platforms (see Table 2.1). The three frequency of play groups did not differ in terms of personality (all p > .294).

Table 2.1. The total number of participants in each VGP Frequency group further split into genre category and platform category.

	Rarely/Never	Occasionally	Frequently
Genre			
Action	4	7	10
Non-action	10	15	11
None of the above [1]	9	7	7
Platform			
Home	7	7	4
Mobile	7	0	1
Both	8	22	22
Unknown [2]	1	0	1
Total	23	29	28

Note. [1] Some participants responded "None of the Above" on the genre question or left it blank. [2] Unknown is when participants left the question blank.

VGP Frequency

Mean reaction times (RTs) in the ANT were calculated for each participant and within-subject factor combination, excluding 3.2% errors and 0.8% outliers (2 *SD* below or above the cell mean). RTs averaged across participants are given in Table 2.2 separately for the three VGP frequency groups. The mean RTs were used to calculate RT indexes for each attention network: The alerting index was calculated by subtracting the mean RT of the four conditions with a tone from the mean RT of the four conditions without a tone. The orienting index was calculated by subtracting the mean RT of the conditions with a valid cue from those with an invalid cue. The congruency index was calculated by subtracting the mean RT of the conditions with congruent flankers from those with incongruent flankers. Indexes averaged across participants in each group are shown in Figure 2.3.

Table 2.2 Mean RTs in milliseconds (*SD*) for each factor combination in the ANT.

	Invalid		Valid	
	Congruent	Incongruent	Congruent	Incongruent
Rarely/never (n = 23)				
No tone	588 (85.8)	698 (90.9)	560 (91.9)	630 (106.3)
Tone	555 (66.9)	667 (73.0)	498 (71.8)	575 (76.9)
Occasionally (n = 29)				
No tone	533 (49.7)	627 (58.1)	485 (53.7)	570 (53.0)
Tone	524 (35.9)	635 (53.4)	456 (37.9)	537 (41.5)
Frequently (n = 28)				
No tone	519 (85.9)	609 (77.4)	462 (56.0)	540 (70.6)
Tone	502 (58.3)	613 (75.7)	442 (56.5)	511 (53.1)

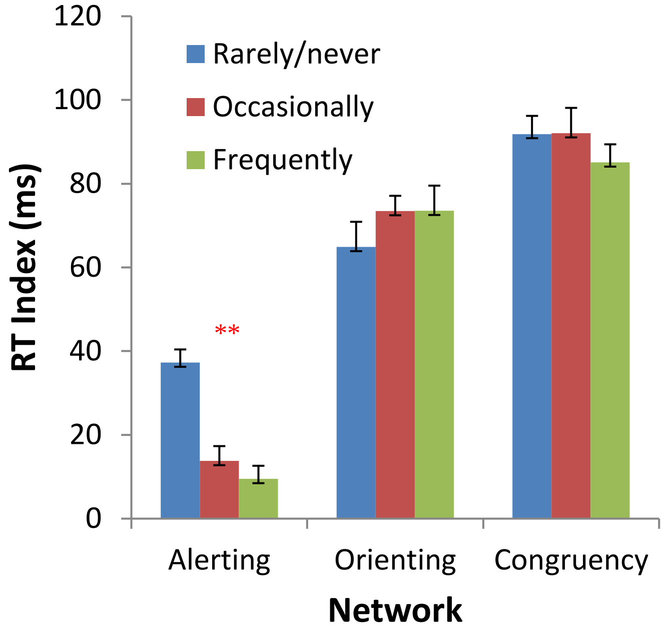

Figure 2.3. Mean reaction time indices and standard error mean (error bars) for the VGP groups as a function of attention network in the ANT.

The individual mean RTs were analysed with a 2x2x2x3 mixed-design Analysis of Variance (ANOVA) with the within-subject factors Alerting (tone, no tone), Orienting (valid, invalid) and Congruency (congruent, incongruent), and the between-subject factor VGP Frequency (rarely, occasionally, frequently). In terms of within-subject factors (not including VGP Frequency), all main effects and two interactions were significant: RTs were 24 ms faster when the alerting tone was present compared to absent, $F(1,77) = 98.3$, $p < .001$, $\eta_p^2 = .561$, they were 68 ms faster when the cue was valid compared to invalid, $F(1,77) = 486.1$, $p < .001$, $\eta_p^2 = .863$, and they were 91 ms faster when the flankers were congruent compared to incongruent, $F(1,77) = 806.5$, $p < .001$, $\eta_p^2 = .913$, Furthermore, the orienting effect was 25 ms larger with the alerting tone present, Alerting x Orienting, $F(1,77) = 40.54$, $p < .001$, , $\eta_p^2 = .345$ and the orienting effect was 27 ms larger when the flankers were incongruent, Orienting x Congruency, $F(1,77) = 45.98$, $p < .001$, $\eta_p^2 = .374$. Of the effects involving VGP Frequency, the Frequency x Alerting interaction reached significance, $F(2,77) = 13.60$, $p < .001$, $\eta_p^2 = .261$: As can be seen from Figure 2.3, those playing videogames rarely or never showed a significantly stronger alerting response than those playing occasionally or frequently (45 vs. 16 or 16 ms, respectively). There was also a significant main effect of Frequency, $F(2,77) = 9.20$, $p < .001$, $\eta_p^2 = .193$. Posthoc *LSD* tests revealed that those playing rarely responded significantly slower than those playing occasionally or frequently (596 vs. 546 or 525 ms, respectively).

To test the possibility that the differences in the alerting index were due to differences in the overall speed, RTs were standardized separately for each participant. The 2x2x2x3 ANOVA on the standardized RTs revealed the same pattern of significant results as the ANOVA on the non-standardized RTs, with the same Frequency X Alerting interaction, $F(2,77) = 12.57$, $p < .001$, $\eta_p^2 = .246$. Thus, the larger alerting effect in participants playing rarely cannot be explained by their overall slower RT.

Overall participants made not many errors (3.2%) and the overall pattern of errors is similar to the overall pattern of RTs. In order to explore possible speed-accuracy trade-offs, RTs were adjusted for errors by calculating inverse efficiency scores separately for each participant, where RTs are divided by accuracy (see Townsend & Ashby, 1983). The 2x2x2x3 ANOVA on the efficiency scores revealed all the same significant effects as the RT ANOVA, including the Frequency x Alerting interaction, $F(2,77) = 9.94$, $p < .001$, $\eta_p^2 = .205$. In addition to these effects, efficiency scores showed a significant interaction between Frequency and Orienting, $F(2, 77) = 5.31$, $p = .007$, $\eta_p^2 = .121$: Those playing video games rarely had a significantly weaker orienting effect than those playing occasionally or frequently (efficiency scores: 70 vs. 99 or 109 ms, respectively).

Mean RTs in the preview search task were calculated separately for each participant and within-subject factor combination, excluding 0.9% errors and 0.7% outliers. Individual RTs were analysed with a 3x3x3 mixed-design ANOVA with the within-subject factors Condition (FEB, HEB, PRE) and Display Size (4, 8, 16 items), and the between-subject factor VGP frequency (rarely, occasionally, frequently). Results showed the typical significant effects found in visual marking studies, with main effects for Condition, $F(2,154) = 289.3$, $p < .001$, $\eta_p^2 = .790$, and for Display Size, $F(2,154) = 485.6$, $p < .001$, $\eta_p^2 = .863$, and with a Condition x Display Size interaction, $F(2,154) = 56.79$, $p < .001$, $\eta_p^2 = .424$: As can be seen from Figure 2.4, RTs were fastest in the HEB condition, and slowest in the FEB condition and in between in the PRE condition (661 vs. 606 and 772 ms, respectively). RTs increased with displays size (overall search slope: 22.1 ms/item), and this increase was smallest in the HEB condition, largest in the FEB condition, and in between in the PRE condition (14.9, 31.1, and 20.4 ms/item, respectively). Of the effects involving Frequency Group, only the main effect of Group was significant, $F(2,77) = 5.35$, $p = .007$, $\eta_p^2 = .122$. Posthoc *LSD* tests revealed that RTs in the rarely/never group were slower than in the frequently group and marginally slower than in the occasionally group (764 vs. 644 and 697 respectively).

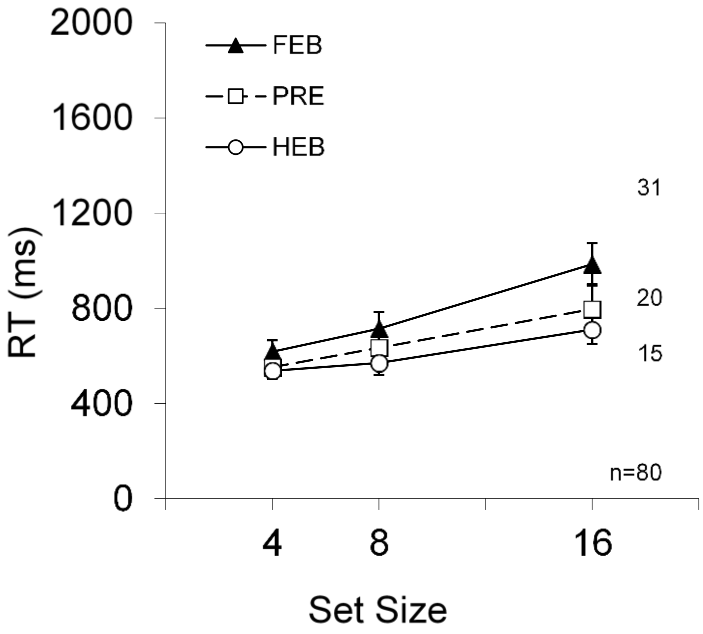

Figure 2.4. Mean RT and standard error mean (error bars) as a function of display size with separate lines for the half-element baseline (HEB), the full-element baseline (FEB), and the preview condition (PRE) in the preview search task.

Figure 2.5 shows the RT slopes (in ms/item) with separate bars for Groups and Conditions. The graph might suggest that frequent players search displays more efficiently than occasional and rare players (19.7 vs. 22.9 and 24.0 ms/item, respectively), however, the Frequency Group X Display Size interaction was only marginally significant, $F(4,154) = 2.01$, $p = .095$, $\eta_p^2 = .050$. The Frequency Group X Condition and the 3-way interactions were both not significant (both $p > .87$). The overall error rate was very low (0.9%), and the corresponding 3x3x3 error ANOVA revealed only a main effect of Condition, *F*(2,

154) = 5.09, *p* = .007, η_p^2 = .062, due to a higher error rate in the FEB than in the PRE and HEB condition (1.2 vs. 0.8 and 0.6%, respectively).

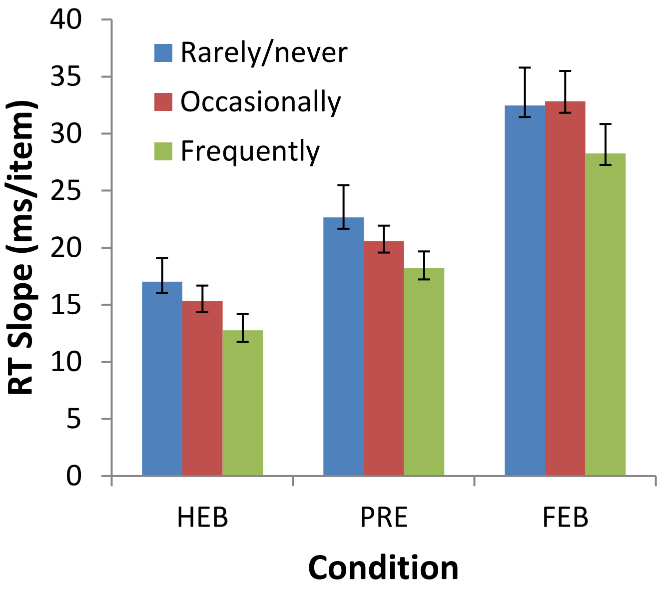

Figure 2.5. Mean RT slopes and standard error means (error bars) across display size in milliseconds per item with separate bars for conditions and VGP groups. Smaller RT slopes indicate more efficient search in the preview search task.

Mean correct RTs and mean errors in the enumeration task were calculated for each participant and within-subject factor combination (see Figure 2.6). A 9x3 mixed-design ANOVA on the individual mean RTs with the within-subject factor Number of Items (1-9) and the between-subject factor VGP revealed a significant main effect of Number of Items, $F(8,584) = 856.31$, $p < .001$, η_p^2 = .921, but no effects involving Group (both *p* > . 815). The equivalent ANOVA on the errors showed also a significant main effect of Number of Items, $F(8,584) = 26.43$, $p < .001$, η_p^2 = .266, but no effects involving Group (both *p* > . 372).

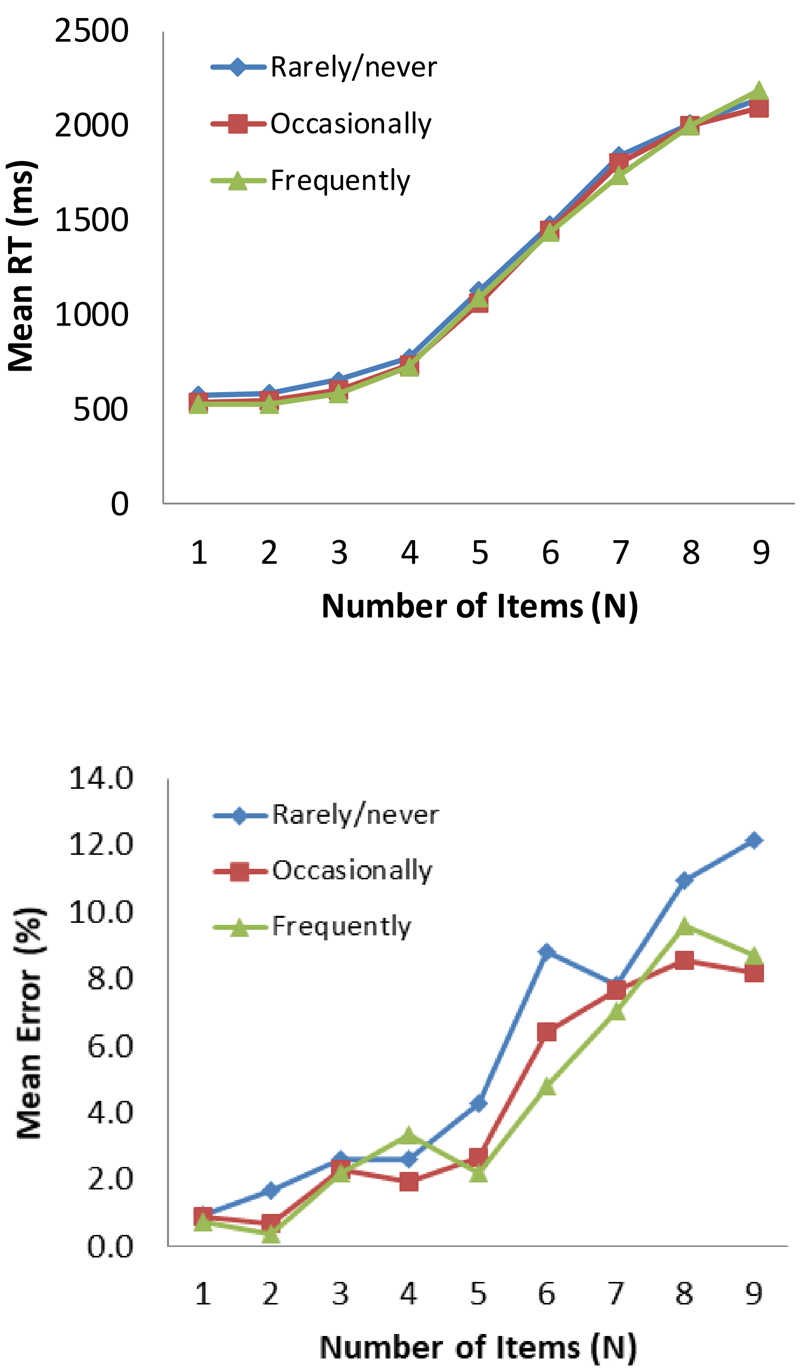

Figure 2.6. Mean reaction time (above) and mean percentage error (below) as a function of number of items with separate lines for low VGP group and high VGP group in the enumeration task.

To estimate the point where participants switched from subitizing to counting, RTs were plotted as a function of Number of Items separately for each participant. Two raters visually inspected each graph and determined the deflection point (i.e., the point where the slope changed from shallow to steep). Cohen's Kappa showed almost perfect inter-rater agreement, $\kappa = 0.854$, $p < 0.001$). The deflection points averaged across groups did not differ between the rarely/never group (3.88), the occasionally group (3.93), and the frequently group (3.69), $F(2,73) = .993$, $p = .376$, $\eta_p^2 = .026$.

VGP Genre

Participants playing video games occasionally or frequently were pooled ($n = 57$) to test whether the genre of the game had an effect on task performance (those playing rarely/never were excluded from this analysis). Participants were split into three groups based on the genre they played most often: The first group ($n = 17$) was called “action” and included first-person shooter, driving, and sports games; the second group ($n = 26$) was called “non-action” and included role-playing, strategy, puzzle, card, and board games. The third group of participants ($n = 14$) responded “none of the above” and they were removed from the analysis (see Table 2.1).

Individual RTs in the ANT were analysed with a 2x2x2x2 mixed-design ANOVA with the within-subject factors Alerting, Orienting and Congruency and the between-subject factor Genre (action, non-action). Of the effects involving Genre, the Genre X Orienting interaction was significant, $F(1,41) = 5.70$, $p =.022$,

η_p^2 = .122, with action players having a larger orienting response than non-action players (78 vs. 61 ms, respectively, see Figure 2.7). This interaction was further qualified by a significant Genre X Orienting X Alerting interaction, $F(1,41) = 8.44$, $p = .006$, $\eta_p^2 = .171$, indicating that the orienting difference between action and non-action players was more pronounced when the tone was absent (72 vs. 42 ms, respectively) than when it was present (84 vs. 79 ms, respectively). None of the other effects involving Genre reached significance (all $p > .38$). To further explore these effects of Genre, a multiple linear regression was calculated to predict the orienting effect based on VGP Frequency and VGP Genre. The regression equation was only marginally significant, $R^2 = .134$, $F(2,40) = 3.103$, $p =$ 0.56). The analysis shows that VGP Frequency did not significantly predict the orienting response, $\beta = 3.75$, $t(42) = 0.544$, $p = .590$, however VGP Genre did significantly predict the orienting effect, $\beta = -16.31$, $t(42) = 2.312$, $p = .026$.

Note that VGP genre (action or non-action) had no effect on search performance in the preview search task (ps > .295 for all effects involving genre), and it also had no effect on the deflection point in the enumeration task, $t(40) =$ .612, $p = .544$.

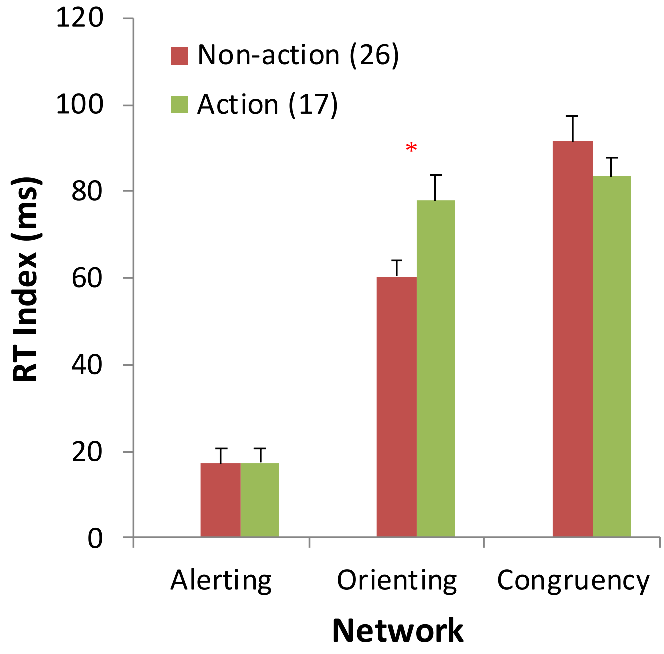

Figure 2.7. Mean reaction time index and standard error mean (error bars) for action versus non-action players as a function of attention network in the ANT.

VGP Platform

To test whether the game platform had an effect on task performance, participants were split into three groups, depending on whether they played games on only home devices, that is, home console devices that are not portable (n = 18), on only mobile devices (n = 8), or on both (n = 52, see Table 2.1). A 2x2x2x3 mixed-design ANOVA on individual RTs in the ANT with the between-subject factors Alerting, Orienting and Congruency and the between-subject factor Platform (home, mobile, both) showed that those playing on mobile devices had a significantly stronger alerting effect than those playing on home or on both platforms, $F(2,75) = 6.73$, $p = .002$, $\eta_p^2 = .152$ (see Figure 2.8). The effect of Platform was further explored with a multiple linear regression predicting the alerting effect based on VGP Frequency and VGP Platform, which was significant, $R^2 = .192$, $F(2,75) = 8.94$, $p < .001$. The analysis shows that Frequency was a much stronger predictor of the orienting effect, β = 12.16, $t(77) = 3.81$, $p < .001$, than Platform (β = -1.94, $t(77) = .65$, $p = .518$). This suggests that the effect of Platform reported above is due to the fact that seven out of eight participants in the mobile group were playing video games rarely or never. Note that VPG platform (home, mobile or both) had no effect on search performance in the preview search task (all $p > .305$), and no effect on the deflection point in the enumeration task, $F(2,71) = 1.151$, $p = .322$.

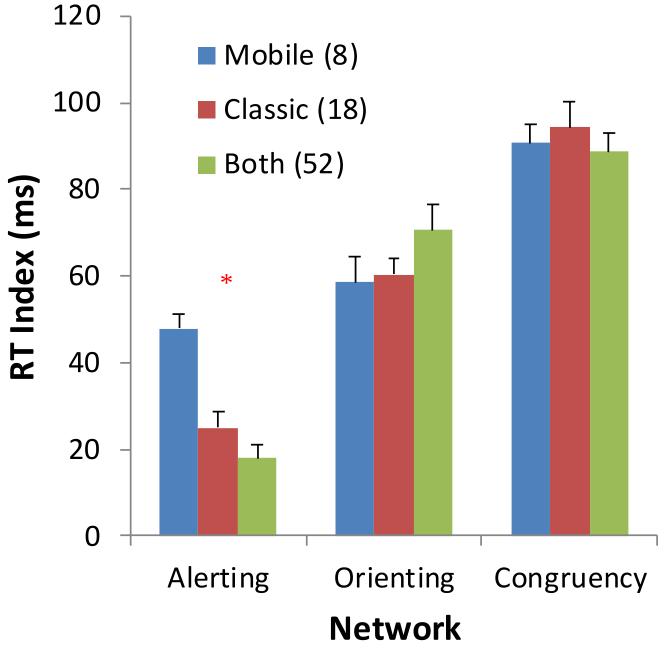

Figure 2.8. Mean reaction time index and standard error mean (error bars) for players grouped by platform as a function of attention network in the ANT.

Discussion

In summary, the current study found VGP effects for alerting in the ANT, but not orienting or congruency. However, an orienting effect was found when comparing action and non-action players. For the preview search task, VGPs had faster reaction times but showed no difference in preview benefit or slope from other VGP groups. VGP genre (action or non-action) and platform (home, mobile) both had no effect on search performance. For enumeration, the VGP groups (frequency, genre, or platform) showed no differences. Green and Bavelier have consistently found attentional improvements of VGPs over NVGPs, and action video game training benefits (e.g., Green & Bavelier, 2003; Dye, Green & Bavelier, 2009; Hubert-Wallander, Green & Bavelier, 2010). However, in line with other studies (e.g., Murphy & Spencer, 2009), which failed to replicate some of Green and Bavelier's findings, the present study showed no performance improvement for VGPs.

ANT

Our study found a significant difference between video game-play frequency and alerting response, with those playing video games never/rarely having a significantly stronger alerting effect than those playing occasionally or frequently. This is in contrast with Dye, Green and Bavelier (2009), who found no effect of action video game play on altering. One possible explanation for these alerting findings might be based on Pacheco-Unguetti, Acosta, Callejas and Lupiáñez's (2010) finding of higher alerting for state anxiety. This could suggest that those who never or only rarely play video games are more anxious when faced with attention tasks compared to those playing video games occasionally or frequently. Compared to those playing occasionally or frequently they might be less familiar and less desensitised to computer tasks, leading to higher alerting effects. Furthermore, the study shows that the alerting effect is driven by VGP frequency and is not affected by VPG genre (action/non-action) or VGP platform (home/mobile/both).

Reaction times showed no difference between VGP frequency groups in the orienting response. Castel, Pratt and Drummond (2005) used the Posner cueing paradigm with VGPs and NVGPs and found that though VGPs had overall faster reaction times, both groups showed a similar amount of inhibition of return. These results suggest that exogenous orienting processes do not differ between VGPs and NVGPs. However, when testing for VGP genre, we found that action VGPs had higher orienting effects than non-action players (78 vs. 60, respectively), similar to the results of Dye, Green and Bavelier (2009), who specifically compared action VGPs to NVGPs (57 vs. 32 ms, respectively). West, Stevens, Pun and Pratt (2008) found stronger attentional allocation to the cued target location in action VGPs compared to NVGPs, with action VGPs having greater sensitivity to exogenous sensory events in the visual array.

For congruency, no differences were found between VGP frequency, genre, or platform groups. Cain, Landau, and Shimamura (2012) used a cueing task (switching between pro-response and anti-response) and found improved attention control in action VGPs, with action VGPs having reduced costs when switching between tasks. They found that with short onset asynchrony (40ms) NVGPs showed a typical exogenous attention effect, but VGPs were less likely to have their attention drawn to the cue location. With longer short onset asynchrony (600 ms), there was no difference between VGPs and NVGPs.

Dye, Green and Bavelier (2009) also reported that VGPs had a larger congruency effect (i.e., they experienced more interference from flankers) than NVGPs. Contrary to these findings, the present study did not find any congruency effects. Pohl et al. (2014) used congruent and incongruent trials with masked primes and found that action VGPs had a larger congruency effect than NVGPs for very short 20 ms primes, but they did not find a difference for longer 60 ms primes. This is in line with our absence of a difference in the congruency effect, however, it does not offer an explanation for the discrepancy between our and Dye et al.’s (2009) result. Note that for other tasks, like the task-switching paradigm, video game practice had an enhancing effect on executive control (Strobach, Frensch, & Schubert, 2012).

Visual Marking

In the preview search task VGPs (playing frequently or occasionally) had overall faster reaction times than those playing never or rarely, but they showed no difference in the preview benefit or in the RT slope. Castel, Pratt and Drummond (2005) had participants complete a task where they searched for a target letter among an array of varied distractor letters and found that action VGPs demonstrated significantly faster reaction times in all conditions, though both groups were equivalent in terms of inhibiting the return of attention to previously cued locations. However, they found an interaction between VGP group and set size, indicating that the VGPs were more efficient in searching the displays than the NVGPs. They suggested that action gaming may change response execution time, rather than the efficiency of visual selective attention. Hubert-Wallander, Green, Sugarman and Bavelier (2011) found that action VGPs had faster search rates than NVGPs, which they stated was consistent with increased efficiency in visual selective attention (for a similar finding see also Wu & Spence, 2013).

Mishra, Zinni, Bavelier and Hillyard (2011) compared NVGPs to action VGPs during a target detection task. They found that VGPs detected targets with greater speed and accuracy than NVGPs. They suggested that the superior target detection capabilities of the VGPs are partially attributable to enhanced suppression of distracting irrelevant information, and more effective perceptual decision processes. Chisholm and Kingstone (2015) also compared action VGPs to NVGPs with a cued visual search task. They found that action VGPs were faster, and less susceptible to distraction than NVGPs. Oei and Patterson (2013) found that match-3, memory matrix and hidden object games improved visual search performance.

Our results are consistent with previous findings that VGP frequency has an impact on reaction speed, but our results did not indicate a difference based on video game play frequency. Another similar mechanism is inhibition of return (e.g., Pratt & McAuliffe, 2002; Wang & Klein, 2010), and these results relate to

Castel, Pratt and Drummond's (2005) findings that there is no difference between VGPs and NVGPs for inhibition of return. Our results also found no difference between action and non-action VGPs in the preview benefit as an indicator for visual marking.

Enumeration

The present study found no difference between VGP groups for the enumeration task, for subitizing or mean percentage errors. There were also no differences when comparing action versus non-action players, and mobile versus home gaming platforms. Previous research by Green and Bavelier (2003, 2006) found a different deflection point between VGPs and NVGPs, suggesting that VGPs were able to subitize a higher number of dots at once and more accurately than NVGPs. However, Collins and Freeman (2014) found no differences between VGPs and NVGPs for enumeration. Furthermore, Boot, Kramer, Simons, Fabiani and Gratton (2008) conducted a replication and extension of Green and Bavelier (2003) and also failed to find any difference between VGP and NVGP players. These results suggested that video game play frequency does not have an impact on visual short-term memory.

Blacker, Curby, Klobusicky and Chein (2014) trained participants with action video games to test visual working memory capacity. Using a change detection task, they found visual working memory increased after action video game training (compared to training with a control game), as well as some improvement to precision. Wilms, Petersen & Vangkilde (2013) found that video game playing does not seem to impact the capacity of visual short-term memory, though it does appear to improve the encoding speed of visual information into visual short-term memory in Bundesen's theory of visual attention (TVA) task. However, they also did not find any differences in the subitizing range of VGPs versus NVGPs. In their literature review, Oei and Patterson (2014) focused on training gains and suggest that previous research results might differ because training gains are very specific, rather than general skills improvement.

Conclusions

In summary, our results show that participants never or rarely playing video games were making more use of a warning tone than those playing occasionally or frequently. In terms of orienting response and congruency, VGP frequency made no difference. However, when splitting the frequent and occasional players into genre groups, those playing action games had a stronger orienting response than those playing non-action games. In the preview search task and in the enumeration task VGP groupings (whether based on frequency, genre, or platform) made no difference, suggesting that VGP had no effect on visual inhibition and short-term memory. The current findings suggest that some of the conflicting results in the literature may be due to differences in the specific tasks used. Alternatively, this may also be partially explained by the way that individuals are distinguished as VGPs versus NVGPs (depending on genre or platform, please see detailed examples of this in the next chapter), a line which blurs when considering increasingly commonly played mobile games.

Chapter 3: Measuring Video Gaming Experience

Abstract

Video game research often requires using a measure of video game experience in order to categorise participants as video game players or non-players. Measures used to group participants are often one-dimensional, for example, using a simple question such as “how many hours of video games do you play a week?”. This chapter presents the development of a new questionnaire to measure video game experience which includes differentiation between home and mobile video game platforms, and between online and offline multiplayer. A number of studies in the past have made a distinction between "action" and "non-action" games, however in this questionnaire we distinguish between eleven different genres of games. The questionnaire was tested with participants in an online study, and the results demonstrate that home gaming was found to be a better predictor of the “gamer” self-rating than mobile gaming. A further questionnaire is developed to look at how these genres may differ in three different cognitive skills (critical thinking, reaction speed and spatial awareness). The second questionnaire was tested with a different set of participants, both experts (individuals working in the video game industry) and non-experts. The results of the second study showed that the genres can be grouped into four clusters (action, adventure, puzzle and simulation), with each cluster having unique cognitive skill profiles.

Introduction

Video game research often compares participants with pre-existing video game playing habits and experience to those without. In general, only training studies will require participants to play specific games for a set number of hours (e.g., Clemenson & Stark, 2015), therefore other studies rely on participants' self-reported game playing experience. Previous research has often used very simple methodologies to measure video game experience and habits. A common approach is simply to ask participants how many hours of games they have played in a set time span and to group them based on their responses. This is a very basic measure of video game habits, as it only takes into account games played more recently, such as over the past month or year (e.g., Green, Sugarman, Medford, Klobusicky & Bavelier, 2012) and circumstances may have changed. For example, if a participant has previously played games competitively for years, but due to a change in circumstances has not played at all in the previous month, they could be classed as a “non-video game player” (NVGP) by this system of grouping. This is despite the fact that earlier they would have been considered to be a video game player (VGP).

Table 3.1. Previously used measures in the literature to distinguish between VGPs and NVGPs.

Study	VGP Selection	Notes
Dye, Green & Bavelier (2009)	Questionnaire	Questionnaire not referenced or included
Green & Bavelier (2003)	Hours played	
Cain, Landau & Shimamura (2012)	Questionnaire	Questionnaire not referenced or included
Appelbaum, Cain, Darling & Mitroff (2013)	Questionnaire	Questionnaire not referenced or included
Greenfield et al. (1994)	Score on game	
Boot, Kramer, Simons, Fabiani & Gratton (2008)	Hours played	
Donohue, James, Eslick & Mitroff (2012)	Questionnaire	Questionnaire not referenced or included
Clark, Fleck & Mitroff (2011)	Questionnaire	Questionnaire not referenced or included
Mishra, Zinni, Bavelier, & Hillyard (2011)	Hours played	
Green & Bavelier (2006)	Hours played	
Green & Bavelier (2007)	Hours played	
Irons, Remington & McLean (2011)	Hours played	
Murphy & Spencer (2009)	Hours played	
Dye & Bavelier (2004)	Hours played	
Karle, Watter & Shedden (2010)	Hours played	
Green, Sugarman, Medford, Klobusicky & Bavelier (2012)	Hours played	
Donohue, Woldorff & Mitroff (2010)	Hours played, Questionnaire	
Strobach, Frensch & Schubert (2012)	Hours played, Interview	
Collins & Freeman (2014)	Hours played	
El-Nasr & Yan (2006)	Questionnaire	Questionnaire not referenced or included
Clemenson & Stark (2015)	Questionnaire	Questionnaire not referenced or included

Table 3.1 is a non-exhaustive list to give an overview of the types of measures used to categorise video game playing. These studies were selected based on a literature search using key terms. There are some studies, as seen above, which report using questionnaires to measure whether a participant should be classed as a VGP or NVGP. However, these questionnaires may be briefly described but, as can be seen in Table 3.1, they are generally not referenced or included in the paper or appendices, with no discussion of validation. Questions are usually not described in detail, so they may include little more than the question of how many hours the participant has played.

For these reasons, it was decided to develop a questionnaire that would give a more concrete and objective measure of video game experience. The following questionnaire provides a more sophisticated measure of understanding an individual's video game playing experience and history than previously used ones, as it goes beyond a simple measure of how many hours of video games individuals are playing per week. As can be seen in the previous chapter, results can depend on more than just video game playing frequency, but also on video game genre. Furthermore, other relevant questions are considered.

Existing VGP Questionnaires

In order to classify participants as VGPs or NVGPs previous studies have often simply asked questions about the number of hours played on average per week. However, a handful of studies did use more detailed questionnaires, as seen in Table 3.1. One example of such a questionnaire, which was included in the appendix of their study, is the Video Game Play History Questionnaire from Gackenbach and Bown (2011). This was adapted from Gackenbach (2006), which built upon work from Preston (1998), though the questionnaires used were not included in either of these articles. This questionnaire considers a number of variables, measuring frequency of playing games, the typical length of a session, the number of games played to date and the age at which they first played games. They were also asked about their favourite genre and the genre they play most often, with five options for each: first-person shooter; role playing/strategy; driving/sports; puzzle/card/board; none of the above. Questions were also asked regarding platforms played, online gaming, motion sickness, timing (i.e., whether respondents had played a video game in the four hours prior to filling out the questionnaire and if so, which games they had played). Finally, questions were asked about game character features, and other questions related specifically to the study.

Some questions previously reported in Gackenbach (2006), were subsequently omitted from Gackenbach and Bown (2011). These included: length of their last session, their peak playing age, and who they play with. It was not stated why these questions were no longer used. These questions were followed with a list of video game types and participants were asked to respond with what frequency they played them. These video game types were identified as follows: action, adventure, arcade, role-playing, strategy, simulation, driving, puzzle, sport and violent, which is a different genre list to that used by Gackenbach and Bown (2011). Gackenbach (2006) grouped participants into three video game player groups: high, medium and low/no history. These were created by four of the video game questions; frequency of play, length of play, age began playing (with a younger start given a higher score), and the number of types of games played. Scores on these four variables were converted to z-scores and summed.

The questionnaire analysis using z-scores, means that the participants are only given a score relative to the other participants in the study. This can lead to a very subjective measure of video game experience, which is dependent on the sample. There are a number of other limitations with this questionnaire. The questionnaire is now outdated, as the platform options include personal digital assistants and only include those that were launched up to the time of the Nintendo Wii (which was released in 2006). Furthermore, the genres used in Gackenbach and Bown (2011) are much more limited than in Gackenbach (2006), and the frequency of playing these genres is no longer reported. This is a limitation as an individual may play some genres very rarely but others more frequently. Gackenbach (2006) appears to have a more exhaustive list of questions, but the questionnaire was only briefly discussed, and the questions were not included in the publication, so there was no information regarding scales.

El-Nasr and Yan (El-Nasr & Yan, 2006, Yan & El-Nasr, 2006) developed a questionnaire by consulting game industry personnel, as well as trying it and developing it over time (El-Nasr, personal communication, June 14, 2015). This questionnaire was not presented in detail in the paper, however, on enquiry, the authors revealed that the questionnaire consisted of eight items, including questions about the number of hours played per week, platforms used and genres played (from the following list: strategy, first person shooter, action, casual, role-playing games (RPGs), sports, music, other, no preference). Four of the eight questions focused on their favourite games, and how easily they adapt to new games. Therefore, this questionnaire covered a number of areas, albeit only briefly.

Method

Questionnaire Development

For the creation of this questionnaire, resources regarding questionnaire development were consulted (e.g., Kazi & Khalid, 2012). Common problems in questionnaire development include questions being unclear, too long, or including jargon that is not understood by respondents. Other issues include leading questions, or those that ask multiple questions at once. For this questionnaire, these common pitfalls were avoided, including considerations into questionnaire style and appearance, as well as the mode of administration.

In order to choose appropriate questions research was conducted into previous methods for measuring video game experience, as well as previous methods for grouping participants in video game research. Similarly to El-Nasr and colleagues, video game industry personnel were also consulted for this questionnaire.

Based on email correspondence, informal interviews, and pilot study data, three main areas of relevance to video game experience were found, which are further explained below:

1. Playing Extent (e.g., hours played, frequency of play etc…)
2. Genre (e.g., action, strategy and puzzle games)
3. Platform (i.e. home and mobile platforms)

Video Game Playing Experience Measures

Many studies into the cognitive effects of video game playing specifically focus on action video gaming (e.g., Basak, Boot, Voss & Kramer, 2008; Castel, Pratt and Drummond, 2005; Dye, Green & Bavelier, 2009; Schmidt, Geringswald & Pollmann, 2018). However, some studies have found that other genres may have different impacts, including strategy games (Ballesteros et al., 2017) and platformers (Clemenson & Stark, 2015). As such, genre was an important focus of this questionnaire in order to enable it to look at genres other than action.

Platforms used is also included in the questionnaire. The “platform” is the type of device used to play the game, such as a specific console or handheld device. This data was gathered in the questionnaire as it may be interesting to see whether different devices have different impacts. Specifically, it may be of interest whether using static devices that require a TV or monitor have a different effect than handheld devices that are potable and have smaller screens. As such, the questionnaire is split into two sections: “Home” and “Mobile” gaming.

The term “home” gaming was chosen as the consoles which were originally released when moving away from arcade games are termed “home video game consoles” since, unlike arcade consoles, they were designed to be used in a home environment. The term “classic” was initially considered to represent these consoles, in consideration of them being in the style of these classic home video game consoles, however, it was concluded that this term has other connotations, such as retro consoles. Therefore, “Mobile” was chosen as it represents the portable nature of handheld game consoles, as well as encompassing other technologies used to play games on the go, such as mobile phones and tablets.

Also included were questions about multiplayer (playing with others). Playing socially, either co-operatively or competitively, may have different impacts on an individual compared to only playing with an artificial intelligence. Therefore, the questionnaire collects information about whether the individual plays multiplayer games, and if so, if this is only with friends, or also with strangers (random online matches).

For face validity, other researchers and individuals from the gaming community were asked to evaluate, through correspondence, informal interviews and questionnaire feedback, whether the questions presented effectively capture video game experience, and in particular the three areas identified above.

What are Genres?

Genres have been used to categories many types of media, such as books, film, music, and more. The Oxford English Dictionary describes genre as "A particular style or category of works of art; esp. a type of literary work characterized by a particular form, style, or purpose" ("Genre", n.d.).

Video games can fall into numerous categories, with many having subcategories. An example is action games, an umbrella genre for first-person shooters, third-person shooters, fighting games and more. Based on industry research, as well as consultations with experts, eleven main genres were identified. To select the genres, those discussed in both Gackenbach (2006) and Gackenbach and Bown (2011) were used as a base. "Violent" was removed from this list, as this is more of a feature that can apply to multiple genres, and Puzzle/Card/Board was condensed into Puzzle. Industry specialists were then consulted, in order to identify if any genres were missing on the list. The feedback from this stage resulted in adding "Platformer" as a genre, instead of arcade, and simulations were split into construction/management simulation and life simulations. This addressed concerns about including suitable genres. The following descriptions of each genre were presented in the questionnaire (Appendix 3), to give clarity to respondents who may not be familiar with them.

Action: Emphasizes physical challenges, including hand-eye coordination and reaction time. The genre includes diverse subgenres such as fighting games and shooter games. Games in this genre include: Call of Duty, Halo, God of War, Devil May Cry.

Role-Playing Game (RPG): Control the actions of a character/characters immersed in a well-defined world e.g., Skyrim, Fallout, Final Fantasy.

Puzzle: Logic puzzles that require critical thinking to progress. Games in this genre include: Tetris, Portal, Lemmings, Minesweeper, Professor Layton.

Adventure: Assume the role of protagonist in an interactive story driven by exploration and puzzle-solving. Games in this genre include: The Secret of Monkey Island, The Wolf Among Us, Phoenix Wright: Ace Attorney.

Massively Multiplayer Online (MMO): In these games the player interacts with other people from around the world as well the game world. Games in this genre include: World of Warcraft, Destiny, RuneScape.

Strategy: Focuses on skillful thinking and planning to achieve victory, emphasising strategic, tactical, and sometimes logistical and economic challenges. Games in this genre include: Civilization, Total War, Age of Empires, Command & Conquer.

Sports (not including racing): Playing a sport, with physical and tactical challenges, testing the player's precision and accuracy. Games in this genre include: FIFA, Madden, MLB (major League Baseball).

Platformer: Involves guiding an avatar to jump between suspended platforms, over obstacles, or both to advance the game. Games in this genre include: Donkey Kong, Sonic the Hedgehog, Mario, Rayman.

Driving/Racing/Flying: The player operates vehicles, often competitively. Games in this genre include: Forza, Need for Speed, Gran Turismo, Mario Kart, Flight Simulator.

Construction and Management Simulations (Sims): Players build, expand or manage fictional communities or projects with limited resources. Games in this genre include: SimCity, Football Manager.

Life Simulations (Sims): The player lives as or controls one or more artificial lifeforms. Games in this genre include: The Sims, Nintendogs.

Genres are important because of the style of gameplay and the types of actions that are taken in these games, as these can use different cognitive processes. Generalising the effects of all video games regardless of the genre would be akin to saying that a romantic comedy film would have the same cognitive effects as a horror film.

Appelbaum, Cain, Darling and Mitroff (2013) asked participants to rate their perceived level of expertise for eight video game genres via 7-point Likert scale expertise ratings. They defined participants as action video game players if they rated their expertise on “action/platforming” or “first-person shooter” games as greater than or equal to 5. Individuals were categorized as NVGPs if they rated their expertise on “action/platforming” and “first-person shooter” games as 0.

Questions

The questions chosen built on those by Gackenbach and Bown (2011), with changes made to address the limitations previously discussed. The first section concerns self-rankings of both general computer skills and video game experience, with all questions rated on a scale of 1-6. Each questionnaire section has different responses for the scale, as seen in Table 3.2. This is to address the concern that general computer skills could be a potential confounding variable. Furthermore, in order to test the validity of the questions which built upon those of Gackenbach and Bown (2011), additional self-ratings of the gamer classification were included.

Table 3.2. Questions from the first section of the questionnaire, with scales.

Question	1	2	3	4	5	6
How confident are you about using computers?	Not At All Confident	Slightly Confident	Somewhat Confident	Moderately Confident	Highly Confident	Completely Confident
Which of the following best describes your computer skill level?	No Skills	Basic Skills	Average Skills	Good Skills	Expert Skills	Professional Skills
How regularly do you use computers? (Reverse Scored)	Daily	2-3 Times a Week	Once a Week	Fortnightly	Once a Month	Rarely or Never
To what extent do you consider yourself a 'gamer'?	Not At All	Slightly	Somewhat	Moderately	Highly	Completely
Which of the following do you consider yourself to be?	Non-Gamer	Novice Gamer	Causal Gamer	Mid-Core Gamer	Hardcore Gamer	Professional Gamer

This is followed by a section with questions regarding the extent of video game play, as well as genres played, and platforms used. The extent of video game play builds upon the four main questions used to group participants in Gackenbach (2006), which were also present in Gackenbach and Bown (2011), with new scales, so that all four questions are on a 6-point scale for scoring and comparison purposes. Detailed descriptions are given for each genre, as well as naming 2-4 example games. These were given for reference, in case participants were uncertain about specific genres, though they would likely be familiar with some. To address the limitations of Gackenbach and Bown (2011) genre responses also included frequency of play thereby allowing for a more in-depth measure of genre use.

These questions (see Table 3.3) are split into two sections, one for home gaming and one for mobile gaming. The same questions are repeated across both sections, with instructions to answer based only on either home or mobile playing. Home gaming is defined as "games which you play within a home environment. For example, this could be your own home, a friend's home, or a recreational centre". Mobile gaming is defined as "games which you play outside of a home environment. For example, this could be games you can play whilst traveling or in a public place." Mobile gaming is not a fixed boundary, as mobile consoles and games can be played in a home environment. This distinction was not addressed in Gackenbach and Bown's (2011) questionnaire, but mobile gaming is now more prominent (Limelight Networks, 2019) so this warrants further research.

The same genres are presented for both the home and mobile sections, however, the platforms are different. The home section listsconsoles such as

Sony PlayStation consoles, Microsoft Xbox consoles, and desktop computers, and the mobile section lists handheld devices such as the Nintendo 3DS, mobile phones, and tablets. These platforms are up-to-date with the video game console releases, addressing the limited selection in the Gackenbach and Bown (2011) questionnaire.

Participants

The questionnaire (Appendix 3) was distributed on the social media site "Reddit". Reddit has a worldwide population with a wide demographic range. In total, 353 participants fully completed the questionnaire. Responses came from self-reported 46 countries, with just under half of the responses being from the United States. Of those who completed the whole questionnaire (i.e. not skipping any questions), ages ranged from 16 to 49 years, with an average age of 23.0 and a standard deviation of 5.90. In total there were 227 male and 102 female participants, as well as 6 participants preferring not to say.

Table 3.3. Questions from the second section of the questionnaire, with scales.

Question	1	2	3	4	5	6
How long do you typically play a game for?	0-1 hour	1-2 hours	2-3 hours	3-4 hours	4-5 hours	5+ hours
How often do you typically play?	Daily	2-3 Times a week	Once a Week	Fortnightly	Once a Month	Rarely or Never
How many hours a week do you play on average?	0-1 hour	1-3 hours	3-6 hours	6-9 hours	9-12 hours	12+ hours
Approximately how many games have you played in total in your lifetime?	Less than 10	10-30	30-50	50-100	100-200	200+
In the last 12 months, how often have you played each genre on average?	Never	Yearly	Quarterly	Monthly	Weekly	Daily
To what extent do you play video games on each of the following platforms?	Never	Yearly	Quarterly	Monthly	Weekly	Daily
How often do you play video games online? (Either cooperatively or competitively)	Never	Rarely	Occasionally	Regularly	N/A	N/A
Who do you play video games online with?	Friends	Strangers	Both	No One	N/A	N/A
How often do you play video games with others offline (i.e. in the same room)?	Never	Rarely	Occasionally	Regularly	N/A	N/A

Results

Demographics and Self-Ratings

The participants who answered the questionnaire, which was named the Video Game Experience Questionnaire, were from a wide range of countries (Figure 3.1). Participants also reported their highest level of education: Secondary Education (*n* = 70), Post-Secondary Education (*n* = 61), Vocational Qualification (*n* = 30), Undergraduate Degree (*n* = 110), Post-graduate Degree (*n* = 28), Doctorate (*n* = 5), with the rest preferring not to say.

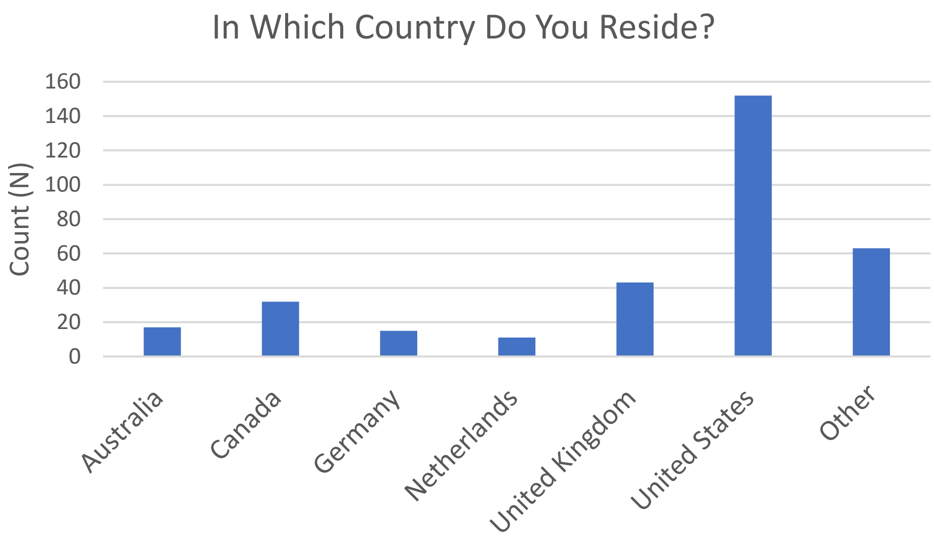

Figure 3.1. Participants' home countries. The "Other" count includes the following countries: Algeria, Argentina, Austria, Belgium, Chile, China, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Greece, Hungary, Iceland, India, Ireland, Italy, Japan, Kenya, Latvia, Malaysia, Mexico, Mongolia, New Zealand, Norway, Philippines, Poland, Russian Federation, Saudi Arabia, Singapore, Slovakia, Spain, South Korea, Sweden, Switzerland, and Uruguay.

328 participants reported using a computer daily, six use one 2-3 times a week, and one participant reported using a computer once a month. 150 participants reported that they were “completely confident” about using computers, 133 were “highly confident”, 43 were “moderately confident”, six participants reported they were “somewhat confident” and three were “slightly confident”. No participants reported not having any confidence about using computers. Similarly, no participants reported having no computer skills, with three participants reporting they have “basic skills”, 30 having “average skills”, 156 having “good skills”, 100 having “expert skills”, and 46 having “professional skills”.

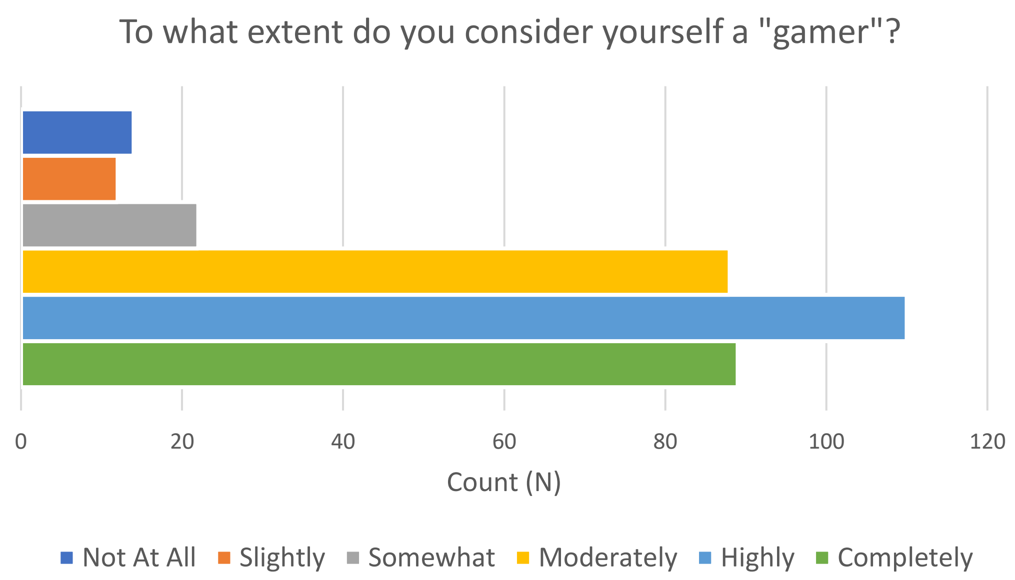

Figure 3.2. Self-ranking of “gamer” title.

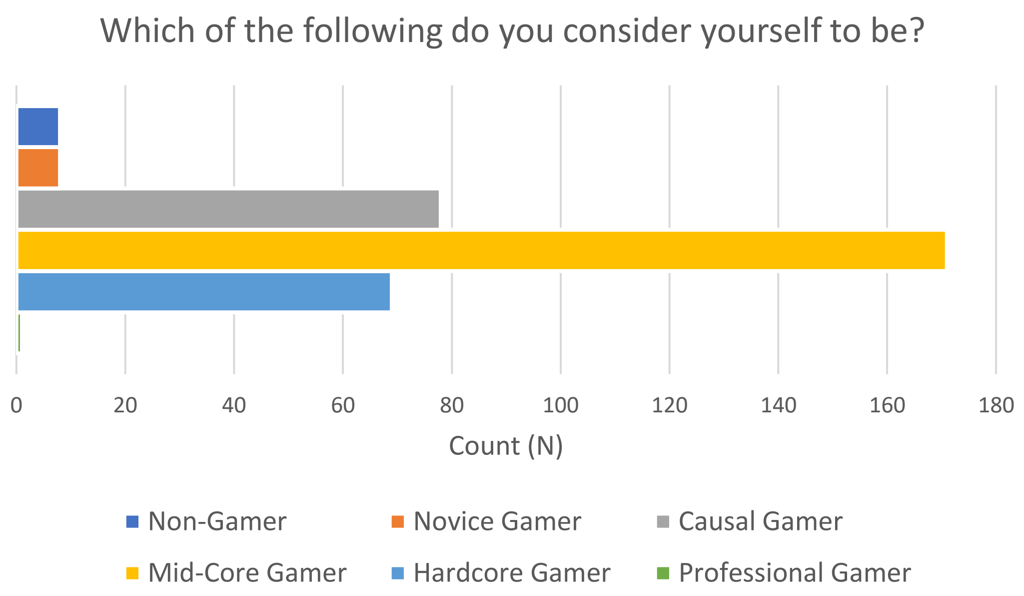

Figure 3.3. Self-ranking of gaming classification scores.

Interestingly, a majority of participants (60%) highly or completely considered themselves to be a gamer, and about a quarter (26%) responded moderately (Figure 3.2). Only 14% of all participants considered themselves not to be a gamer or to be somewhat a gamer. The gaming classification question (Figure 3.3) showed a similar pattern, with "mid-core gamer" having been picked by 51% of the respondents and "hard-core gamer" by 21% of the respondents. There was also one respondent who classified themselves as a "professional gamer".

Pearson's correlations between selected demographic variables (Section 1: Sex, Age and Education) and Computer Skills and Gamer ratings (Section 2) can be found in Appendix 4. Note that the correlations were corrected for multiple comparisons using Bonferroni adjusted alpha levels by dividing 0.05 and 0.01 by the total number of correlations conducted in this study (165), thus resulting in new alpha levels of 0.0003 and 0.00006, respectively. The results revealed a highly significant correlation between Age and Computer Skill Level, $r(334) = .22$, $p < .00006$, thereby indicating a trend that older participants had higher levels of computer skills. There was also a correlations between Sex and Gamer Type, $r(334) = -.20$, $p < .0003$ (Appendix 4, Table A.1), and between Sex and Total Lifetime Games (see next section and Appendix 4, Table A.2), $r(334) = -.24$, $p < .00006$. This indicates a trend that male participants considered themselves to be a gamer more, and have played more games in total in their lifetime than female participants.[4]

Gaming Experience

Sections 2 and 3 of the questionnaire contained questions about home playing and mobile playing, respectively. First home and mobile playing in terms of gaming experience, genre, and social gaming will be compared, and then looked at how they are correlated. Finally, how well home and mobile gaming experience can predict the Gamer self-evaluation will be tested.

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[4] Note that there was also a highly significant correlation between the Computer Confidence and Computer Skills ratings, *r!*334) = .68, p < .00006. However, these intra-correlations were not of particular interest, and so they were not included the table.

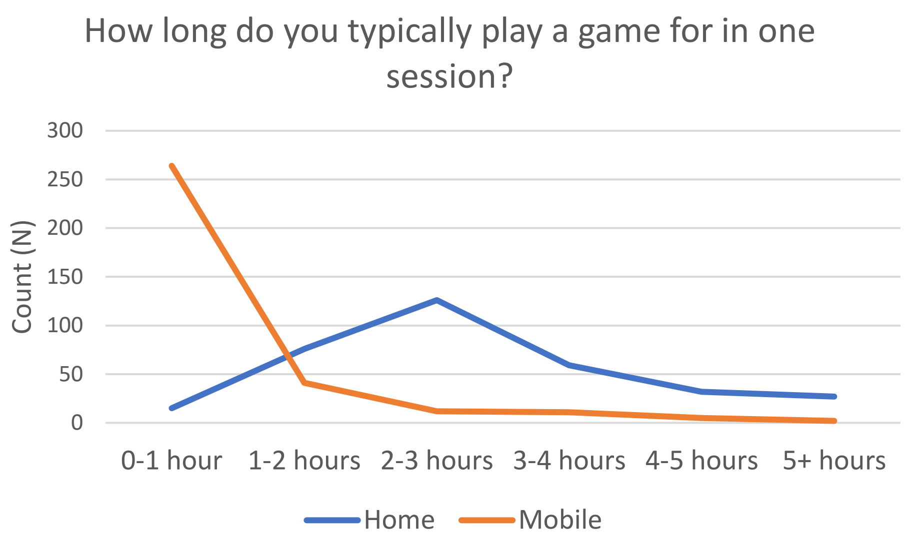


Figure 3.4. Responses for length of play in each session compared between home and mobile gaming.

Figure 3.4 shows how long respondents play home and mobile games for in a typical length session. The large majority of respondents (280) only played mobile games for up to an hour at a time, with drastically reducing numbers for longer periods, dropping from 42 playing 1-2 hours at a time, down to only 2 participants playing for 5+ hours. Length of play for home gaming appears to follow more of a bell curve pattern, with the most responses at 2-3 hours (134), with shallower decreases either side for both shorter and longer periods of play.

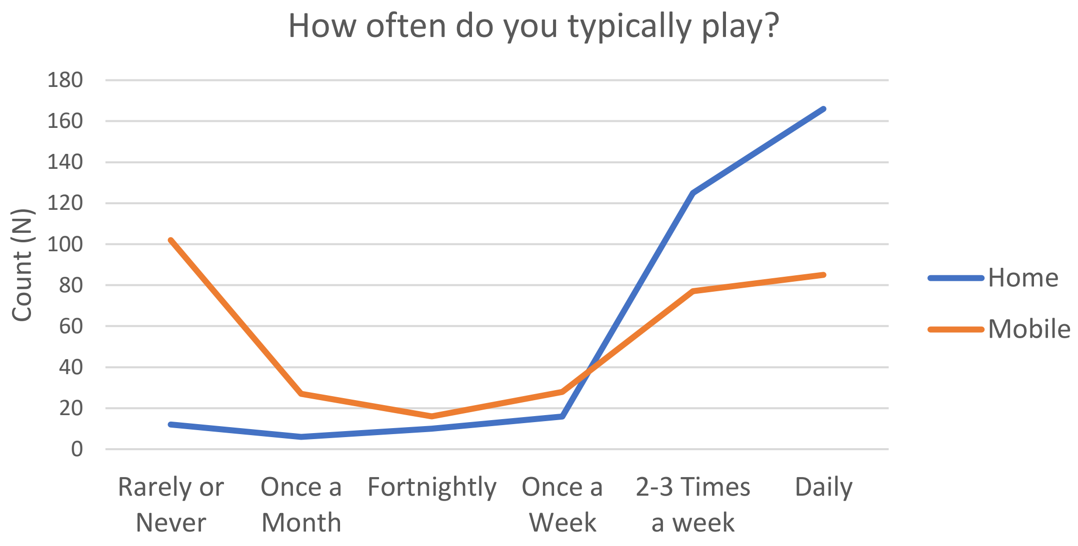


Figure 3.5. Responses for frequency of play in each session compared between home and mobile gaming.

As can be seen in Figure 3.5, home gaming was typically found to occur either daily (177) or 2-3 times a week (130). Mobile gaming, on the other hand, was more evenly split between occurring rarely or never (87), once a month (81), or daily (108). Very few participants played either of these platforms only once a week or fortnightly.

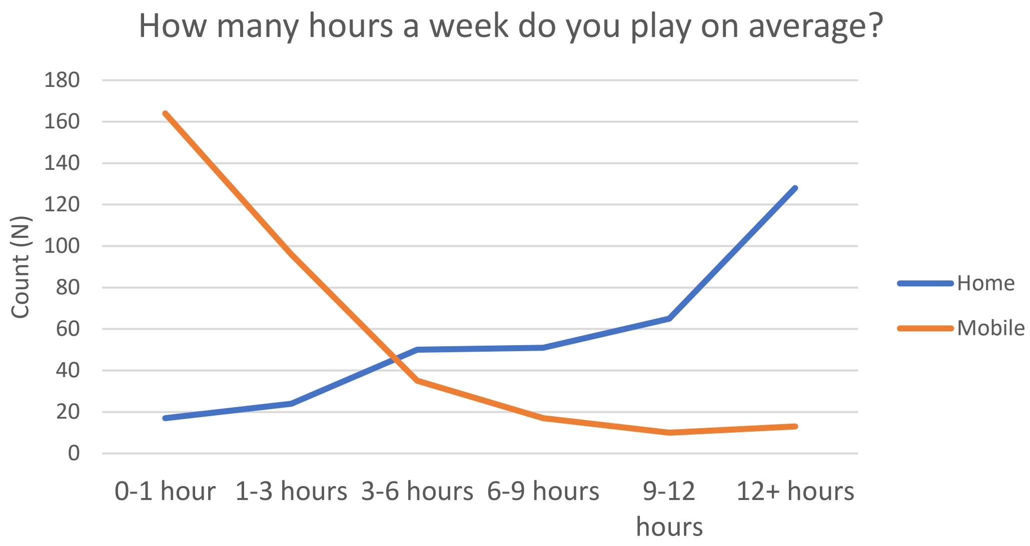


Figure 3.6. Responses for length of play on a weekly basis compared between home and mobile gaming.

Weekly hours spent playing video games demonstrated opposite trends for home and mobile gaming (Figure 3.6). The number of hours played being were much lower for mobile gaming and, exhibited a steep downward slope. Home gaming on the other hand, followed an upward slope, with more hours of play being more common.

Pearson's correlations of demographic variables and Self-Ratings (Section 1 and 2) with home gaming experience (Section 3a) can be found in Appendix 4 (see Table A.2). Table A.2 shows that the home gaming experience (i.e., Session Length, Playing Frequency, Weekly Hours) does not depend on demographics or computer skills, however all gaming experience variables show highly significant correlations with gamer self-ratings (all rs from .41 to .65).

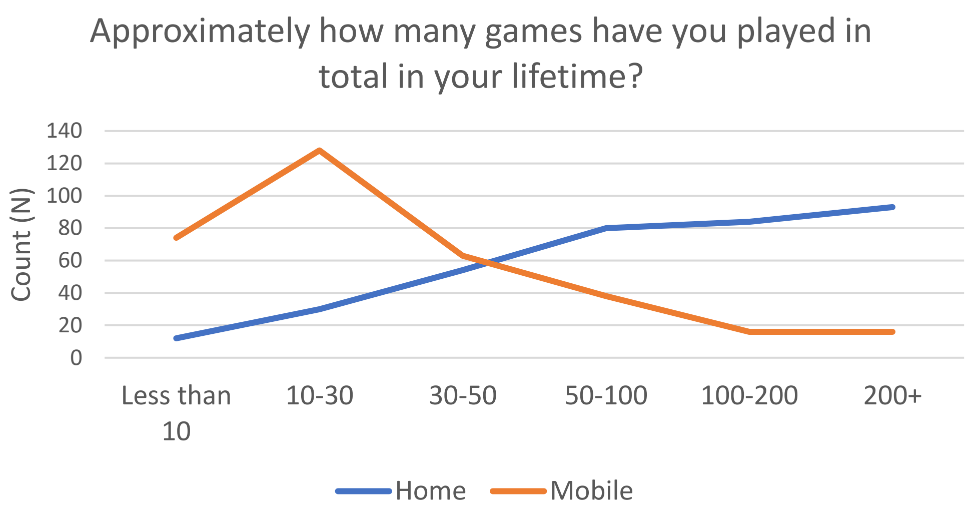


Figure 3.7. Responses for total games played compared between home and mobile gaming.

The ratings of the four home VGP questions (i.e., session length, playing frequency, weekly hours, and total lifetime games) were entered as predictors in a multiple linear analysis to estimate their contribution to the dependent variable Gamer rating. The analyses used a forward selection strategy, starting without variables in the equation, entering the most significant predictor in the first step, and then continuing to add and delete variables until the amount of variance explained no longer improved significantly (α-to-enter was set to .05, α-to-remove to .10).

Table 3.4. Summary of stepwise regression analysis with the home VGP questions (Playing Frequency, Session Length, Total Lifetime Games, and Weekly Hours) predicting the gamer rating.

Variable	*B*	*SE B*	β
Step 1 (R^2 = .43)			
Constant	24.89	0.10	
Playing Frequency	0.71	0.05	.65**
Step 2 (R^2 = .50)			
Constant	23.75	0.18	
Playing Frequency	0.61	0.05	.56**
Session Length	0.29	0.04	.29**
Step 3 (R^2 = .55)			
Constant	22.68	0.25	
Playing Frequency	0.51	0.05	.46**
Session Length	0.25	0.04	.25**
Total Lifetime Games	0.23	0.04	.25**
Step 4 (R^2 = .56)			
Constant	22.15	0.36	
Playing Frequency	0.40	0.07	.37**
Session Length	0.21	0.05	.20**
Total Lifetime Games	0.22	0.04	.24**
Weekly Hours	0.12	0.06	.14 *

Note R^2 = .74 for Step 1; ΔR^2 = .07 for Step 2, $F(1,332) = 50.31$, $p < .001$; ΔR^2 = .02 for Step 3, $F(1,331) = 36.05$, $p < .001$; ΔR^2 = .01 for Step 4, $F(1,330) = 4.30$, p = .039.

* $p < .05$. ** $p < .01$

The results for home VGP are summarized in Table 3.4. The first variable selected by the stepwise regression procedure described above was Playing Frequency accounting for 43% of the variance. The next variable selected was Session Length, increasing the amount of explained variance to 50%. The next variable was Total Lifetime Games, increasing the amount of explained variance to 55%. Finally, Weekly Hours was selected, which increased the amount of explained variance only very little, to 56%. In terms of the final regression weights (B), Playing Frequency contributed about twice as much to the gamer rating as Session Length and Total Lifetime Games, whereas Weekly Hours contributed relatively little (even though its contribution to the gamer rating was still significant). For the subsequent analysis, the average of the four home VGP ratings was calculated and used as a measure of overall VGP experience (i.e., Home VGP Mean in Table A.2).

Pearson's correlations of demographic variables and Self-Ratings (Section 1 and 2) with mobile gaming experience (Section 4a) can be found in Appendix 4 (see Table A.3). Table A.3 shows that the mobile gaming experience (i.e., Session Length, Playing Frequency, Weekly Hours) does also not depend on demographics or computer skills. The gaming experience variables show no or much weaker correlations with gamer self-ratings (r range from .07 to .28).

The ratings of the equivalent four mobile VGP questions (i.e., session length, playing frequency, weekly hours, and total lifetime games) were also entered as predictors in a multiple linear analysis to estimate their contribution to Gamer rating, using the same selection strategy as for home VGP. The results are summarized in Table 3.5. The only variable selected by the stepwise regression procedure was Total Lifetime Games, accounting for 8% of the variance. The other variables (Session Length, Playing Frequency, and Weekly Hours) were all excluded from the model. For comparison to the equivalent home VGP regression analysis, the average of the four mobile VGP ratings was calculated (for correlations using the Mobile VGP Mean see Appendix 4). The Home VGP Mean score was chosen as a measure of overall VGP experience, as the gamer rating was better predicted by home playing (56%) than by mobile playing (8%). [5]

Table 3.5. Summary of stepwise regression analysis with the mobile VGP questions (Playing Frequency, Session Length, Total Lifetime Games, and Weekly Hours) predicting the gamer rating.

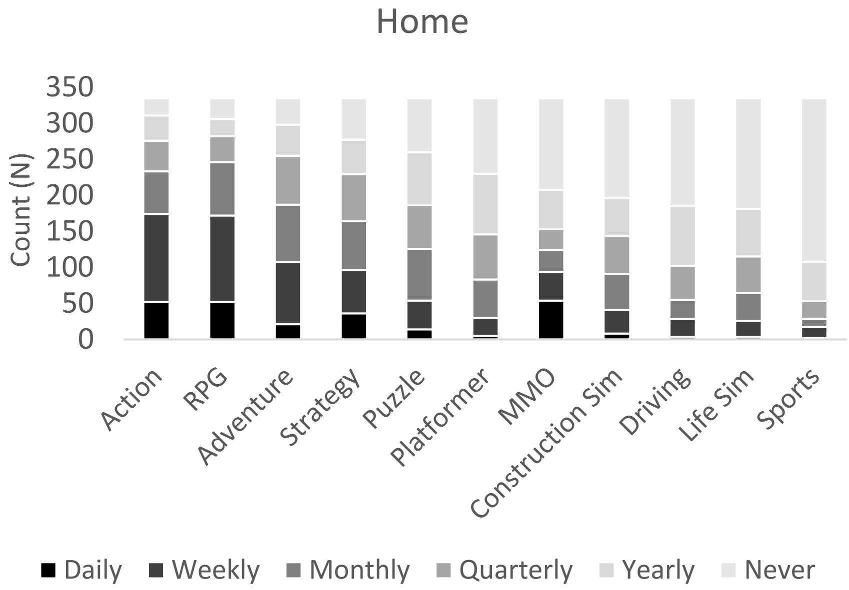
Variable	*B*	*SE B*	β
Step 1 (R^2 = .08)			
Constant	22.81	0.14	
Total Lifetime Games	0.27	0.05	.28**

Note ** $p < .01$

Genre

Similarly, mobile gaming tended to have a lower total number of games played than home gaming (Figure 3.7). This could perhaps be partially attributed to home consoles being available for longer than mobile consoles and devices.

[5] A multiple regression analysis including both the home and the mobile VGP questions as predictors to estimate their contribution to the Gamer rating explained 56% of the variance.



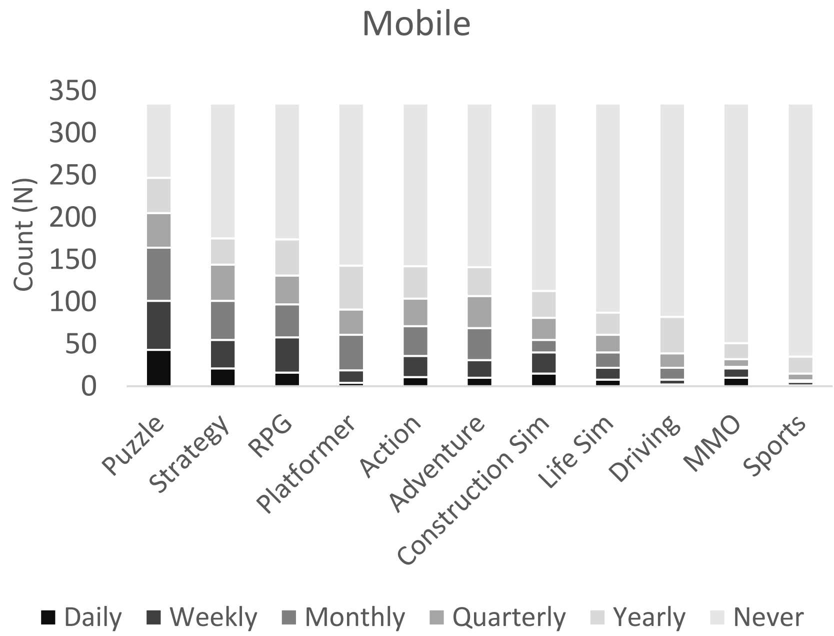


Figure 3.8. Frequency of genres played for both home (above) and mobile (below). The order of genre on the x-axis is sorted by those “never” playing.

As can be seen from Figure 3.8, Action and RPG games were played most frequently on home platforms, whereas on mobile platforms, Puzzle was the most frequently played genre. Pearson's correlations of demographic variables (Section 1) with home and mobile Genres (Sections 2b and 3b) can be found in Appendix 4 (see Table A.4). Table A.4 shows that Sex correlates negatively with home Action, $r(334) = -.24$, $p < .00006$, and with home Driving, $r(334) = -.23$, $p < .00006$, but positively with both home and mobile Life simulation, $r(334) = .34$, $p < .00006$, and $r(334) = .27$, $p < .00006$, respectively. This indicates that male participants prefer to play home action and driving games, whereas female participants prefer to play both home and mobile life simulation games. Furthermore, it also shows a negative correlation between Age and home Action, $r(334) = .27$, $p < .0003$, indicating that younger participants prefer to play home action games.

Pearson's correlations of mean home and mean mobile gaming experience with Genres (Sections 2b and 3b) can be found in Appendix 4 (see Table A.5). Table A.5 shows that home gaming experience correlates with Action, RPG, Adventure, MMO, Strategy, Platformer), suggesting that participants playing those six genres often would have a higher gaming experience score. Mobile gaming experience correlates with all but one genre (i.e., with all except Sports), suggesting that participants playing those ten genres would have a higher gaming experience score.

Platform

Data in Figures 3.9 and 3.10 is based on the question “To what extent do you play video games on each of the following platforms?”. The graph demonstrates the number of all respondants playing at least “yearly” for each device.

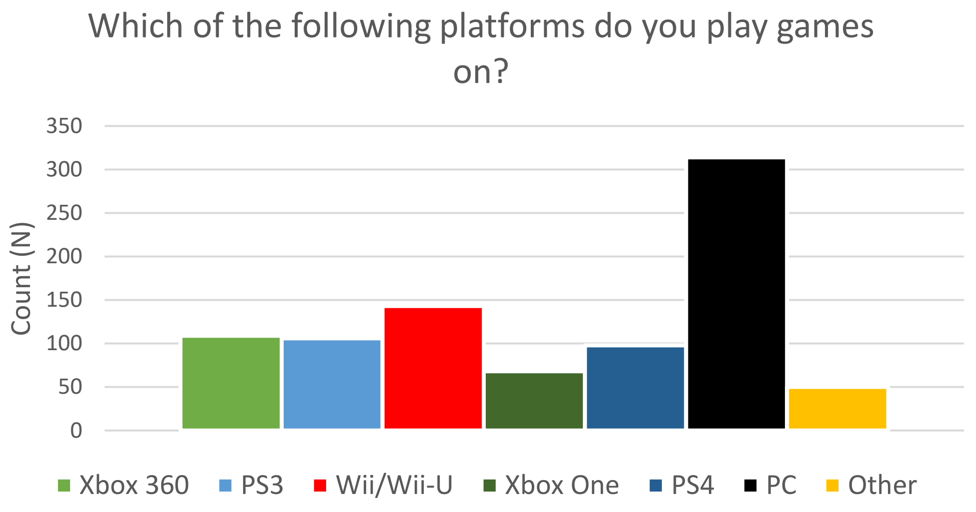


Figure 3.9. Number of respondents playing each of the shown home platforms.

The most common home gaming platform (Figure 3.9) was by far PC (331), followed by similar numbers recorded for the Nintendo, Sony and Microsoft consoles (ranging between 71-151). For mobile gaming (Figure 3.10) the most common platform was mobile phones (281) and this was followed by the Nintendo DS/3DS (170) and laptops (154).

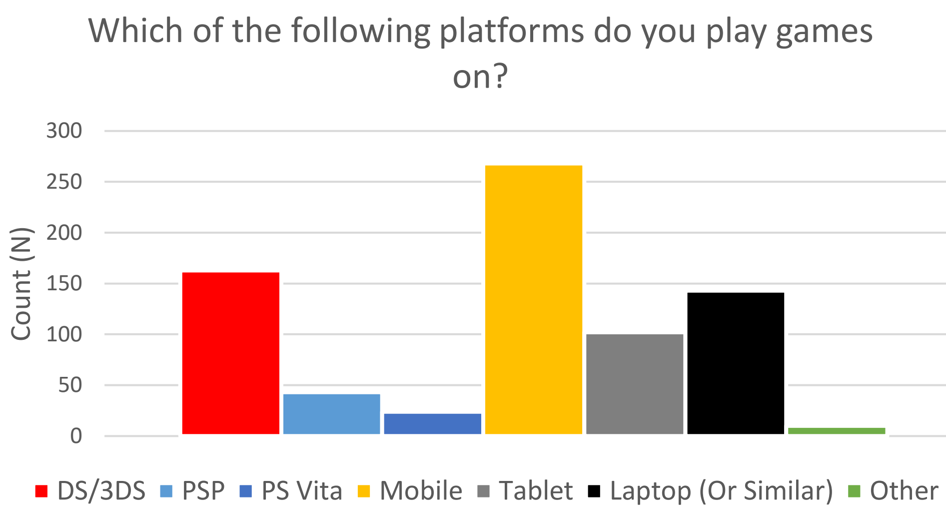


Figure 3.10. Number of respondents playing each of the shown mobile platforms.

Pearson's correlations of mean home and mean mobile gaming experience with Platform (Sections 3c and 4c) can be found in the Appendix 4 (see Table A.6 and Table A.7). Table A.6 shows a very strong correlation between home gaming experience and PC, $r(334) = .53$, $p < .00006$, indicating that gamers (i.e., participants with an overall high gaming experience score) have a preference for playing on a PC. There is also a weaker positive correlation between home gaming and Handhelds, $r(334) = .53$, $p < .00006$, indicating a small preference for Handhelds. Table A.7 shows significant correlations between mobile gaming experience and all named platforms, with the strongest correlation being between mobile gaming experience and Mobile platform, $r(334) = .54$, $p < .00006$ (range of r for other platforms from .21 to .37).

Social Gaming

Six questions were asked about playing video games with others in different settings. As can be seen from Figure 3.11, on average participants reported playing more offline than online games, and to play more on mobile devices than on home platforms. This was confirmed with a 2x2 repeated-measure ANOVA with the factors Platform (home, mobile) and Gaming Mode (online, offline), which revealed significant main effects for Platform, $F(1, 334) = 399.85$, $p < .001$, $\eta_p^2 = .545$, and for Gaming Mode, $F(1, 334) = 152.33$, $p < .001$, $\eta_p^2 = .313$. The ANOVA also showed a significant interaction, $F(1, 334) = 58.17$, $p < .001$, $\eta_p^2 = .148$, demonstrating that the Gaming Mode profiles are different across the home and mobile platforms, with a larger difference between online and offline for home platforms, $t(334) = 13.03$, $p < .001$, than for mobile platforms, $t(334) = 5.29$, $p < .001$.

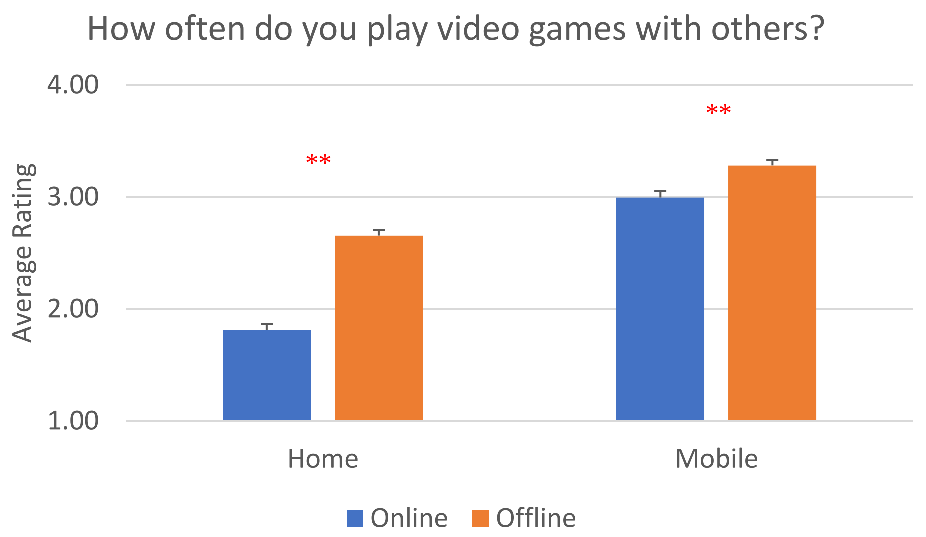


Figure 3.11. Average rating for online and offline gaming on a four-point scale from 1 (never) to 4 (regularly) for home and mobile platforms.

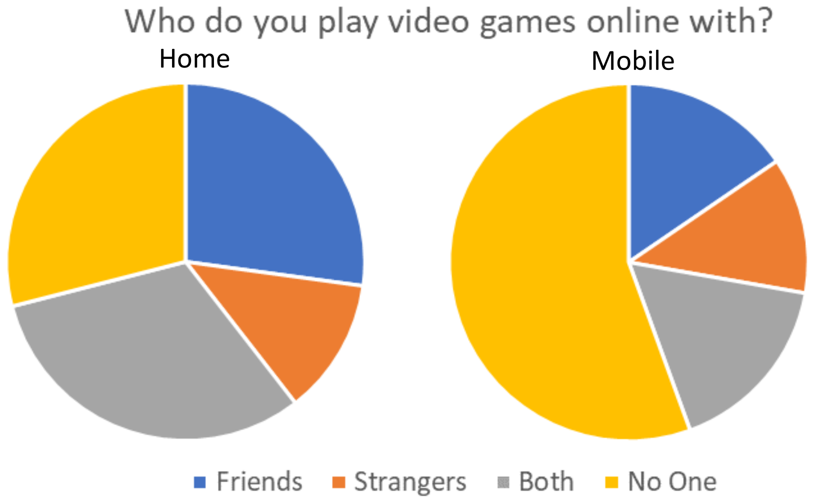


Figure 3.12. Comparison of who online co-operative games are played with for both home and mobile, only including respondents who played online rarely, occasionally, or regularly.

Data from participants who reported that they played games online rarely, occasionally, or regularly (i.e. excluding those who stated that they never played games online) was then used to look at who they played online with (Figure 3.12). Although most of the respondents reported playing online, it can be seen that the majority of online mobile play, and a large proportion of online home play is with "no one". This suggests that even when they play online, many don't play with specific people. This can be the case for many mobile games which are only able to be played online, and include mechanics such as guilds or world rankings, but do not support direct player interaction. This can also apply to home games for many open world online games, for example *Grand Theft Auto Online*, *Red Dead Redemption Online*, *Fallout 76*, and others, where players share a game world, but gameplay is not specifically team based. Of those who do specifically play with people, this is pretty evenly split between friends (37), strangers (38), or both (46).

Discussion

The video game studies often rely on participants self-ratings of their video game playing experience, however there is very little discussion around these measures. Few studies provide in-depth information about the questions used. The new questionnaire created here, the Video Game Experience Questionnaire, expands and improves on these previous questionnaires. The questionnaires used in Gackenbach (2006) and Gackenbach and Bown (2011) were the most in-depth questionnaires available but had limitations, so have been improved upon with the present questionnaire.

One substantial addition to this questionnaire is the distinction between home and mobile gaming. The results of the survey support this distinction, as they showed differences between home and mobile gaming. For example, in general participants play more (frequently or occasionally) on home platform than on mobile platform (53 vs. 27%, respectively). Home gaming was also revealed to be a better predictor of the "gamer" self-rating than mobile gaming experience.

Multiplayer trends were also shown to differ between home and mobile playing, with a larger difference between online and offline for home platforms, and overall less multiplayer gaming on home platforms. There were also genre differences between home and mobile platforms. Action and adventure games are more dominant on the home platform, whereas puzzle and strategy games are more dominant on the mobile platforms, while RPG games were dominant on both platforms.

Other particularly interesting findings included the differences between lengths of gameplay for mobile games compared to home games. Mobile games are typically played for much shorter periods of time per session than home games, as well as having a much shorter number of total hours played per week compared to home gaming. Also of note was that PC was by far the most common home platform, and mobile phones were the most common mobile platform and that although playing online is common, this tends to not be team playing.

Questionnaire 2

Method

Previous research has often focused on action gaming, either comparing it to non-gaming or non-action gaming (e.g., Castel, Pratt & Drummond, 2005; Dye, Green & Bavelier, 2009; Green & Bavelier, 2007; Mishra, Zinni, Bavelier & Hillyard, 2011; Obana & Kozhevnikov, 2012). In order to further understand why differences in cognitive benefits may be found between different genres, a questionnaire was developed to consider to what extent different cognitive processes were relevant to each genre of video games. The same approach was taken to developing this questionnaire as the previous one, ensuring common pitfalls are avoided, and experts were consulted for face validity.

Skills

Data was gathered from both psychological researchers and people in the gaming community, who were approached and asked for their input on the skills used in gaming. Some were approached with probing questions regarding skill sets used for video game playing. From these responses, coupled with literature research, the following three skills were identified as being relevant to video gaming, as well as being distinct cognitive processes: (1) Critical Thinking, (2) Reaction Speed, and (3) Spatial Awareness.

After this initial identification, other researchers and individuals from the gaming community were asked what they thought of these three chosen skills in relation to video game playing in different genres, for face validity. Informal feedback agreed that these three skills were relevant, and no other skills were suggested that were significantly different enough to these components to justify any additional dimensions.

Questionnaire

Instructions were given to the participants explaining how to fill out the questionnaire, and they were provided with detailed descriptions of each of the three cognitive processes they were to rate (Figure 3.13). This was to ensure respondents had a consistent understanding of the three processes, thereby resulting in a more accurate rating. Respondents were asked to rate how relevant they thought the three cognitive skills were to each of the 11 identified genres.

For this survey you will be asked to rate how important/relevant 3 skills are to game genres. The scale is 1-10, with 1 being 'not relevant', 10 being 'extremely relevant'.

Critical Thinking: Objective analysis and evaluation to form a judgement on how to respond.

Reaction Speed: The speed at which you respond to the presentation of a stimulus.

Spatial Awareness/Skills: The awareness of where you are in a space and in relation to objects around you. Being able to mentally manipulate 2-dimensional and 3-dimensional figures.

For this first section, please only consider **single-player** aspects of games from these genres, the **multiplayer** (split screen and online) ratings are to be given in the following section.

Figure 3.13. Instructions given for the video game playing genre skills questionnaire.

These instructions were followed with a matrix table for each of the 11 genres, allowing for ratings of 1 to 10 (least relevant to most relevant) on each of the three cognitive skills (critical thinking, reaction speed, spatial awareness). These matrix tables were then repeated in the second section, asking for multiplayer rankings for the same genres.

Participants

The questionnaire (Appendix 5) was distributed to experts, who were recruited based on having a current position in the video game industry, both known contacts and those approached online. A total of 10 industry specialists responded to the questionnaire, including video game developers, video game marketing specialists, and video game events managers. Participants were approached. This questionnaire was also given to a non-expert population of 91 students, all of whom took part in the task switching study described in Chapter 4), and 84 of these completed the questionnaire. These participants took part in the study for course credit at the University of Warwick for their undergraduate Psychology degree. The participants (82 females, 8 males) were 19.0 years old on average (range 18-32). The results of these rankings were compared to those of the experts.

Results

Ratings for the three cognitive skills for each genre were averaged separately for experts and non-experts (Table 3.6). Some genres demonstrated a similar pattern of skill ratings. Therefore, to see which genres were aligned, a cluster analysis was conducted.

Table 3.6. Average ratings (1-10 scale) in critical thinking, reaction speed, and spatial awareness for each genre separately for experts and non-experts.

	Expert (*n* = 10)			Non-expert (*n* = 84)		
	Critical thinking	Reaction speed	Spatial awareness	Critical thinking	Reaction speed	Spatial awareness
Action	5.1	9.2	7.9	5.6	7.9	7.3
RPG	6.3	6.2	6.9	5.9	5.8	6.2
Puzzle	9.3	5.8	7.6	8.6	5.3	5.9
Adventure	6.9	5.9	6.9	6.2	5.8	6.7
MMO	6.7	7.5	7.2	6.4	5.8	6.6
Strategy	9.0	5.6	8.0	8.2	5.4	6.3
Sports	5.4	8.1	6.8	5.1	7.6	7.4
Platformer	5.4	7.9	7.9	4.5	6.8	6.6
Driving	4.2	8.7	7.4	4.7	8.0	7.5
Con. Sim.	7.9	2.3	5.8	6.9	3.7	5.6
Life Sim.	4.4	2.5	3.7	5.6	3.4	4.9

Expert Ratings

The result of hierarchical cluster analysis on the averaged expert ratings (*n* = 10) with the three variables thinking, speed, and spatial, is shown in the dendrogram in Figure 3.14. The two-clusters solution (cut-off point in squared Euclidean distance of 25) separated sports, driving, action, and platformer from the other seven genres. The three-cluster solution (cut-off point 15) further isolated construction simulation and life simulation from the rest. The four-clusters solution was chosen for further exploration, which is at the cut-off distance of 10, which indicates an 80% or more similarity rate (Greenacre & Primicerio, 2013). The first cluster containing the genres action, sports, driving, and platformer were labelled “Action”. The second cluster consisting of adventure, RPQ, and MMO was labelled “Adventure”. The third cluster “Puzzle” contained puzzle and strategy, and the fourth cluster “Simulation” contained construction simulation and life simulation.

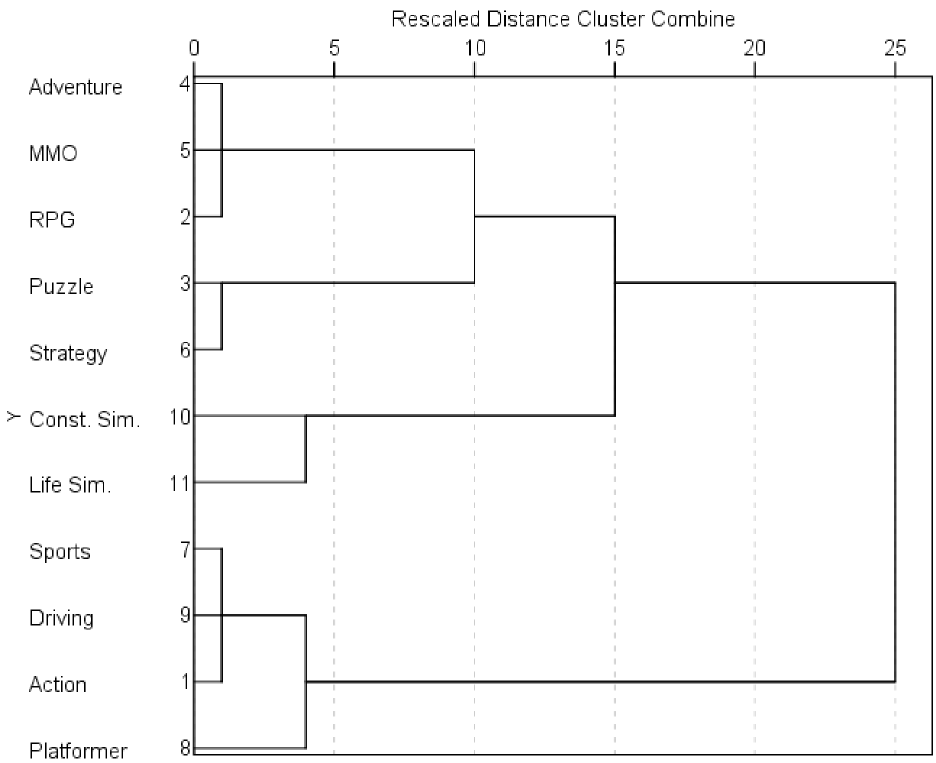


Figure 3.14. Dendrogram showing the result of hierarchical cluster analysis for experts with genres and clusters represented on the vertical axis and the squared Euclidean distance on the horizontal axis as a measure of dissimilarity.

Figure 3.15 shows the average expert ratings for critical thinking, reaction speed and spatial, separately for each Genre Cluster. The individual expert ratings for each cluster were subjected to a 4x3-way repeated measure ANOVA with the factors Genre Cluster (action, adventure, puzzle, simulation) and Skill (critical thinking, reaction speed, spatial awareness). The ANOVA revealed a significant main effect of Genre Cluster, $F(3,27) = 21.671$, $p < .001$, $\eta_p^2 = .707$, indicating that the ratings were overall highest for the puzzle and the action cluster, followed by the adventure cluster, and with the lowest rating in the simulation cluster (7.21, 7.01, 6.53, and 4.50, respectively). Posthoc *LSD* revealed that ratings were lower for simulation than for the other three clusters (all $p < .001$). The main effect of Skill, $F(2,18) = 8.798$, $p = .002$, $\eta_p^2 = .494$, was also significant, indicating that the ratings were overall higher for critical thinking and spatial awareness than for reaction speed (6.74 and 6.61 vs. 5.59, respectively). Posthoc *LSD* revealed that the rating for reaction speed was lower than the ratings for the other two skills (both $p < .005$). The Genre Cluster x Skill interaction was also significant, $F(6, 54) = 21.700$, $p < .001$, $\eta_p^2 = .706$. As can be seen from Figure 3.15, the action cluster showed a different skill profile than the puzzle and simulations cluster. Action games require high reaction speed and spatial awareness, whereas puzzle and simulation games require more critical thinking and spatial awareness. Finally, adventure games require an equal amount of each skill. This interpretation was supported by four split-up ANOVAs, one for each Genre Cluster. The Action, Puzzle, and Simulation ANOVA each showed a significant skill main effect, $F(2,18) = 37.62$, $p < .001$, $\eta_p^2 = .807$, $F(2,18)$

= 18.75, $p < .001$, $\eta_p^2 = .676$, and $F(2,18) = 18.28$, $p < .001$, $\eta_p^2 = .670$, respectively, but not the Adventure ANOVA, $F(2,18) = 0.12$, $p = .885$, $\eta_p^2 = .013$).

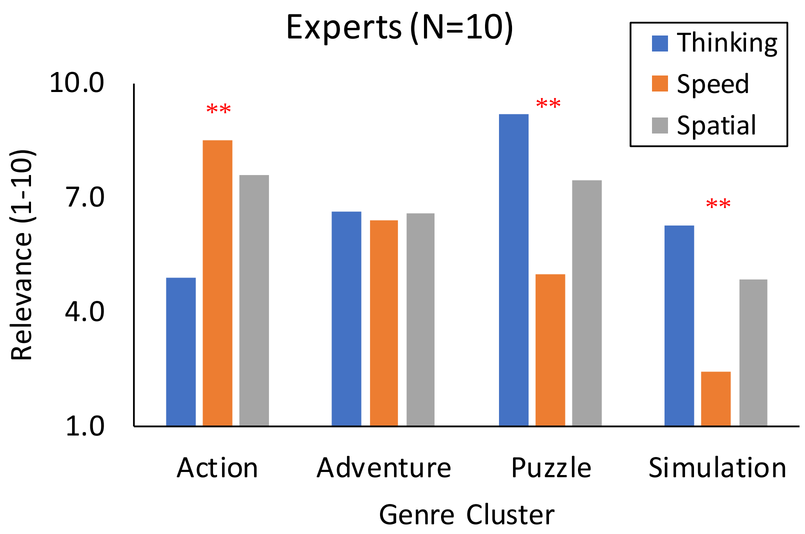


Figure 3.15. The experts' average relevance ratings for each of the three skill categories separately for each Genre Cluster.

Non-Expert Ratings

The result of hierarchical cluster analysis on the averaged non-expert ratings ($n = 84$) with the three variables thinking, speed, and spatial, is shown in the dendrogram in Figure 3.16. The dendrograms for expert and for non-experts look quite similar. One difference is that with non-experts the genres "construction simulation" and "life simulation" are not only more dissimilar from each other, but also more dissimilar from the other clusters. Furthermore, with non-experts, the action cluster and the adventure cluster are more similar to each other. Given these similarities, and in order to allow a direct comparison between experts and non-experts, the same four-cluster solution from the expert ratings (action, adventure, puzzle, and simulation) was also used for the non-expert ratings.

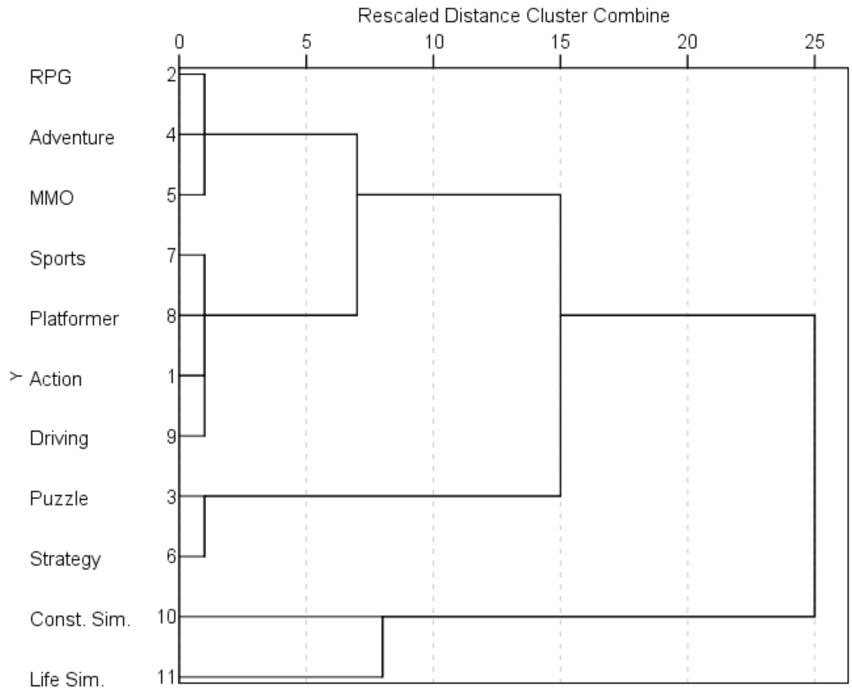


Figure 3.16. Dendrogram showing the result of hierarchical cluster analysis for non-experts with genres and clusters represented on the vertical axis and the squared Euclidean distance on the horizontal axis as a measure of dissimilarity.

Figure 3.17 shows the average non-expert ratings for critical thinking, reaction speed and spatial, separately for each Genre Cluster. The 4x3-way repeated measure ANOVA with the factors Genre Cluster and Skill revealed again a significant main effect of Genre Cluster, $F(3,249) = 79.683$, $p < .001$, $\eta_p^2 = .490$, with highest ratings for the puzzle and the action cluster, followed by the adventure cluster, and with the lowest rating in the simulation cluster (6.64, 6.60, 6.18, and 5.00, respectively). Posthoc *LSD* revealed that all ratings significantly differed from each other except for the rating of the puzzle and the action clusters (all $p < .001$). The main effect of Skill, $F(2,166) = 38.065$, $p < .001$, $\eta_p^2 = .314$, was significant, indicating that the ratings were overall higher for critical thinking and spatial awareness than for reaction speed (6.47 and 6.27 vs. 5.58, respectively). *LSD* tests revealed that the reaction speed rating was lower than the ratings for the other two skills (both $p < .001$). The Genre Cluster x Skill interaction was also significant, $F(6, 498) = 116.188$, $p < .001$, $\eta_p^2 = .583$. The expert and non-expert ratings follow a similar pattern, as can be seen visually in Figures 3.15 and 3.17, though this was not submitted to a mixed design ANOVA due to the uneven group sizes. As in the expert ratings, action games require high reaction speed and spatial awareness, puzzle and simulation games require more critical thinking and spatial awareness, and adventure games require an equal amount of each skill. However, with non-experts, all four split-up ANOVAs showed significant main effects for skill, including the adventure cluster (all $p < .001$).

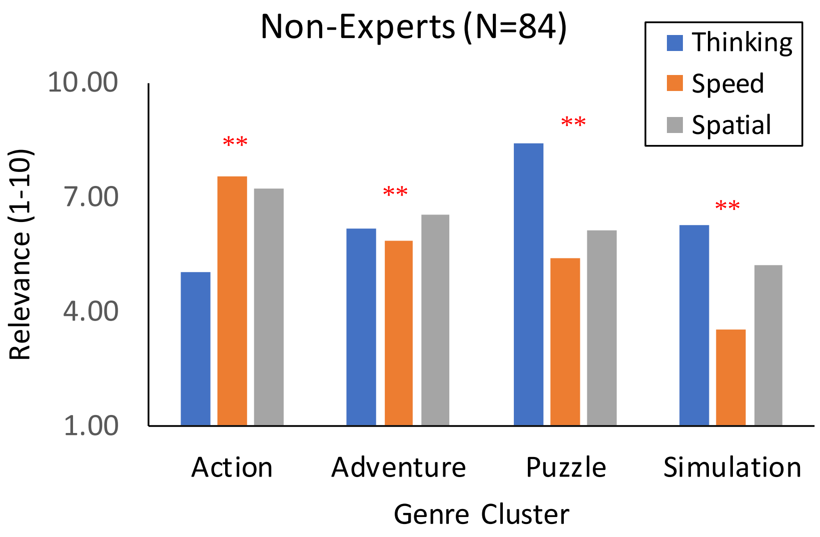


Figure 3.17. The non-experts' average ratings for each of the three skill categories separately for each Genre Cluster.

Single-Player versus Multiplayer

Participants rated each genre and skill twice, once for single-player and once for multiplayer games, however in the previous analysis gameplay ratings were averaged in order to focus on differences between expert and non-expert ratings. In order to test whether gameplay matters, the expert and non-expert datasets were combined, removing 11 participants with some missing values, for a total N = 83. The combined ratings were subjected to a 2x4x3-way repeated measure ANOVA with the factors Gameplay (single-player, multiplayer), Genre Cluster (action, adventure, puzzle, simulation) and Skill (thinking, speed, spatial). As before, the ANOVA showed the same significant main effects of Genre Cluster, Skills, and of their interactions (all $p < .001$). In addition, there was also a significant Gameplay x Skill interaction, $F(2, 164) = 4.53$, $p = .012$, $\eta_p^2 = 052$ and a significant three-way interaction, $F(6, 492) = 4.14$, $p = 001$, $\eta_p^2 = 048$.

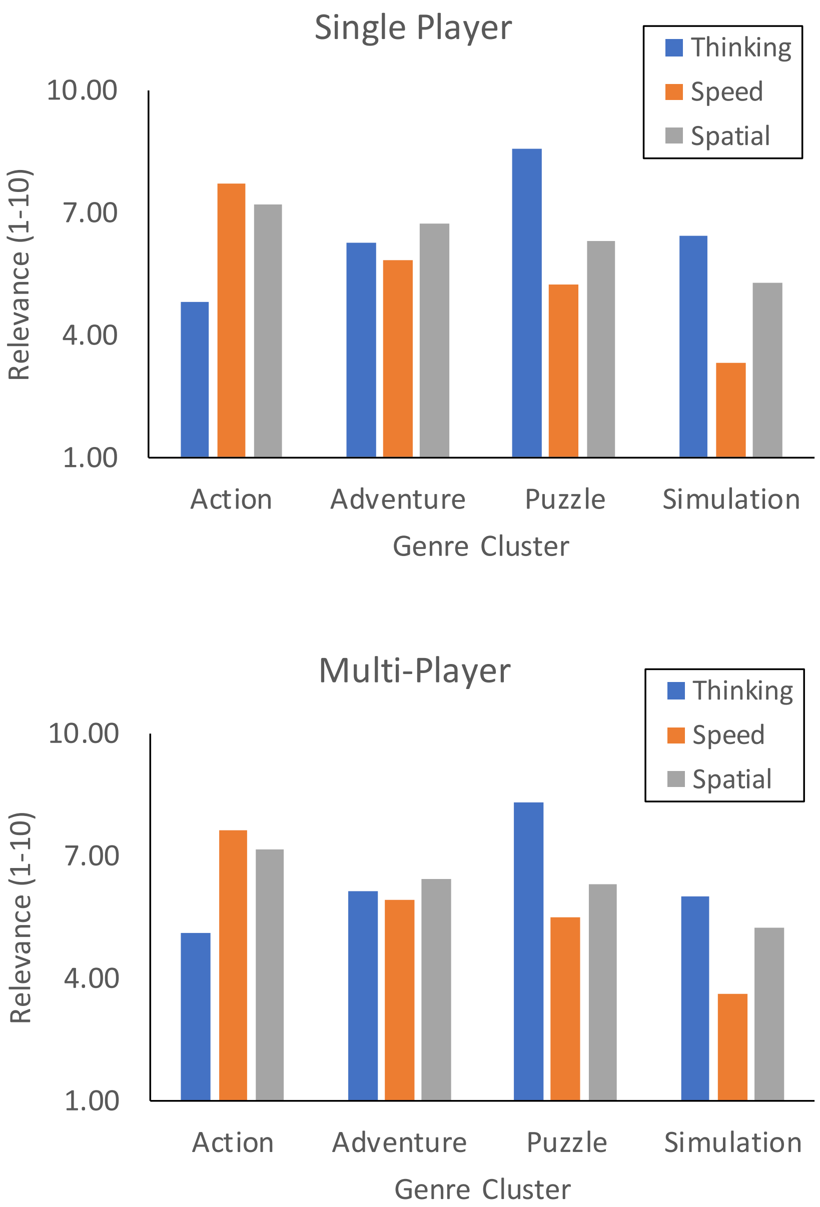


Figure 3.18. The relevance ratings from experts and non-experts combined for each of the three skill categories separately for each Genre Cluster. The top graph shows the ratings for single-player gameplay and the bottom graph multiplayer gameplay.

As can be seen from Figure 3.18, the two Gameplay conditions showed overall a very similar pattern, however, skill effects seem to be more pronounced in single-player than in multiplayer gameplay, but only in the adventure, the puzzle, and the simulation cluster and not in the action cluster. In other words, the relative rating for reaction speed in these three clusters appears to be higher for multiplayer than for single-player gameplay.

Discussion

Participants rated to what extent three cognitive skills (critical thinking, reaction speed and spatial awareness) were important to 11 video game genres. These 11 genres had been identified as part of the creation for the first questionnaire. To see whether any of these genres were similar enough to be combined, a cluster analysis was conducted.

The cluster analysis revealed four genre clusters. The first cluster was called action, which included four genres: action; sports; driving; and platformer. The second cluster included the adventure, MMO, and RPG genres, and was called adventure. The third cluster, called puzzle, included the puzzle and strategy genres. The final cluster, called simulation, consisted of the life simulation and. and management simulation genres.

A skill profile was generated for each of the four clusters for comparison. Each cluster demonstrated a unique skills profile. For the action cluster, reaction speed was rated as most important, followed closely by spatial awareness, with significantly lower scores for critical thinking. The adventure cluster had very similar scores for all three skills, with spatial awareness the highest, then critical thinking, then reaction speed. The puzzle cluster highly prioritised critical thinking, with spatial awareness as the next most important, followed by reaction speed. The simulation cluster showed a similar pattern to the puzzle cluster, but with lower scores for all three skills. These skills profiles for the clusters followed the same pattern across experts and non-experts.

Similarly, a very similar skills profile pattern can also be seen across single-player and multiplayer ratings. However, skill effects appear to be more pronounced in single-player than in multiplayer gameplay, but only in the adventure, the puzzle, and the simulation cluster and not in the action cluster. Results indicate that this is due to the relative rating for reaction speed in these three clusters being higher for multiplayer than for single-player gameplay.

Overall Conclusions

The first questionnaire, the Video Game Experience Questionnaire, provides a more comprehensive measure of video game playing experience, including questions around genre and differentiation between home and mobile game playing. Home gaming was revealed to be a better predictor of the "gamer" self-rating than mobile gaming, suggesting that this is an important distinction to make.

The second questionnaire built upon the genre distinctions made in the first questionnaire by considering the cognitive skills utilised by each of these genres. Whilst all of these cognitive skills are used to some degree across video games generally, the findings demonstrate that the extent to which they are used, and the order in which they are important, differs based on genre. Four genre clusters were found (action, adventure, puzzle and simulation), with each having different cognitive skills profiles.

Overall, the results from the two questionnaires presented show the importance of distinguishing between different genres of video games and platforms used to play them, as the findings demonstrate the differences between these.

Chapter 4: Does Video Game Playing Affect Task Switching Ability?

Abstract

90 participants completed a task switching test and were measured on video game experience, the Barratt Impulsiveness Scale and a brief 10-item personality questionnaire. This task was run with a newly created questionnaire designed to measure video game experience, integrating video game playing experience with genres played and platforms used. Participants were presented with digits in a sequence at specific locations of a wheel. Depending on the location of the digit (top of bottom half of the wheel), they switched between parity (odd or even) and magnitude (smaller or greater than five) tasks. Video game playing did not affect task switching, and neither did video game genre or platform. However, correlations were found between video game playing, conscientiousness, and two first-order subscales of the Barratt Impulsiveness Scale suggesting that video game players are generally less conscientious and more impulsive.

Introduction

Task switching is the ability to shift cognitive resources between one task and another (see Liebherr, Antons & Brand, 2019; for further discussion). This is an executive control function requiring high-level cognitive processing (e.g., Monsell, 2003; Schneider & Logan, 2009). Task switching ability can be measured by having participants frequently switch between simple tasks, such as between high/low versus odd/even classification of a number. Research has demonstrated that participants respond slower (latency), and usually with more errors after switching from one task to the other (switch trial) compared to when the task does not change (no-switch trial). This increase in latency and errors is referred to as “switch cost” (e.g., Manoach, 2009; Monsell, 2003; Wasylyshyn, Verhaeghen & Sliwinski, 2011).

Executive control has previously been linked to impulsiveness. Whitney, Jameson and Hinson (2004) studied whether deficits in the executive control system of working memory could explain some of the cognitive problems shown by individuals who were identified as impulsive via self-report measures. They measured impulsivity with the Barratt Impulsiveness Scale (Barratt, 1965; Patton, Stanford & Barratt, 1995), and used a series of executive control tasks including a reading span task, an N-back task, and a new task they called the continuous memory scanning task. Their results indicated that different subtypes of impulsivity are related to different aspects of executive control. Impulsiveness has also been linked to video game playing. Gentile, Swing, Lim and Khoo (2012) found that individuals who are more impulsive spend more time playing video games (even when initial video game playing is statistically controlled), suggesting that there is a bidirectional causality between video game playing and impulsiveness.

A variety of studies have looked at the effects of playing action video games on perceptuo-motor skills, which has been reviewed by various researchers (e.g., Hubert-Wallander, Green, & Bavelier, 2011; Spence & Feng, 2010). Task switching is one of the tasks used by researchers in order to examine whether video game players (VGPs) have different executive control abilities to non-video game players (NVGPs). For example, Boot, Kramer, Simons, Fabiani and Gratton (2008) conducted a study comparing action gamers and non-gamers on a number of different cognitive skills. They found that action video game players (i.e. those who play action genre video games, typically fast-paced games such as first-person shooters) were faster at task switching. They could also track faster-moving objects, were more efficient at mentally rotating objects, were better at detecting changes to objects stored in visual short-term memory. In another study, Basak, Boot, Voss and Kramer (2008) trained participants on video games. They found that after fifteen 1.5-hour training sessions across 4-5 weeks, participants significantly improve not only in the game, but they also improved their performance in other tasks that suggested an increase in executive control functions compared to a group of control participants that received no video game training. The executive control functions they measured included working memory, visual short-term memory, reasoning and task switching. Specifically, they found that individual improvements in game performance were positively correlated with improvements in task switching.

Green, Sugarman, Medford, Klobusicky and Bavelier (2012) ran a study on task switching and action video game playing with four experiments. For their experiments they classified participants action VGPs or non-action VGPs, based on their responses to a questionnaire completed before the experiment. The action VGP criteria was playing a minimum of five hours per week of action video game over the previous six months (in experiments 2 and 3 this was increased to a year), or 3-5 hours per week with extensive habitual play reported for the previous few years. The non-action VGP group could only play minimal to no first-person shooter video game usage over the previous year, and minimal sports or fighting games. In the first experiment action video game players showed an improvement in task switching over the non-action video game players not only with mapping responses onto buttons (as would be common in an action video game), but also with vocal responses. The second experiment revealed task switching advantages for VGP versus non-VGP in both perceptual tasks (i.e. colour and shape) and in cognitive tasks (i.e. magnitude and parity of numbers). The third experiment showed that these VGP advantages were also present for both goal-switches and motor switches. Finally, the fourth experiment was a training study, using an action VGP group and a control group with no prior experience with video games of any type. All participants played 50 hours of video games (average length: 8.5 weeks, range 6–14 weeks), with the action VGPs playing action games and the control group playing *The Sims 2*.

Though they found that the action VGP group had a greater decrease in switch cost than the control group, when these switch costs were corrected for baseline reaction time, the difference between groups did not reach significance.

Cain, Landau, and Shimamura (2012) also studied the effects of action video game playing on the cost of switching tasks. 44 participants were in either the action VGP group (minimum 6 hours per week playing primarily first-person shooter or action games) or the NVGP group (less than 2 hours per week of first-person shooter and action games). They investigated switching between responding with the same direction of an arrow (familiar task), or with the opposite direction of the arrow (novel task), indicated by the colour of the arrow. They used long inter-trial intervals, no pre-cues, and unpredictable task sequences, so participants would not know when the task was going to switch. They found large switch costs for switching from the novel task to the familiar task for NVGPs, with small costs when switching from the familiar task to the novel task. They found no significant interaction between group and task type (switch or no-switch), suggesting no overall difference in task-switching costs between groups. However, they did find that VGPs had overall smaller and more symmetric switching costs compared to NVGPs, from which they suggested that experience with action video games improves executive functioning.

Boot, Blakely and Simons (2011) noted several methodological issues with some of the previous video game studies, which may have led to placebo effects, differences in demand characteristics, and underreporting which might have produced false positive findings. Specifically, they discussed if participants know that they are being recruited for being expert action gamers, this may cause them to be motivated to perform well on cognitive tasks. These differences in motivation could contribute to the measured cognitive differences between expert and novice gamers. Furthermore, they raised concerns that some studies tested the same participants with multiple outcome measures but did not explicitly state how many other tasks they used and what they were. These additional tasks could potentially have led to fatigue or interference problems.

Strobach, Frensch and Schubert (2012) conducted a study which incorporated some of the methodological improvements suggested by Boot, Blakely and Simons (2011), including using a training study to confirm cross-sectional game effects and identifying all of their outcome measures. Strobach et al. (2012) found improvements for VGPs compared to NVGPs for task switching. They also found improvements in NVGPs after 15 hours of action video game training, indicating a causal relationship between video game playing and improved executive control skills. However, Boot and Simons (2012) note that there are still some methodological issues present in the Strobach et al. (2012) study, which should restrict how the evidence is interpreted, such as their overt recruitment method, specifically targeting expert and novice VGPs, causing motivation differences between participants.

Other studies reported mixed findings, that do not fully support the findings that video game players have improved task switching. Andrews and Murphy (2006) found reduced switching costs for VGPs only at short inter-trial intervals, but no difference at long inter-trial intervals. Other research has also examined whether benefits of video game playing are localised to specific aspects of task switching performance. Karle, Watter and Shedden (2010) found a task switching benefit in VGPs compared to NVGPs, specifically with minimal trial-to-trial interference from task set rules which don't overlap (i.e. each tasks' rules are independent from each other). However, they found that this benefit disappeared if there was an increase in proactive interference between tasks, via substantial overlapping of stimulus and responses in task set rules. They argued that VGPs don't have a generalised benefit for the cognitive control processes which are used for task switching in comparison to NVGPs. Instead they suggested that the reduced switch costs in VGPs were due to a more specific benefit in controlling selective attention.

Collins and Freeman (2014) tested 66 participants in a switching task, a visual short-term memory task, a mental rotation task, an enumeration task, and a flanker interference task, and they found no significant differences between VGPs and NVGPs on any of the tasks. This suggests an overall lack of benefit of cognitive processes for VGPs compared to NVGPs, contrary to a variety of research. However, these findings may be common but not supported by the literature due to publication bias, with null findings being published less often (e.g., Sterling, 2017; Sterling, Rosenbaum & Weinkam, 1995).

The present research will examine whether task switching differs based on video game playing, genre played, and platform played, as much of the previous research focuses specifically on only action video game players. Whilst the effects of genre and platform are exploratory and do not have a prediction, based on previous studies we predict that there will be differences in reaction speed and switching costs between VGPs and non-VGPs when switching between tasks (e.g., Green, Sugarman, Medford, Klobusicky & Bavelier, 2012; Strobach, Frensch & Schubert, 2012).

Method

Participants

Data was collected from a total of 90 participants. These participants took part in the study for course credit at the University of Warwick for their undergraduate Psychology degree. The participants (82 females, 8 males) were 19.0 years old on average (range 18-32), and all participants reported normal or corrected-to-normal vision. All participants gave informed written consent and the study was approved by the University of Warwick Humanities & Social Sciences Research Ethics Committee.

Apparatus

Both the questionnaires and the task were presented on a 19” LCD monitor running with 60 Hz at a 1820 x 1080 pixels resolution, with participants seated approximately 57 cm away from the computer screen. The experiment was controlled by an IBM-PC compatible computer using custom-written software. Responses were recorded with a standard computer keyboard and mouse.

Questionnaires and Procedure

The Video Game Experience Questionnaire used various questions regarding the participant's history with video games, as well as their current interactions. This includes four main questions to score video game play experience on a 6-point scale, looking at frequency of play (from never or rarely to daily), length of play (from ≤1 to ≥5 hours), number of games played in lifetime (from ≤10 to ≥200 games), and average weekly play (from ≤1 hour to ≥12 hours). For comparison to the study in Chapter 2 the same VGP categories were recreated, with participants grouped depending on their average score of these four questions: playing video games rarely/never (score 1), occasionally (score 1-2) or frequently (score >2). As well as considering extent of experience, the questionnaire also splits video game experience into "home" and "mobile" video game playing. Participants were also asked to note exactly which platforms they used, and which genres they played on both home and mobile platforms.

Impulsivity was measured, as it has previously been linked to executive control (Whitney, Jameson & Hinson, 2004). This was measured with the Barratt Impulsiveness Scale (Barratt, 1965; Patton, Stanford & Barratt, 1995), containing 30 items on a scale of 1-4 (Appendix 6). These items make six first-order factors, which were further grouped into three second-order factors; attention and cognitive instability (attentional), motor and perseverance (motor) and self-control and cognitive complexity (non-planning).

Finally, as personality has been previously linked to video game playing (e.g., Braun, Stopfer, Müller, Beutel & Egloff, 2016), a brief 10-item personality questionnaire was used (Gosling, Rentfrow & Swann, 2003) which scored each of the Big 5 Personality traits on a scale of 1-7, using 2 items for each of the traits (Extraversion, Agreeableness, Conscientiousness, Emotional Stability, Openness to Experience) on a scale of 1-7 (from disagree strongly to agree strongly).

First, participants were asked to complete the Video Game Experience Questionnaire on the PC in front of them via Qualtrics, an online questionnaire platform. Participants were then asked to fill out the Barratt Impulsiveness Scale and the personality scale. Following the questionnaires, participants were presented with the task switching task on the computer.

Tasks and Stimuli

Participants were presented with a wheel with 8 sections on the screen. They were instructed to use the left and right arrow keys to respond. The type of response they were instructed to give depended on where the number was on the wheel. The numbers moved around the wheel in a clockwise direction.

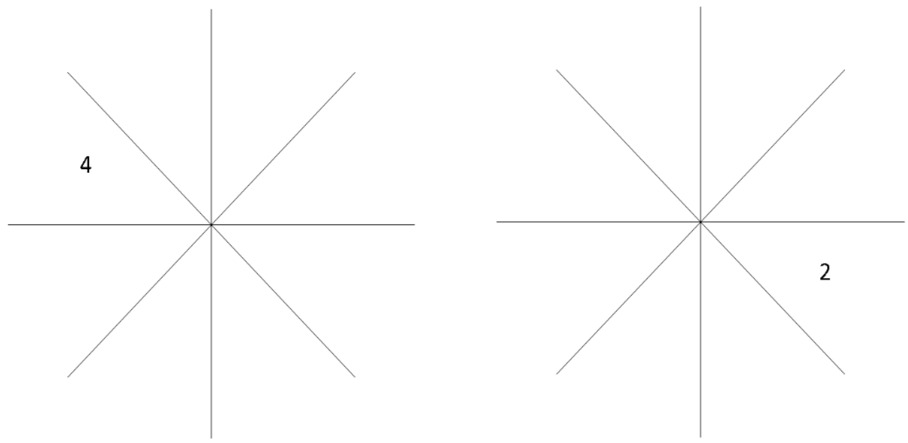


Figure 4.1. Visual examples of the stimuli screen. These two positions demonstrate the locations where the tasks switched between parity and magnitude. In the left example, the correct response would be the right arrow key for the parity task. In the right example, the correct answers would be the left arrow key for the magnitude task.

Participants were instructed that numbers appearing in the top half of the wheel required a parity task and they needed to respond with the left arrow key if the number was odd, or with the right arrow key if it was even. This is in line with Collins and Freeman (2014), who also required participants to switch between parity and magnitude tasks. Numbers appearing on the bottom half of the wheel required a magnitude task, whereby they had to distinguish whether the number presented was less than five by using the left arrow key, or greater than five by using the right arrow key. Participants were informed that errors would be reported at the end of each block. They were instructed to “try to make no more than 3-5 errors per block”.

There were 8 practice trials followed by 512 experimental trials, which were divided into 8 blocks of 64 trials, each with short breaks between blocks. The wheel in the centre of the screen was 15° in size. Stimuli were numbers which were black on a white background, in 48-pt Calibri font (~0.7°), presented centrally at an eccentricity of 7.5° in one of the eight sections of the wheel. Positions one and five (see Figure 4.1) were switch trials, in which the task switched between parity and magnitude. Aside from the first trial in each block, all trials at these locations were clusters switch trials. The other six positions were classed as non-switch trials, for the within-subject variable Trial (switch, no-switch).

Results

The split of participants between each experience group of home and mobile playing can be seen in Table 4.1. To test the effect of playing home video games on task switching, a 2x3 mixed design ANOVA on RT with the within-subject factor Trial Type (switch, non-switch) and the between-subject factor Home VGP Experience (rarely, occasionally, frequently) was calculated. The results revealed a significant main effect for Trial Type, $F(1, 87) = 376.17$, $p < .001$, $\eta_p^2 = .812$, due to slower RTs in switch trials compared to non-switch trials (846 vs. 617 ms, respectively). The interaction effect between VGP Experience and Trial Type did not reach significance, $F(2,87) = 1.672$, $p = .194$, $\eta_p^2 = .037$, nor did the between-subject main effect VGP Experience, $F(2,87) = 0.07$, $p = .931$, η_p^2

= .002, showing that there was no difference in switching cost or in overall speed between the video game experience groups (see Figure 4.2).

Table 4.1. Number of participants in each mobile and home category from the questionnaire.

Number of Participants				
	Rarely	Occasionally	Frequently	Total
Home	22	40	28	90
Mobile	24	35	31	90

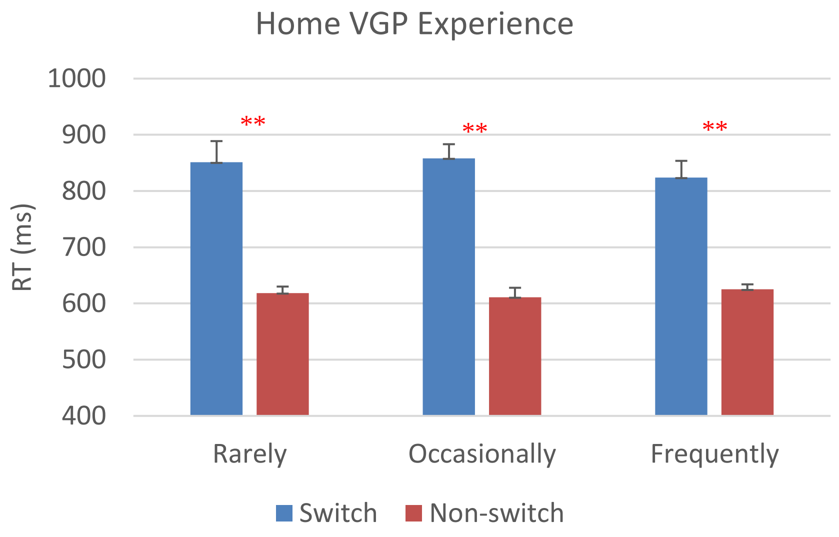


Figure 4.2. Mean Reaction time for switch and non-switch trials for the three Home VGP Experience groups.

As can be seen from Figure 4.3, errors showed a very similar pattern to the RTs. The corresponding 2x3 mixed design ANOVA on the error rate with the factors Trial Type and Home VGP Experience confirmed this impression, with a significant main effect for Trial Type, $F(1, 87) = 45.59$, $p < .001$, $\eta_p^2 = .344$, due to a higher error rate in switch than in non-switch trials (7.9 vs. 6.6%, respectively).

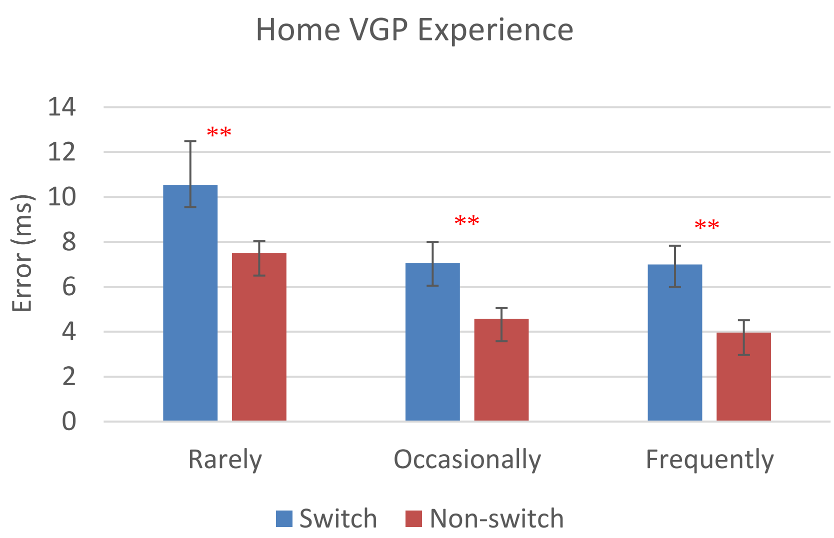


Figure 4.3. Mean error rate for switch and non-switch trials for the three Home VGP Experience groups.

To test the effect of playing mobile video games on task switching, an equivalent 2x3 mixed design ANOVA was calculated with the factors Trial Type and Mobile VGP Experience (rarely, occasionally, frequently). The results again showed a significant main effect for Trial Type, $F(1, 87) = 381.71$, $p < .001$, $\eta_p^2 = .814$, but no effects involving Mobile VGP Experience (both $p > .752$, see also Figure 4.4). The pattern of error rates was very similar to the pattern of RT results. Participants were also grouped into one of three genre categories, depending on how many action genre games (i.e., action, sports, driving, or platformer) they reported that they played rarely, occasionally or frequently (0 action genres, 1 to 2 action genres, 3 to 4 action genres). A 2x3 mixed design ANOVA on RT with Trial Type (switch, non-switch) and the between-subject factor Action Experience (no action genres, 1-2 action genres, 3-4 action genres) also revealed only a significant main effect for Trial Type, $F(1, 87) = 392.73$, $p < .001$, $\eta_p^2 = .816$, but no effects involving Action Experience (both $p > .482$). The pattern of error rates was again very similar to the pattern of RT results.

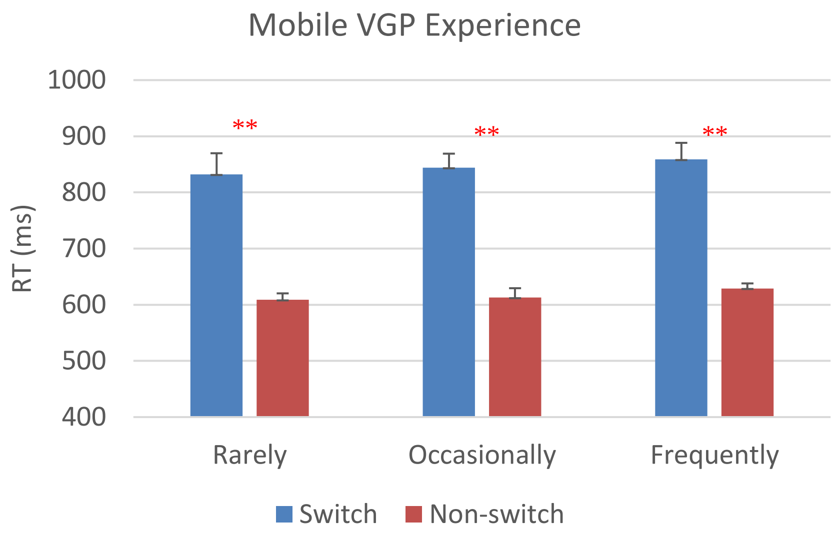


Figure 4.4. Mean Reaction time for switch and non-switch trials for the three Home VGP Experience groups.

Correlations were of interest between home and mobile video game playing and impulsivity. Pearson's correlation, corrected for multiple comparisons using Bonferroni adjusted alpha levels of .0167 per test (.05/5), found a significant correlation between the second-order factor “attentional” (see Methods) and home video game playing. *r*(86) = .287, *p* = .007. The equivalent correlation between attentional and mobile video game playing was only marginally significant, *r*(86) = .254, *p* = .018. Those playing video games more often rate themselves worse on questions such as "I concentrate easily" and "I am a steady thinker". A significant correlation was also found between home video game playing and the second-order factor and "non-planning", *r*(85) = .262, *p* = .007. Further analysis into the second-order factor "non-planning" revealed a significant correlation (alpha levels .025) between video game playing and the first-order factor "self-control", *r*(85) = .375, *p* < .001. Those playing video games more often rate themselves worse on questions such as "I plan tasks carefully" and "I am a careful thinker".

Correlations were also run to look for any associations between video game playing and the five personality traits. Pearson's correlation, corrected for multiple comparisons using Bonferroni adjusted alpha levels of .01 per test (.05/5), found a significant negative association between video game playing and the personality trait conscientiousness, *r*(86) = -.358, *p* = .001. Those playing video games more often see themselves as less conscientious (i.e., less disciplined and less dependable, and more disorganized and more careless). Finally, correlations between personality and impulsivity (alpha levels .003) showed significant negative correlations between conscientiousness and "attentional", *r*(86) = -.507, *p* < .001, and conscientiousness and "non-planning", *r*(86) = -.506, *p* < .001. Finally, not that task switching costs (switch RT – non-switch RT) did not correlate with any of the impulsivity scales (all r between -.05 and .06) nor with any of the personality traits (all r between -.10 and .12).

Discussion

The findings suggest that video game players tend to be less conscientious, and more impulsive, specifically in regard to attentional abilities and self-control. However, this does not translate to differences in executive functions, as task switching costs were not affected. This is in contrast with findings of some previous studies which identified a significant difference in task switching between action video game players and non-video game players (e.g., Green, Sugarman, Medford, Klobusicky & Bavelier, 2012; Strobach, Frensch & Schubert, 2012). Further analysis also showed that task switching did not depend on genre (action versus non-action games).

The difference in these results may be partially due to the predictability of the task switching, as locations for the task switching were set, with participants knowing when each task needed to be carried out. Cain, Landau and Shimamura (2012), on the other hand, used unpredictable task switching. Previous research showed that being able to prepare for, or predict the task switching, reduced switching costs (e.g., Monsell, 2003; Monsell, Sumner, & Waters, 2003). So, it is possible that task switch costs were simply not large enough to show a dependence on VGP experience, which may only have an impact on higher costs that happen when the switching is unpredictable.

However, the findings of the present study are in line with those of Collins and Freeman (2014), who also required participants to switch between parity and magnitude tasks, specifically reporting whether numbers were high or low (above or below five), or odd or even. They also found no difference in the task switching abilities of video game players and non-video game players. Unlike in the current study, where trial type was based on location, trial type in Collins and Freeman's study was based on the colour of the screen background, with the task for each trial being chosen at random, meaning that it was unpredictable. This suggests that the variations in the findings of other studies, some of which find a task switching benefit for VGPs while others do not, are perhaps not due to predictability, as other studies have found reduced switching costs for VGPs using predictable task orders (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010). The tasks used may be an alternative explanation for the different findings, as the present study has the same findings using the same tasks as Collins and Freeman (2014), with different predictabilities.

Karle, Watter and Shedden (2010) suggest that there is no benefit for executive control in VGPs. Although they found a difference in task switching abilities of VGPs and NVGPs, this disappeared with overlapping of stimulus and responses in task set rules. The present study supports these findings, as no difference was found due to video game playing, when switching between tasks using the same stimulus and response keys. Therefore, this implies that some disparity between the results of previous studies may be due to the tasks used.

Further to the task switching findings, the findings of the VGP scales were also of interest. For both home and mobile gaming, occasional play is the most common, with those playing rarely or never accounting for around a third of the sample size. Therefore, two thirds of the sample played video games frequently or at least occasionally, suggesting it is a common hobby for young adults. The trend of the grouping for mobile and home categories suggests that people tend to play mobile and home games in equal measures. This indicates that if they play home games frequently, they are also likely to play mobile games frequently, or vice versa.

Overall, video game players appear to be less conscientious, and more impulsive, tending to be non-planning, with poorer attentional abilities such as concentration, and worse self-control. However, no effects were found of video game playing on task switching, regardless of how much is played, or what genre it is. This suggests that video game playing does not have an impact on executive control, regardless of personality and impulsivity differences.

Chapter 5: Impacts of Video Game Experience on Learning and Memory

Abstract

Video game playing is becoming increasingly common, especially with mobile gaming on the rise. Many people have access to video games on their phones, which enables them to play whilst out and about, not only at home on consoles or PCs. The impact that these video games have on the players is still debated. Studies researching the impacts of video games on learning and memory, particularly those focused on training studies, have had mixed results. The current study compared the effects of home and mobile gaming on three different types of learning and memory: implicit memory, explicit memory, and working memory. Implicit memory was measured with a contextual cueing task, explicit memory was measured with a word recall task, and working memory was measured with a colour sequence task. Results showed that home video game players (those playing on home consoles) have improved implicit and explicit memory, but not working memory. However, mobile video game players did not have any improvements in implicit, explicit, or working memory. This suggests that only home-based video gaming leads to memory improvement.

Introduction

Video games have been discussed widely in the media, as well as being the subject of scientific research (Rebetez & Betrancourt, 2007). The positive and negative effects of playing them are regularly discussed and debated. One area in which there is a multitude of research is learning and memory, which are intrinsically linked (e.g., Clemenson & Stark, 2015; Schmidt, Geringswald & Pollmann, 2018). Memory involves three stages: encoding, storage, and retrieval. Much of classical learning requires memorising facts and information, and then understanding how to apply them. Even learning skills often requires memorisation of certain steps or actions.

Clemenson and Stark (2015) researched the impact of video games on memory. All participants completed an enumeration task, which rapidly displayed between 1-9 dots on-screen, and the participants were required to report how many were displayed. They also undertook a Mnemonic Similarity Task (MST) (Kirwan & Stark, 2007), in which pictures of everyday objects were displayed and participants were asked to make an indoor/outdoor judgement on them. Although they did not find a difference between video game players and the control group for the simple recognition memory measure, they did find a difference for the hippocampally mediated lure discrimination index (LDI) measure from the MST. The LDI measure assesses participants' ability to differentiate between repeated items and highly similar lure items. Further analysis found that the difference between groups was not due to playing frequency, but was instead due to the types of games played. They ranked the top three games of each player by complexity, based on the type of perspective it used. They considered multiple variants of 2D and 3D perspectives. For 2D video games, they subdivided into the following viewpoints, giving the following examples: static (*Tetris*); side-scrolling *(Super Mario Bros* or *Sonic the Hedgehog*); top-down (*The Legend of Zelda*); and pseudo-3D (*Diablo*). For 3D games, they subdivided into first-person (*Halo* or *Destiny*), third-person (*Grand Theft Auto V* or *Super Mario 64*), and third-person omniscient (*LOL, Defense of the Ancients 2*). 2D static was given the lowest complexity rating, and third-person omniscient was given the highest. Their data showed that video game players who played complex 3D video games performed better, and those who played 2D games performed similarly to non-gamers.

They also ran an experimental task with novice video game players, who had limited to no video game experience. 69 participants were split into one of three groups: the experimental group (3D games), the active control group (2D games), and the passive control group (no games). At the beginning of the experiment, all participants completed three tasks: an enumeration task, the MST, and a virtual water maze task - in which they navigated a virtual maze, mimicking the Morris water maze (Morris, 1984). Subsequently, the experimental group played 30 minutes of the game *Super Mario 3D World* every day for two weeks; the active control did the same with the game *Angry Birds* (a 2D game), and the passive control group played nothing. At the end of these two weeks participants took the same three tasks again. Finally, after another two-week period in which no participants played any games, they took the tasks a final time.

Consistent with their previous results, they found no effect for any groups on the recognition memory measure, but they did find a difference in LDI between the groups, with improvement for the 3D experimental group only. They also found limited improvements on the virtual water maze task for the 3D experimental group, with an overall improvement of spatial memory compared to the control groups for the amount of time spent searching. These results were also later replicated with older adults (mean age 68.5 years), and further results found that the improvements lasted for up to 4 weeks past the intervention (Clemenson, Stark, Rutledge, & Stark, 2019).

This research implies that many modern video games, particularly the more complex types of games that tend to be available on home platforms such as home consoles and PC's, which have higher computing power than mobile devices, can in fact improve memory. However, there are different types of memory, which are follow different cognitive processes. Looking at different types of memory is of interest, as the impacts of video game playing on memory and learning may not be generalised across these types, and this may have implications on video game usage or training. This study will consider three types of memory: explicit memory, implicit memory, and working memory.

Explicit memory (also known as declarative memory) is memory which requires conscious recollection of information (Eysenck & Keane, 2015). It is often split into episodic memory (storage and retrieval of specific events) and semantic memory (general knowledge and information), however these often overlap. Explicit memory as a whole is therefore about remembering specific facts or events. Non-action video game training (*Lumosity*, an online program of brain-training games) was found to improve episodic memory for older adults when compared to a passive control group (Toril, Reales, Mayas & Ballesteros, 2016), and some gains persisted during a three-month follow-up period.

Savulich et al. (2017) used a novel memory game, played on an iPad, for cognitive training. They compared this training to a control group, with both the control and experimental groups using patients with a diagnosis of amnestic mild cognitive impairment. They found a significant improvement for episodic memory in the cognitive training group, along with high levels of enjoyment and motivation and additionally, their self-ratings of their memory ability improved over time. Yang, Ewoldsen, Dinu & Arpan (2006) researched the effectiveness of advertising and video games by looking at both implicit and explicit memory for brands. The brand advertising was in two sports computer games, and memory was measured using a word-fragment test and a recognition test. They found that the participants had low levels of explicit memory (recognition test) for the brands but did show implicit memory (word-fragment test) for the brand names.

Implicit memory (sometimes known as non-declarative memory) is memory which does not depend on conscious recollection. Schacter, Wagner and Buckner (2000) identified two implicit memory systems, one of which is procedural memory, which they defined as “the learning of motor and cognitive skills” (p. 636). This is now more widely referred to as skill learning. Contextual cueing tasks measure implicit memory ,using a visual search paradigm, where the target item must be located amongst distractor items in a display (e.g., Colagiuri & Livesey, 2016). For contextual cueing, certain displays are repeated across blocks, whereas other displays are new, being randomly generated. Studies have found that participants become more efficient at searching through the repeated (old) displays, even though they are generally unaware of the repetitions (e.g., Chun, 2000; Chun & Jiang, 1998, 2003). This suggests that spatial context can be learnt implicitly and then used to help search through a context that is re-encountered.

One study compared action video gamers, handball players, and a control group in a contextual cueing task, to test for differences in implicit learning (Schmidt, Geringswald & Pollmann, 2018). They hypothesised that both action video gamers and team sports players (the handball players group) would have increased contextual cueing, due to previous research demonstrating improved visual search performance and distractor inhibition when compared to non-gamers (e.g., Bavelier et al. 2011; Buckley et al. 2010; Chisholm & Kingstone 2012). All groups exhibited a contextual cueing effect, showing incidental learning of repeated displays, however, contrary to their predictions, the groups did not differ in the strength of this effect.

Working memory is a concept which can be attributed to Baddeley and Hitch (1974) and Baddeley (1986). The concept of working memory is sometimes considered to be synonymous with short-term memory, but some researchers consider them to be distinct processes (Cowan, 2008). Typically working memory is defined as a multicomponent cognitive system that is responsible for temporarily holding information available for processing, which manipulates information storage for more complex cognitive utility (for an overview of working memory see Chai, Abd Hamid & Abdullah, 2018). As well as episodic memory, non-action video game training (*Lumosity*) was found to improve visuospatial working memory for older adults when compared to a passive control group (Toril, Reales, Mayas & Ballesteros, 2016). However, other studies did not find an improvement (e.g., Ballesteros et al., 2014), and there was no difference in visuospatial working memory improvements when compared to an active control group (strategy games) (Ballesteros et al., 2017).

Mishra, Bavelier and Gazzaley (2012) reviewed research methods into the effects of video game playing on working memory, including both visual working memory and verbal working memory. Based on previous research (e.g., Anderson, Kludt & Bavelier, 2011; Berry et al., 2010), they hypothesised that action video game players would show working memory benefits. They describe a number of tasks designed to measure working memory, including the Digit

Span and Letter Number Sequencing (LNS) tests (Wechsler, 1997). These involve the experimenter listing sequence of numbers, or a random mix of letters and numbers (LNS), which the participant then has to repeat. These tasks are usually spoken tasks to measure verbal working memory. For the current study, working memory was measured with colour sequencing. This task works in a similar way; however, it visually displays colour squares in sequence, which the participants then have to repeat in order. Later research found that training with a custom-designed 3D video game (*NeuroRacer*) led to enhanced working memory in older adults (Anguera et al., 2013). This would suggest improved working memory for video game players. However, one study found that playing the video game *Angry Birds* during a short learning break negatively impacted on working memory as measured by the *n*-back task (Kuschpel et al., 2015). They found that the *Angry Birds* condition led to a decline in task performance over the course of the *n*-back task compared to eyes-open resting and listening to classical music, although overall task performance was not impaired.

Based on the above literature the main aim of the present study was to see whether playing home or mobile video games differently affects three different types of memory. This was achieved by measuring implicit memory, explicit memory, and working memory by using a contextual cueing task, a word recall memory tasks, and a colour sequencing task. Based on previous findings, it is expected that video game players will show better performance in all three memory tasks. Home video game players are also expected to show better memory performance than mobile video game players, as home games tend to be higher in terms of their complexity (see Clemenson and Stark, 2015) due to difference in processing power between home and mobile devices.

Method

Participants

A total of 156 participants took part (143 female, 12 male, 1 transgender, age range 18-30, mean age: 19.0 years). All participants were first-year Psychology students at the University of Warwick, who completed the study for course credit. The study was given full ethical approval by the University's Psychology Department Ethics Committee, and all participants gave informed written consent and were aware of their right to withdraw at any time.

Apparatus

All tasks and questionnaires were presented on a 19" LCD monitor (60 Hz) at a resolution of 1920 x 1080 pixels. The experiment was controlled by an IBM-PC compatible computer using custom-written software and responses were recorded using a standard computer mouse and QWERTY keyboard. Participants were seated, with their heads approximately 57 cm away from the computer screen.

Stimuli and Tasks

Participants completed three memory tasks:

Task 1 was a word recall task, measuring explicit memory. This was a visual version of the Rey Auditory Verbal Learning Test (RAVLT) with written instead of spoken responses, using the same word lists as the original RAVLT (Rey, 1964; Schmidt, 1996). The task comprised of two lists of 15 words, List A (drum, curtain, bell, coffee, school, parent, moon, garden, hat, farmer, nose, turkey, colour, house, river) and List B (desk, ranger, bird, shoe, stove, mountain, glasses, towel, cloud, boat, lamb, gum, pencil, church, fish). The words were presented in the centre of the screen, each for 1500ms, with a blank interval of 800ms between words. Letters were printed in Arial 24-point font (height of 0.4° visual angle). Participants were asked to recall as many words as they could (in any order) by entering them on the computer keyboard. The same word list was presented in the same order and immediately recalled five times (lists A1, A2, A3, A4, and A5). This was followed by a trial of another 15 words (list B1), which were presented as a distractor list, which the participants again had to recall. Finally, at the end of the experiment which took 20 minutes, participants were asked to recall the first list again but without seeing it (A6).

Task 2 was a colour memory task to test explicit memory. Coloured squares were presented to participants in a randomised sequence. There were a total of six possible colours: Red (RGB: 196, 0, 0), green (RGB: 0, 196, 0), blue (RGB: 0, 0, 196), yellow (RGB: 196, 196, 0), magenta (RGB: 196, 0, 196), and cyan

(RGB: 0, 196, 196). The sequence consisted of either three, five, seven, or nine colour squares. There were five sets of each length of sequence. Each colour square was 2.7° x 2.7° pixels in size and was presented in the centre of the screen for 500ms followed by a 500ms blank screen. At the end of the sequence, each of the six colours available were presented on screen for participants to select from (Figure 5.1). This task could be considered comparable to the Corsi Block-Tapping Task, which is frequently used to measure working memory (e.g. Vandierendonck, Kemps, Fastame & Szmalec, 2004). Notably, backward span task performance in the Corsi Task has been reported as no more difficult than forward span (Kessels, Van Den Berg, Ruis & Brands, 2008), with two implications for this experiment. Firstly, this highlights the critique that the task may only engage visual and/or visuo-spatial short-term memory aspects of working memory (see Zupan, Blagrove & Watson, 2018; for an example from the developmental literature), rather than the full range of executive functions implicated in working memory function (e.g., monitoring, updating and shifting; Miyake et al., 2000). Secondly, in practical terms, given these were the mechanisms we were most interested in here - and that equivalent performance was seen in backwards and forwards span - only the latter type of trial was used in this study.

There were two conditions for this task. The first condition had participants choose the correct colours in sequence with the mouse. The second condition required participants to enter the correct sequence using the corresponding numbers on the numerical keyboard thereby requiring additional cognitive processing. These two versions were split between the participants (mouse condition *n* = 79, number condition *n* = 77), and which condition they were in was determined before they started the tasks.

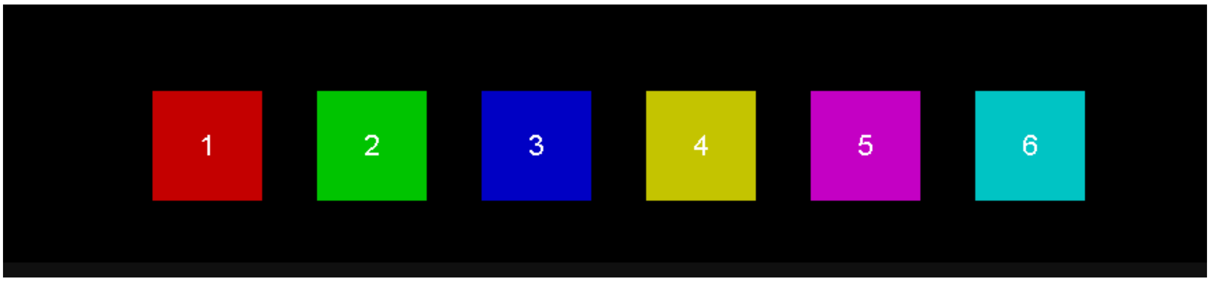


Figure 5.1. Colour sequence response options. Participants had to either click on the colour squares in the correct sequence or type the corresponding numbers for each colour in the correct sequence.

Task 3 was a contextual cueing task to measure implicit memory. Participants were asked to find a tilted letter T among upright, tilted and upside-down Ls (see Figure 5.2 for an example display). Each trial started with the presentation of a central fixation cross (size 0.8°) for 500ms. This was followed by the search display, in which participants responded with the directional arrow keys on the computer keyboard. Each display contained one target letter "T" —tilted 90 degrees either to the left or to the right—and 11 distractor letter "L"s—rotated randomly by 0°, 90°, 180°, or 270°. Both letters had a size of 1.2° x 1.2° and were presented in grey (RGB: 128, 128, 128) on a black screen.

Participants were instructed to press the left arrow key if the stem of the "T" pointed to the left, or the right arrow key if it pointed to the right. Stimuli were placed within an invisible 8 by 6 matrix (cell size 4° x 4°) with positions randomly jittered by +/-0.8° horizontally and vertically. This task consisted of 24 practice trials, followed by 16 experimental blocks with 24 trials in each block, resulting in a total of 384 experimental trials. Error feedback was given after each trial by showing "Error - Wrong Response" for 1s at the centre of the screen. For each participant, 12 configurations were randomly generated and shown repeatedly across blocks. In these, the target was presented in the same location for that configuration, but may be oriented either left or right.

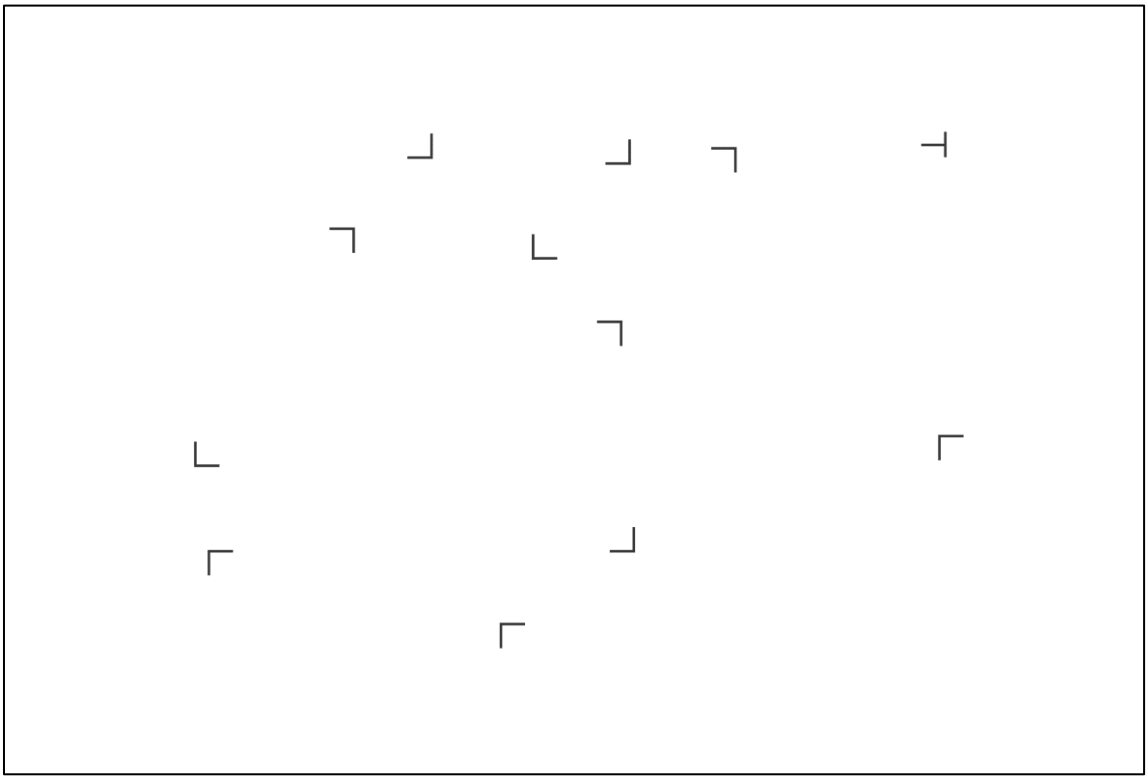


Figure 5.2. Contextual cueing example. In this case, the participant would have to press the left arrow key as the stem of the tilted "T" is facing left.

After completing the 16 blocks of the main search task, participants were asked to perform a memory test. They were informed that certain display configurations had been repeated during the experiment and they were asked if they recognised whether displays had been shown previously or not. 12 of the 24 displays had already been used in the experiment, and 12 were new randomly generated configurations. No error feedback was given for these trials. Participants were informed that some displays were repeated and that they had to indicate whether they believed the display was new or had been seen previously. This was done by using either the left or right arrow key.

Questionnaires

The Video Game Experience Questionnaire used was developed by one of the authors and it asks various questions regarding the participant's history with video games, as well as their current interactions. This includes four main questions to score video game play experience, using a 6-point scale, looking at frequency of play (from never or rarely to daily), length of play (from ≤1 to ≥5 hours), number of games played in lifetime (from ≤10 to ≥200 games), and average weekly play (from ≤0-1 hour to ≥12 hours). The questionnaire also splits video game experience into "home" and "mobile" video game playing. Home gaming was herein classified as "games which you play within a home environment. For example, this could be your own home, a friend's home, or a recreational centre." Mobile gaming was classed as "games which you play outside of a home environment. For example, this could be games you can play whilst travelling or in a public place." Additionally, questions regarding which video game genres they played were included.

Procedure

Firstly, participants' video game experience was assessed with the Video Game Experience Questionnaire, which was presented via Qualtrics.

They were then presented with a number of tasks, the first being word recall. Five repetitions of list A were given, followed by one repetition of List B. Following the word lists, the colour sequence memory task was run in its entirety. The next task was the contextual cueing task. Finally, after the 20 minutes it took to complete the colour sequencing and contextual cueing tasks, the participants were once again asked to recall the words from List A without them being displayed on the screen. The tasks were not counterbalanced due to the requirement for the 20-minute distraction period for word recall.

Results

The answers of the four main questions on video game play experience were averaged separately for home video gameplay and for mobile video gameplay. There was a positive correlation between home gameplay and mobile gameplay, $r(157) = .401$, $p < .001$, indicating that those playing home frequently also tend to play mobile frequently. The average scores were then split into three groups: rarely (=1), occasionally (1-2), frequently (>2), again separately for home and mobile video game play (see Table 5.1 for the number of participants in each category). This means that each participant was in one of the home categories (rarely, occasionally, frequently), and one of the mobile categories (rarely, occasionally, frequently), and they may be in different categories for each (e.g., a participant may be frequently for home but rarely for mobile).

Table 5.1. Number of participants in each mobile and home category based on the questionnaire.

Number of Participants				
	Rarely	Occasionally	Frequently	Total
Home	50	64	42	156
Mobile	33	64	59	156

Colour Sequencing

The first two colour sequences were practice and the remaining 18 were used to calculate an overall memory score by counting the total number of correctly identified colour patches at their right location across all sequences (to a possible maximum score of 3x3+5x5+5x7+5x9=116). The scores of all participants ranged between 36 and 101. An independent sample t-test on the colour sequencing scores revealed that responding was easier with the mouse than with the keyboard, $t(154) = 3.109$, $p = .002$ (65.9 vs. 60.4, respectively). The data from mouse and keyboard responses were combined and submitted to a 3x3-way ANOVA with Home VGP Experience (rarely, occasionally, frequently) and Mobile VGP Experience (rarely, occasionally, frequently) revealed no significant effects: Home VGP Experience, $F(2, 147) = 0.109$, $p = .897$, $\eta_p^2 = 001$; Mobile VGP

Experience, $F(2, 147) = 0.480$, $p = .520$, $\eta_p^2 = 006$; and 2-way interaction, $F(4,147) = 0.157$, $p = .960$, $\eta_p^2 = 004$ (see Figure 5.3).

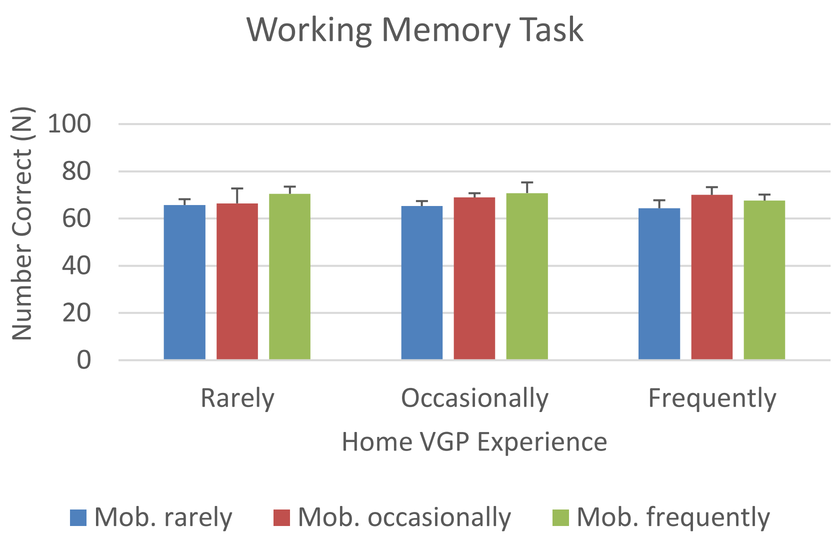


Figure 5.3. Total number of correctly identified colour patches as a function of Home VGP Experience and Mobile VGP Experience. Error bars indicate standard error means.

Contextual Cueing

Two participants were removed due to very high error rates (40% and 48%) in the contextual cueing task, indicating that they did not follow the task instructions, giving a total of 154 participants with an average error rate of 3.0%.

A 2x4x3x3 mixed-design ANOVA with the within-subject factors Display Type (old, new) and Epoch (1-4), and the between-subject factors Home VGP Experience (rarely, occasionally, frequently) and Mobile VGP Experience (rarely, occasionally, frequently) revealed several significant effects. There was a significant main effect of Display Type, $F(1, 145) = 20.701$, $p < .001$, $\eta_p^2 = .125$. As can be seen from Figure 5.4, average RTs were overall faster for old than for new displays (1081 vs. 1110 ms, respectively). There was also a significant main effect of epoch, $F(3, 435) = 86.666$, $p < .001$, $\eta_p^2 = .374$, due to decreasing RTs with increasing epochs (from 1183, 1105, 1074 to 1020 ms, respectively).

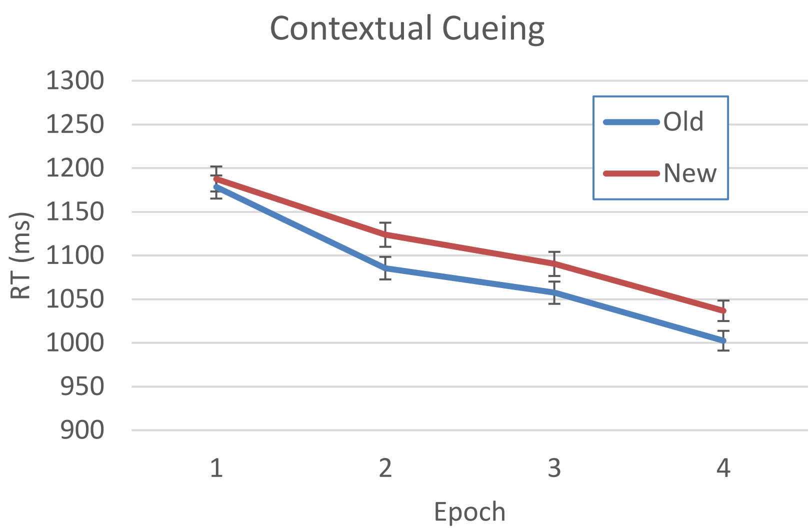


Figure 5.4. Mean Reaction times (ms) as a function of time (epoch) for old and new displays. Error bars indicate standard error means.

The ANOVA further showed that the contextual cueing effect depends on home video game experience (Display Type x Home VGP Experience), $F(2, 145) = 4.788$, $p = .010$, $\eta_p^2 = .062$. This is due to the rarely/never players having an overall smaller contextual cueing effect (averaged across all epochs) than those playing occasionally or frequently (6ms vs. 65ms, or 44ms, respectively). The Mobile video game experience did not have a significant effect on contextual cueing, (Display Type x Mobile VGP Experience), $F(2,145) = 3.020$, $p = .052$, η_p^2 =

.040. None of the other main effects or interaction effects reached significance (all $p > .341$), including the three way interaction between Display Type, Home VGP Experience and Mobile VGP Experience, $F(4, 145) = 0.967$, $p = .428$, $\eta_p^2 = .026$, nor the 4-way interaction, $F(12,435) = 0.799$, $p = .651$, $\eta_p^2 = .022$.

An equivalent 2x4x3x3 mixed-design ANOVA was also run for errors, revealing a significant three-way effect between Display Type, Home and Mobile $F(4, 145) = 2.672$, $p = .034$, $\eta_p^2 = .069$. The overall pattern of errors is reversed in comparison to the RT pattern, with those playing mobile videogames rarely making fewer errors than those playing occasionally or frequently (1.7 vs. 3.4, or 4.5%, respectively). This could be an indicator for a possible speed-accuracy trade-off, that is, frequent players might in comparison to non-players respond faster to targets at the cost of making more errors. None of the other main effects or interaction effects reached significance (all $p > .248$).

In the final display recognition test participants did not seem to recognise old displays, as the recognition rate (51.9%) was slightly above chance, $t(153) = 2.269$, $p = .025$. A 3x3 ANOVA with the between-subject factors Home VGP Experience (rarely, occasionally, frequently) and Mobile VGP Experience (rarely, occasionally, frequently) was run on the recognition rates but revealed no significant effects (all $p > .13$).

Word Recall

Two participants were removed from this task due to technical problems with saving their data files, leaving a total of 154 participants. A 3x3 ANOVA on the word recall for list A5 (the last recall of the first list before the distractor list) with the between-subject factors Home VGP Experience (rarely, occasionally, frequently) and Mobile VGP Experience (rarely, occasionally, frequently) revealed a statistically significant main effect of Home VGP Experience, $F(2, 145) = 6.159$, $p = .003$, $\eta_p^2 = .080$. As can be seen from Figure 5.5, those playing home videogames frequently remembered more words compared to those playing rarely or occasionally (14.6 vs. 14.0 or 13.8 words, respectively). The main effect for Mobile VGP Experience did not reach significance, $F(2, 145) = 2.675$, $p = .072$, $\eta_p^2 = .035$, but there was a significant interaction effect, $F(4, 145) = 6.607$, $p < .001$, $\eta_p^2 = .154$.

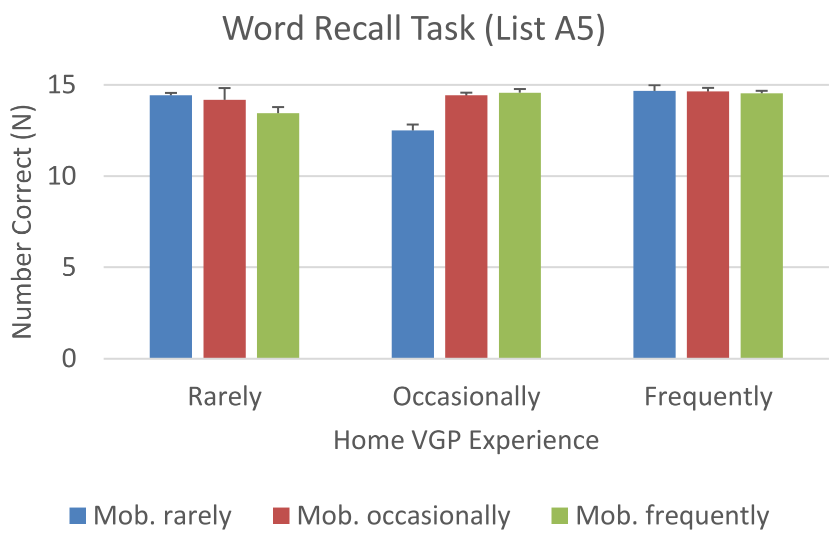


Figure 5.5. Total number of correctly identified words in the penultimate word list as a function of Home VGP Experience and Mobile VGP Experience. Error bars indicate standard error means.

The same 3x3 ANOVA was run on list A6 (the final recall after a 20 minute distraction period), which also revealed a statistically significant interaction between the effects of Home and Mobile VGP Experience on word recall, $F(4, 145) = 2.838$, $p = .026$, $\eta_p^2 = .074$. Further split-up ANOVAs revealed the same result as with list 5 (see Figure 5.6).

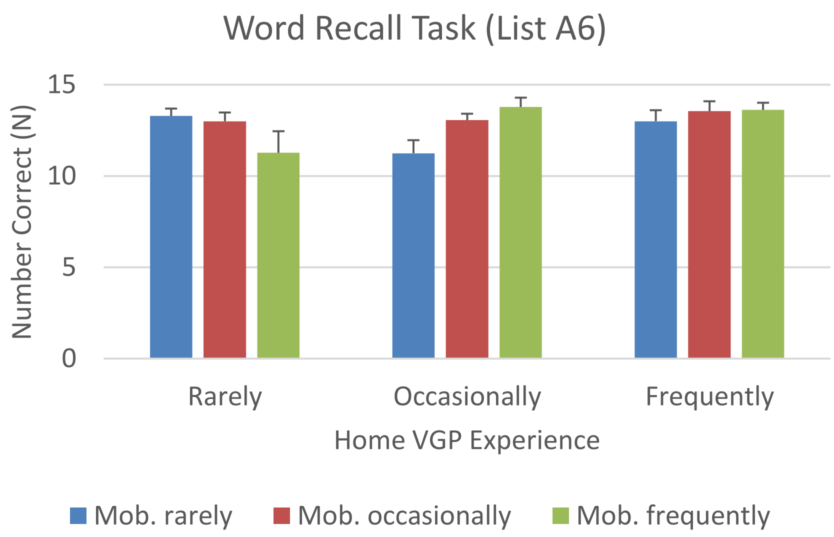


Figure 5.6. Total number of correctly identified words in the final word list as a function of Home VGP Experience and Mobile VGP Experience. Error bars indicate standard error means.

The equivalent 3x3-way ANOVAs were also run on lists A1 and B1 (the first time each list was displayed), but there were no significant effects for Home or Mobile VGP Experience on word recall for list A1 (all $p > .126$) or list B1 (all $p > .227$).

Finally, the three types of memory scores did not correlate with each other: implicit with explicit memory: $r(153) = -.007$, $p = .927$, implicit with working memory: $r(153) = .035$, $p = .669$, and explicit with working memory: $r(153) = .156$, $p = .054$.

Discussion

Our first prediction, that home video game playing will show better memory ability than mobile video game playing, was supported by the data from the contextual cueing and word recall tasks. In the contextual cueing task, the contextual cueing effect was shown to depend on home gaming, but not mobile gaming. Likewise, in the word recall task for lists A5 and A6 the word recall ability depended on the home group, but not the mobile group.

The difference between most home and mobile platforms may be due to the complexity of the games, or their 2D versus 3D perspectives, as suggested by Clemenson and Stark (2015). Clemenson and Stark do note that they cannot determine whether their results are due to the perspective, the volume of information, or the spatial aspects of the information. Similarly, the difference in results found between the home and mobile platforms in this study could be attributed to these reasons. However, as not all games on home platforms are 3D, or all games on mobile platforms are 2D, this may suggest that is more likely due to the volume or spatial aspects of the information in these types of games that contributes to the differences. Likewise, as Clemenson and Stark ranked these 2D and 3D games by complexity, the difference in complexity of home and mobile games may be a contributing factor.

Furthermore, Clemenson and Stark (2015) found that performance in both hippocampal-associated behaviours correlated with performance in the 3D game, but not the 2D game, indicating that how individuals explored the virtual environment may influence hippocampal behaviour.

Our second prediction, that video game players will have improved implicit memory was partially supported by the data, as the contextual cueing effect depended on home video game experience, with those occasionally or frequently playing video games showing more contextual cueing. The findings of the present research fit with predictions based on previous research demonstrating improved visual search performance and distractor inhibition compared to non-gamers (e.g., Bavelier et al. 2011; Buckley et al. 2010; Chisholm & Kingstone 2012). Unlike the present study, Schmidt, Geringswald and Pollmann (2018) did not find improved implicit memory for video game players. This may have been be due to their recruitment process, as they specifically focused on action video game players who needed to play action video games such as Call of Duty and Battlefield for a minimum of five hours a week for at least one year, and compared them to a control group who played less than 1 hour per week of action video games. In contrast, the present study did not distinguish between action and non-action video games, instead focusing on platform. Their control group may have in fact played multiple hours a week of non-action video games on home consoles, such as platformers like *Super Mario 3D World* (used by Clemenson & Stark, 2015), or strategy games, which don't show a difference when compared to training as demonstrated by Ballesteros et al. (2017).

Our third prediction, that video game players will have improved explicit memory, was partially supported by the results from the word recall task. These findings support previous research which found an improvement in explicit memory from video game playing (e.g., Toril, Reales, Mayas & Ballesteros, 2016; Savulich et al., 2017; Yang, Ewoldsen, Dinu & Arpan, 2006). The lack of difference in performance for the first viewing of each list between groups suggests that video game experience does not make a difference when something is presented the first time. However, as there is a difference for the A5 and A6 lists (the fifth recall and the final sixth recall after 20 minutes) for the Home factor, this indicates that home video game experience can improve encoding and storage of information which is repeated multiple times. This implies that there may be a benefit to video game players learning through repetition. However, the ceiling effect of this task does need to be taken into consideration.

Our final prediction, that video game players will have improved working memory, was not supported, with no significant effects for the colour sequencing task. This does not fit with some previous research which found enhanced working memory from playing video games (Toril, Reales, Mayas & Ballesteros, 2016; Anguera et al., 2013). However, both of these studies focused on older adults, whereas the current study which used young adults, and younger adults are known to have long working memory stands and faster processing speeds than older adults (e.g., Feld & Sommers, 2009), so may not get as much benefit from playing video games. This may therefore account for the difference in the findings, which instead supports some previous research that did not find an improvement for working memory with a video game playing (e.g., Ballesteros et al., 2014; Ballesteros et al., 2017).

The results of the present study also do not support a negative impact of video game playing, unlike Kuschpel et al. (2015), who found a decrease in working memory from playing video games, specifically with the game *Angry Birds*, which is a 2D game typically played on mobile devices. However, just as platform did not account for any differences found in previous studies, the age difference in participants likely does not entirely explain the disparity in results from those studies which found enhanced working memory from playing video games. Studies have found that improvements in working memory from training are comparing across younger and older adults (Carretti, Borella, & De Beni, 2007), or better for younger adults in some tasks (Brehmer, Westerberg, & Bäckman, 2012).

In conclusion, both implicit and explicit memory were affected by video game playing, specifically home platform video game playing. This applies that more complex games are more able to improve cognitive processes such as memory, than typically simpler games on mobile platforms. This may account for some differences in previous training studies, depending on what type of video game was used for the training purposes, and on what type of platform. As mobile platforms, such as phones and tablets are generally more accessible and common, it's unsurprising that many studies have utilised these tools, however they may not be suitable for improving cognitive processing.

Chapter 6: Learning in Virtual Reality: Effects on Performance, Emotion, and Engagement

Abstract

Recent advances in virtual reality (VR) technology allow for potential learning and education applications. For this study, 99 participants were assigned to one of three learning conditions: traditional (textbook-style), VR, and video (a passive control). The learning materials used the same text and 3D model for all conditions. Each participant was given a knowledge test before and after learning. Participants in the traditional and VR conditions had improved overall performance (i.e., learning, including knowledge acquisition and understanding) compared to those in the video condition. Participants in the VR condition also showed better performance for ‘remembering’ than those in the traditional and the video conditions. Emotion self-ratings before and after the learning phase showed an increase in positive emotions, and a decrease in negative emotions for the VR condition. Conversely there was a decrease in positive emotions in both the traditional and video conditions. The web-based learning tools evaluation scale also found that VR participants reported higher engagement than those in the other conditions. Overall, VR displayed improved learning experience when compared to traditional and video learning methods.

Introduction

Interactive technology is progressing at an incredibly fast rate, and advances in virtual reality (VR) technology lead to many potential new applications. VR is widely used for entertainment purposes; with most individuals' experiences of VR being from video games and other widely distributed media. These media are widely advertised, and well-known, leading to higher popularity. However, VR has broader application possibilities, thanks to significant advances in the technology, including the technology now being available in a mobile format, along with Augmented Reality.

VR technologies allow the user to see and interact with virtual environments and objects. Modern VR is delivered through a headset, which allows the user to see – and in some cases, hear – the 3D environment. In this way the user is totally immersed in the virtual environment, as it replaces the physical environment around them. Immersion and engagement can be considered intrinsically linked in virtual environments (McMahan, 2003). Mount, Chambers, Weaver and Priestnall (2009) discussed the relationship between immersion, presence and engagement. They explored what it means for a learner to be immersed, and considered immersion and engagement in 3D virtual environments, to outline how 3D virtual environments can be used to enhance learner engagement.

VR boasts a number of features that could be useful for education: they present environments in 3D, they are interactive, and they are able to give audio, visual and even haptic feedback. Presenting learning materials in 3D can be especially beneficial for teaching subjects where it is important to visualise the learning materials (e.g., in chemistry or in engineering). Though visualising is one of the most obvious benefits to VR, this could also be accomplished with simple video. However, videos are passive learning objects, whereas VR allows for a direct interaction with the environment. Interactivity and feedback can be valuable for all subjects, as there are specific benefits to interactive learning, as it promotes active learning instead of passive learning.

The usefulness of VR in education might also depend on the type of learning. Learning styles theories suggest that there are various ways to learn, and some individuals learn better with some methods than others, as they have different approaches to information processing. The well-known Visual-Auditory-Kinesthetic learning styles model (Barbe, Swassing and Milone, 1979) suggests there are three types of learning styles: visual, auditory, and kinesthetic. VR allows all three of these learning styles to be targeted in one application, as VR headsets allow for complex visual renderings, audio, and movement tracking. Though there has been much contention over learning styles theories, with research finding it to be a problematic simplification of learning (e.g. Evans & Sadler-Smith, 2006; Sharp, Bowker & Byrne, 2008; Willis, 2017), having one learning environment which can encompass multiple learning styles could be very beneficial to be suitable for a much wider range of individuals.

Another benefit that comes with VR is the interactive learning environment it allows; as well as being active learning, several learning styles theories also suggest that interaction can be an important learning method. For example, Kolb's learning styles theory (Kolb, 1976; 1981; 1984) states that ‘active experimentation’ is important for effective learning. Kolb states that effective learning happens through a four stage cycle: concrete experience; reflective observation; abstract conceptualisation; and active experimentation. Kolb outlays four learning styles which use these four stages differently, with active experimentation being integral aspects of the accommodating and converging learning approaches.

Other learning styles models include the importance of learning through different perceptual modalities, many of which are able to be targeted in VR (for an overview of various learning styles theories see Cassidy, 2004). Learning styles theories work on the basis that individuals naturally prefer certain ways of learning over others. VR technology potentially has the capability to provide a flexible learning environment. Therefore, activities in VR could be designed to include multiple learning styles, where students can choose to engage with the learning materials in the manner which suits them best.

Other scholars are more critical of learning styles theories (e.g., Pashler, McDaniel, Rohrer and Bjork, 2008; Riener and Willingham, 2010), stating that, though there are many theories, there is little empirical evidence for learning styles. However, others still consider it important to be aware of varying sensory modalities and learning approaches due to students' differing learning habits and preferences (e.g., Hawk and Shah, 2007; Kharb, Samanta, Jindal and Singh, 2013). The impact of learning styles on e-learning is also debated (Truong, 2016), including how best to design adaptive virtual learning environments whilst considering learning styles (Kanninen, 2008). There are potential benefits of targeting multiple methods of learning within VR, to allow for different information processing. This could be not only due to learning styles and preferences for individuals, but also for how different types of information may be better presented in some formats than others (e.g., language may be best learnt with audio, whereas engineering may suit visualisation more).

VR is not necessarily equally suitable for all subject areas; benefits of visualising are more significant in some subjects than others. As such, VR applications may be more suited to some areas of education than others. The revised Bloom's Taxonomy (Bloom, Englehard, Furst, Hill and Krathwohl, 1956; see also Anderson et al., 2001) suggests that there is not simply one way in which information is processed and learnt; instead it presents learning as a hierarchy of learning, consisting of six stages that involve cognitive processes from simplest to most complex (from remember, understand, apply, analyse, evaluate, to create). It is suggested that these different types of learning can be processed differently, some methods of study which are used in education are only applicable to some subjects. Debates, for example, are often good at engaging students with material that requires critical thinking (Camp and Schnader, 2010; Scott, 2008), but are less suited to learning more concrete information, such as for sciences like physics or chemistry. VR, for example, may not be very beneficial for learning a language, but may be particularly useful for topics where spatial arrangement is important, or there are dynamic changes.

Though not many empirical studies have yet been conducted, VR has been compared to traditional learning in some areas. In one study a group of military students were taught with either the lecture-based teaching methods which are traditionally used for the subject material (corrosion prevention and control), or with an immersive VR-based teaching method (Webster, 2015). They found that whereas the traditional learning group had an improvement of 11%, the VR group had a higher improvement of 26.%.

Bellamy and Warren (2011) conducted a case study where online simulations were used to create simple interactive simulations which mimicked real experiments. 83% of their students reported that they found these online simulations helpful or very helpful, and their demonstrators stated that the students seemed much better prepared and more willing to answer questions when they had done the online simulations. These and other examples promote for learning the usefulness of simulated environments as alternatives to real life scenarios.

Creating educational applications for VR could be a laborious and costly endeavour, so it is important to investigate whether these applications are useful for learning or not. Therefore, explorative research can help answer whether the development of educational applications for this type of hardware is worth pursuing. As VR technology has only recently become more accessible and affordable, research in the past using VR in educational and pedagogic settings has typically used smaller sample sizes with less rigorous methodologies. This study looks to address that, considering not only test performance (used as a measure of learning), but also other outcomes of using VR for learning, such as effects on emotion and engagement. The VR condition is predicted to have better outcomes than the video and textbook-style conditions, in terms of learning performance, engagement, and emotion (with higher positive emotions and lower negative emotions).

Method

Participants

All participants were first year Psychology students at the University of Warwick who completed the study for course credit. A total of 99 participants (84 females, 15 males), were assigned randomly to one of three learning conditions: traditional (textbook-style), VR, and video. All participants reported normal or corrected-to-normal vision. The study was approved by the University's Humanities & Social Sciences Research Ethics Committee, and all participants gave informed written consent and were aware of their right to withdraw at any time.

Apparatus

The questionnaires and learning materials were presented on a 19” LCD computer screen (1920 x 1080 pixels, 60 Hz) using Microsoft Word and Qualtrics. Responses were collected through mouse and keyboard. A HTC Vive (Figure 6.1) was used for the VR condition. The headset weighs 550g, and displays a 3D environment via two OLED displays (1080 x 1200 pixels per eye 90 Hz) with a field of view of 100 x 110 degrees. Participants controlled the VR environment with the standard handheld HTC Vive controller.

Figure 6.1. The HTC Vive headset and examples of the 3D model used as learning material for all conditions from the Lifeliqe Museum VR environment.

Learning Materials

The learning materials used the same text and 3D model of a plant cell for all three conditions. The VR condition presented the model from the application "Lifeliqe Museum" on the HTC Vive headset, allowing the participants to see and interact with a 3D model, with accompanying descriptive text (Figure 6.1). The 3D plant cell model was fully interactive, allowing participants to highlight individual cell parts, change the size of the cell, and rotate it. They could also teleport around the virtual room, with the plant cell appearing as a floating object in the room with them, which they could navigate around. A menu was available, virtually attached to one of the controllers, showing names of each part of the plant cell. Participants could select one of these parts from the menu (e.g., the golgi apparatus) and it would highlight the part on the 3D model. This could also be done the opposite way, by selecting the part on the model, which would highlight the name on the menu. A written explanation of the purpose of each part of the plant cell was also available on this menu. The option of a narrator was disabled for this study, in order to remove audio learning as a confounding variable.

The video condition used a 2D recording from the HTC Vive, matched from participants in the VR condition, and presented on a computer screen. Participants were informed that they could navigate this video at will (play/pause, fast forward, rewind), as they would in a distance learning scenario. This acted as a control to the VR condition as it presented the same visual information, with the same graphics, but did not have other VR features, such as interactivity and immersive 3D display.

The textbook condition used screenshots of the 3D model with the same accompanying text and presented them on a computer screen as a pdf file (Figure 6.2). This ensured that all three groups had the same information and visuals to learn with, with the only difference being the format in which these materials were presented. Whilst this meant that none of the conditions were ideal examples of how these formats would be best designed for learning, they were directly comparable, without extraneous variables. For instance, the textbook-style condition did not use ideal textbook diagram design, and audio was not included with the VR or video conditions.

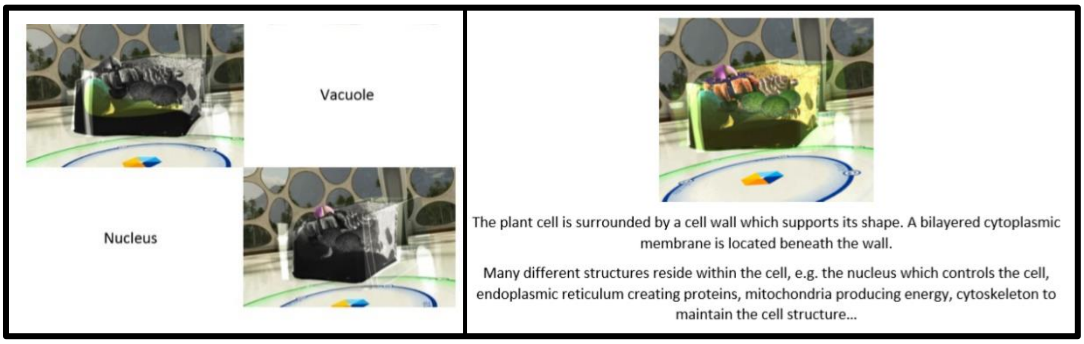


Figure 6.2. Example of the textbook conditions, using the same text and screenshots from the Lifeliqe Museum VR environment.

Rating Scales

An adapted version of the Differential Emotions Scale (DES, Izard, Dougherty, Bloxom, and Kotsch, 1974), with nine emotion categories (interest, amusement, sadness, anger, fear, anxiety, contempt, surprise, and elatedness) was used to measure participants' mood before and after the learning phase (Appendix 8). Participants were asked to rate to which extent the emotional adjectives, each represented with 3 words (e.g., surprised, amazed, astonished), applied to them on a scale from 1 (not at all) to 5 (very strongly). Five of the categories related to negative emotions, and four related to positive emotions.

The web-based learning tools (WBLT) Evaluation Scale questionnaire (Kay, 2011) was used to measure engagement (Appendix 9). The WBLT Evaluation Scale asks participants to rate what they thought about the learning tools across 13 questions on a scale of 1 (strongly disagree) to 5 (strongly agree). The questions included items such as "the learning object helped teach me a new concept", and "I would like to use the learning object again". The questions can be grouped into the three categories "learning", "design", and "engagement".

Procedure

The procedure was the same for each participant, starting with a pre-test (Appendix 7) and the DES, followed by the learning phase. For the learning phase participants were instructed to learn as much as they could from the learning materials, and all conditions were given the same amount of time (7 minutes). After the learning phase participants completed a post-test consisting of the same questions as the pre-test, the DES, the WBLT, and one question which allowed for qualitative feedback. The improvement from pre-test to post-test was used as the main measure of learning performance. This method was used in order to account for any participants with prior knowledge of the subject (plant cells). Questions used for the test were either sourced directly from a British AQA Biology A-Level exam, or in the same style as these questions.

Results

Learning

The seventeen biology knowledge questions were marked as correct or incorrect and used in the calculation of an overall percentage correct, separately for each participant. The top half of Table 6.1 shows the average knowledge scores in the pre-test and in the post-test, together with the difference scores as an indicator for learning. Here the overall difference between pre-test and post-test is referred to as performance to differentiate it from the “learning” scores of the WBLT Evaluation Scale. The corresponding average confidence ratings are given in the bottom half of the table.

Table 6.1. Number of participants (*N*), knowledge scores (percentage correct) and confidence ratings (1—5) in the pre-test and post-test separately for the three conditions.

Condition	*N*	Pre-test	Post-test	Difference
Knowledge Scores				
Virtual	34	28.1%	56.5%	28.5%
Video	34	27.9%	43.9%	16.1%
Textbook	31	25.3%	50.2%	24.9%
Confidence Ratings				
Virtual	34	2.24	3.35	1.12
Video	34	2.33	3.04	0.71
Textbook	31	2.14	3.32	1.18

The knowledge scores were analysed with a mixed-design ANOVA with the between-subject factor Condition (textbook, video, virtual) and the within-subject factor Test (pre, post). The ANOVA revealed a significant main effect for Test, $F(1,96) = 273.25$, $p < .001$, $\eta_p^2 = .740$, indicating that knowledge improved overall by 30.0% from pre-test to post-test, and a significant Test x Condition interaction, $F(2,96) = 6.80$, $p = .002$, $\eta_p^2 = .124$. The significant interaction was further analysed with two split-up ANOVAs, separately for pre-test and for post-test. The ANOVA on the post-test data revealed a significant condition effect, $F(2,96) = 3.51$, $p = .034$, $\eta_p^2 = .068$. Post-hoc *LSD* showed that participants in the VR condition scored significantly higher than participants in the video condition (56.5% vs. 43.9%, respectively, $p = .009$). The pre-test ANOVA showed no significant effect ($p = .793$)

The confidence ratings showed a similar pattern of results as the knowledge data (see bottom half of Table 6.1). The equivalent mixed-design ANOVA revealed a significant effect for Test, $F(1,96) = 266.96$, $p < .001$, $\eta_p^2 = .736$, due to participants being more confident in the post-test than in the pre-test (3.24 vs. 2.24, respectively), as well as a significant Test x Condition interaction, $F(2,96) = 5.80$, $p = .004$, $\eta_p^2 = .108$, due to less confidence gain in the video than in the VR or textbook condition (0.71 vs. 1.12 and 1.18, respectively).

The knowledge questionnaire data was further analysed by splitting the questions into two categories on the basis of Bloom's Taxonomy (Bloom, 1956). The first group (12 questions) related to the remembering of information, whereas the second group (5 questions) was more concerned with the understanding of information. The overall percentage correct in each category are shown in Figure 6.3. A 3x2-way ANOVA on the remembering scores showed a significant Test x Condition interaction, $F(2,96) = 6.28$, $p = .003$, ηp2 = .116. Further split-up ANOVAs and *LSD* tests revealed that in the post test participants scored significantly higher in the VR than in the video and the textbook condition (53.1% vs. 40.6% and 43.6, $p = .008$ and $p = .041$, respectively). The corresponding analysis of the understanding scores also revealed a significant interaction $F(2,96) = 3.15$, $p = .047$, ηp2 = .062, however further tests showed no difference between VR and textbook, but scores in the video condition were lower than scores in the VR and textbook conditions (50.2% vs. 60.2% and 62.3%, $p = .071$ and $p = 0.79$, respectively). In summary, participants in the VR group showed better remembering than participants in the textbook group, but there was no difference between the two groups in terms of understanding.

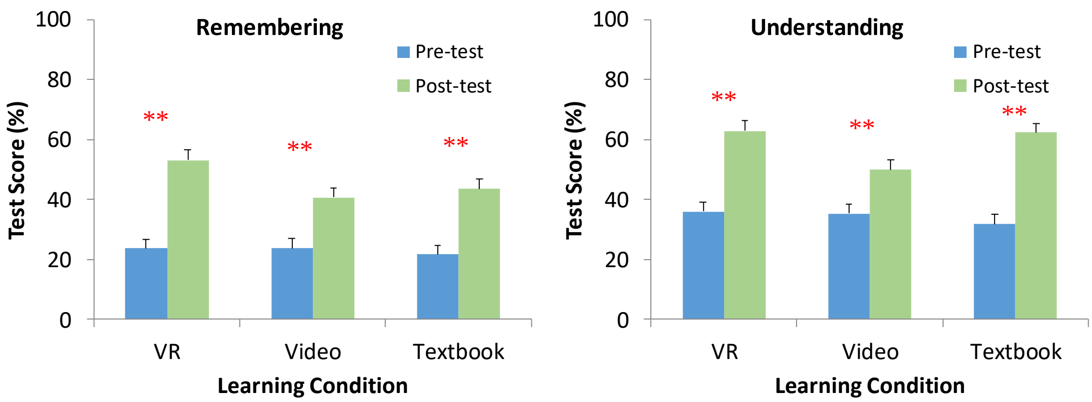


Figure 6.3. Percentage test scores and SEM (error bars) for the remembering questions (left) and for the understanding questions (right).

Emotional Response

DES ratings were split into the two categories; positive emotions (interest, amusement, surprise, and elatedness), and negative emotions (sadness, anger, fear, anxiety and disgust), and average ratings are sown in Figure 6.4. A 3x2 way ANOVAs with the factors Condition and Test on the positive emotions revealed a significant main effect of Condition, $F(2,96) = 13.24$, $p < .001$, ηp2 = .216, and a significant interaction effect, $F(2,96) = 31.40$, $p < .001$, ηp2 = .395. The significant interaction was further analysed with three split-up t-tests, to see whether ratings changed from pre- to post-test. Positive emotion significantly increased from 3.2 to 3.8 in the VR condition, $t(30) = 4.73$, $p < .001$, and significantly decreased in the video condition, $t(33) = 4.92$, $p < .001$, and in the textbook condition, $t(30) = 4.37$, $p < .001$. The corresponding ANOVA on the negative emotions also revealed a significant interaction effect, $F(2,96) = 4.37$, $p = .015$, ηp2 = .084, which was due to a significant decrease in negative emotion (from 1.7 to 1.3) in the VR condition, $t(30) = 4.20$, $p < .001$, and no change in the video or textbook condition (both *p*s > .50).

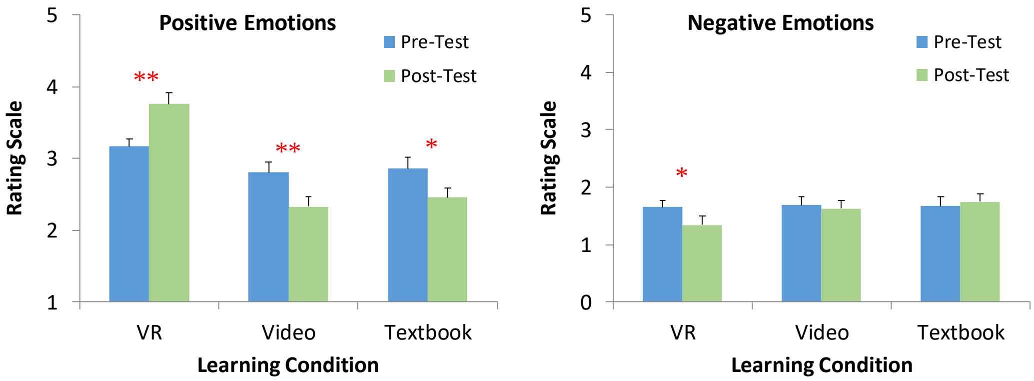


Figure 6.4. Mean rating and SEM (error bars) for positive emotions (left) and for negative emotions (right).

Learning Experience

Average WBLT ratings were grouped into the three categories “learning”, “design”, and “engagement” and calculated separately for each category (see Figure 6.5). Three separate one-way ANOVAs revealed a significant effect of condition for each of the three sub-scales (all $p < .001$). Post-hoc *LSD* tests showed that both learning and engagement ratings were significantly higher in the VR than in the textbook condition ($p = .005$ and $p < .001$, respectively), and they were significantly higher in the textbook than in the video condition ($p < .001$, and $p = .016$, respectively). For design, ratings were significantly higher in the VR and textbook conditions than in the video condition (both $p < .001$), but there was no difference between the VR and the textbook condition.

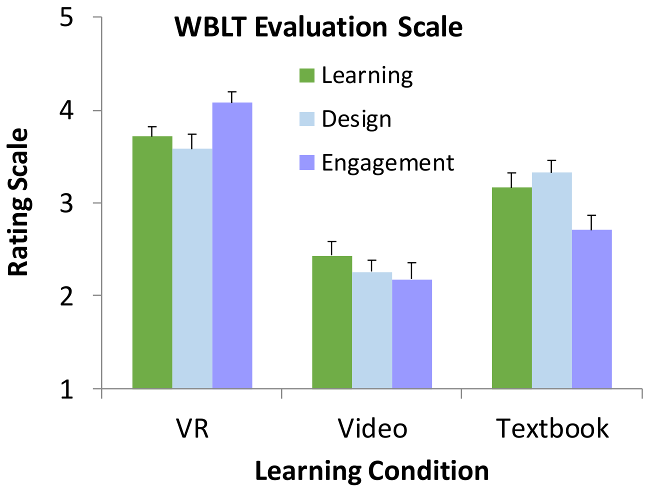


Figure 6.5. Mean WBLT ratings and SEM (error bars) for learning, design and engagement.

Qualitative Feedback

Qualitative data was also gathered; participants were asked as part of their online questionnaire “What did you think of the format of the learning materials/the equipment used?”. The question was optional, and about half of the participants (n = 52) gave some written feedback. Each participant that responded with qualitative feedback was grouped into positive, negative, and mixed feedback, and the overall count for each category and condition are given in Table 6.2. Multiple participants reported that the video learning material was “confusing”, and multiple participants stated that the textbook-style learning materials were “boring” and “bland”. On the other hand, participants found that the VR was “difficult” to use, often clarifying “at first”, but found it more “engaging”, with one participant stating that it “made learning more exciting”.

Table 6.2. Number of participants that responded with qualitative feedback in grouped types: positive, negative, and mixed feedback.

Condition	Positive	Negative	Mixed
Virtual	5	3	5
Video	2	13	2
Textbook	1	15	6

Discussion

The aim of this study was to consider the effects of using VR headsets for learning. Overall, participants in both the VR and the textbook-style conditions showed better learning than participants in the video condition. Further breakdown of the learning data showed that participants in the VR condition were better at 'remembering' than those in the video and traditional conditions, and participants in both VR and traditional conditions were better at 'understanding' than those in the video condition.

That the VR condition showed better test results compared to the video condition suggests that the learning in the VR condition is not due to the graphics or visuals of the equipment, as these were the same in both conditions. Instead, the learning appears to be due to either the 3D immersion or the interactivity of the VR environment. A further study may benefit from comparing VR to other active learning methods. This study compares interactive VR, an active learning method, to passive video watching and traditional textbook-based methods. The distinction between active learning and passive learning plays an important role in many existing educational theories. Bonwell and Eison (1991) define active learning as "a method of learning in which students are actively or experientially involved in the learning process”. They also note that “there are different levels of active learning, depending on student involvement".

There is evidence that active learning is beneficial to students (e.g., Pereira-Santos, Prudêncio and Carvalho, 2017), which could suggest that the benefits found for VR are simply benefits of active learning. However, active learning is not always found to be better than passive learning (e.g., Haidet, Morgan, O’Malley, Moran and Richards, 2004), so the benefits shown in VR may also be due to other factors. Furthermore, Gutiérrez et al. (2007) compared medical education using either a fully immersive VR environment with a head mounted display or a partially immersed (computer screen) virtual environment, reporting that the immersed group showed a significantly higher gain than the partially immersed group. They concluded that there was an enhanced effect of full-immersion using a HMD vs. a screen-based VR system.

The current results show a difference in learning stages as defined by Bloom’s Taxonomy, further research into the other stages would be of interest. This study looked at the lower ends of the learning hierarchy, remembering and understanding. VR may compare differently to traditional methods for applying, analysing, evaluating and creating. In particular, the 3D aspects of VR, along with the interactivity it affords, may be beneficial for ‘creating’ in many subjects. Alternatively, participants’ unfamiliarity with the equipment, which they hadn’t used before, may mean that improvements of the VR condition were diminished, as individuals need time to adapt to new technology systems (e.g., Cook and Woods, 1996). This could explain why VR participants were not significantly better at 'understanding' compared to participants in the traditional condition.

VR was also found to have a very positive impact on mood, with participants having an overall increase in positive emotions and an overall decrease in negative emotions. Conversely the other conditions showed a decrease in positive emotions. Enjoyment has been previously linked as an important part of student performance (e.g., Goetz et al., 2006, Valiente, Swanson and Eisenberg, 2012). This suggests that using VR headsets can have a positive impact on the learning experience.

The WBLT Evaluation Scale also shows that engagement can be increased through the use of VR. The importance of student engagement has been recognised previously (e.g., Kuh, 2009; Strydom, Mentz and Kuh, 2010; Wolf-Wendel, Ward and Kinzie, 2009). Participants also rated the VR environment higher for learning, demonstrating that they felt that they had learnt better from the VR. Student self-rating of learning has been shown to be a valid measure of student performance (Benton, Duchon, and Pallett, 2013), with participants here reporting higher learning in the VR condition, which was found for 'remembering'.

The positive effects on emotion and engagement in VR are important benefits for both within and outside classroom learning (e.g., distance learning, self-teaching). These aspects of learning are sometimes overlooked, with the focus being on other outcomes such as test scores. However, it has been demonstrated that individuals' emotions, engagement and motivation are highly linked with each other and they are all important aspects of learning (Pintrich, 2003).

This research has demonstrated how VR can replicate or complement traditional learning methods. It is important to consider how VR technology allows for learning beyond the classroom. The technology, though suitable for classroom use, is also particularly suitable for distance learning, self-teaching, and other learning environments. This can be achieved as the equipment can allow for rich, detailed learning environments that can be programmed to any scenario. Such VR environments can allow for learning that could not be replicated in reality (e.g., dangerous environments or experiments), or would be too costly to be accessible (e.g., expensive equipment or materials).

Future studies, for example, may want to consider the possible advantages of the auditory options available with equipment such as VR, which were not utilised for this project as they may be a confound. As discussed, this could be of interest in relation to learning styles, which are prevalent in a number of learning theories, though the concept of learning styles has received some criticism (e.g., Pashler, McDaniel, Rohrer and Bjork, 2008). Regardless of learning styles, there may be some benefit to including audio to increase immersion and engagement (e.g., Paterson and Conway, 2014; Wharton and Collins, 2011).

Many VR headsets also share the benefits of mobile learning, most obviously the VR headsets which run through mobile phones. Though not as powerful and capable of detailed environments as PC-based VR headsets like the HTC Vive and Oculus Rift, these mobile headsets share many of the same benefits. Though the headset used in the study, the HTC Vive, is currently only mobile with the use of a portable backpack PC, there is a new mobile, portable version of the HTC Vive headset called the Vive Focus. The Vive Focus is currently available for developers, and is expected to be released later this year, which means that applications such as the one used in this study will be fully mobile, allowing for more flexible learning.

Overall, VR does seem to be a potential alternative to traditional textbook-style learning, with similar performance levels, and improved mood and engagement. These benefits may have a longer-term impact on learning, such as improvements due to the learning experience. However, the results may be partially due to the novelty of the VR equipment, so the improvements may not be sustained over longitudinal studies. On the other hand, these improvements could increase over time, as individuals become more familiar with the equipment and abler to navigate it easily. Therefore, further longitudinal studies are needed to address these questions. VR does show great potential, not only as an option to supplement or replace traditional learning methods, but to develop novel learning experiences which have not been used before.

Chapter 7: Education in the Digital Age: Learning Experience in Virtual and Mixed Realities

Abstract

In recent years Virtual Reality has been revitalized, having gained and lost popularity between the 1960s and 1990s, and is now widely used for entertainment purposes. However, Virtual Reality, along with Mixed Reality and Augmented Reality, has broader application possibilities, thanks to significant advances in technology and accessibility. In the current study, we examined the effectiveness of these new technologies for use in education. We found that learning in both virtual and mixed environments resulted in similar levels of performance to traditional learning. However, participants reported higher levels of engagement in both Virtual Reality and Mixed Reality conditions compared to the traditional learning condition, and higher levels of positive emotions in the Virtual Reality condition. No simulator sickness was found from using either headset, and both headsets scored similarly for system usability and user acceptance of the technology. Virtual Reality, however, did produce a higher sense of presence than Mixed Reality. Overall, the findings suggest that some benefits can be gained from using Virtual and Mixed Realities for education.

Introduction

Although virtual environments have arguably existed since the 1920s (Rolfe & Staples, 1986), with early head-mounted displays developed in the 1960s (Comeau & Bryan, 1961; Goertz, Mingesz, Potts & Lindberg, 1965), virtual reality (VR) technology has only just become commonly accessible, driven primarily by the entertainment industry. VR is a computer-generated 3D environment, typically viewed in a headset, which replaces the real world. Sales figures for two of the most popular VR headsets (Oculus Rift and HTC Vive) are estimated to be in the millions. However, other approaches have been introduced in which 'virtual objects' are overlaid onto the real world; Augmented Reality (AR) and Mixed Reality (MR) systems. The difference between MR and AR is not clearly defined, but commonly MR allows real and virtual objects to interact whereas AR doesn't. MR combines the real and virtual worlds, with physical and digital objects co-existing and interacting in real-time. Extended Realities (XR, a term which encapsulates VR, AR and MR) are often treated as the same, but they offer very different experiences and possibilities; therefore, their advantages and disadvantages need to be matched to any given application.

Education is often slow to adopt technological improvements (e.g., Cuban, 1986; Selwyn, 2017). However, learning with electronic media (e-learning) has been shown to be effective in numerous studies (e.g., Rosenberg, 2001; Zhang, Zhao, Zhou & Nunamaker, 2004). In a meta-analysis including 1105 papers, Schmid et al. (2014) found a small but reliable advantage for non-Internet computer-assisted instruction compared with classroom instruction. In a recent study, Allcoat and von Mühlenen (2018) compared learning in a VR condition with traditional and video conditions. They found not only improved learning for VR, but VR participants also reported higher engagement and more positive emotions than those in the other conditions. Being in a positive mood can also have reciprocal effects on learning, for example by enabling increased cognitive flexibility (Nadler, Rabi, & Minda, 2010), or simply by creating a positive academic climate (Seligman, Ernst, Gillham, Reivich, & Linkins, 2009). Indeed, Olmos-Raya et al. (2018) found a significant effect of both positive emotion and high immersion on knowledge acquisition.

According to the constructivist learning theory (e.g., Duffy, 2013; Fosnot, 1996) learning is an active process, whereby learners construct knowledge for themselves (as opposed to passively receiving information). This theory builds on ideas and suggestions from Piaget's theory of cognitive development (e.g., Piaget, 1937; 1950), Dewey's functional psychology (Dewey, 1938) and Vygotsky's social development theory (Vygotsky, 1980), which have been expanded and researched within cognitive psychology.

E-learning often promotes active learning through interactive technology tools, which constructivism would claim as beneficial. Kay (2011) developed an evaluation scale for Web-Based Learning Tools (WBLT) which focuses on three key constructs: learning, design, and engagement. Kay found an improvement in pre- versus post-test scores on remembering, understanding, application, and analysis when using WBLT compared to standard methods of teaching. These categories were derived from the revised Bloom's Taxonomy (Bloom, 1956; see also Anderson et al., 2001). This is a model used to classify educational learning objectives based on cognitive principles and suggests that there is not simply one way in which information is processed and learnt, instead proposing a hierarchy of learning. This hierarchy consists of six stages of cognitive processing from simplest to most complex: remember, understand, apply, analyse, evaluate, and create.

Technologies can complement classroom teaching rather than replace it, with technologies like VR being particularly applicable for teaching practical tasks, and virtual laboratories can offer advantages over traditional methods, such as providing greater flexibility for conducting experiments (Valdez, Ferreira, Martins & Barbosa, 2015; for reviews see Albidewi & Tulb, 2014; Hilgarth, 2010; Welsh, Wanberg, Brown & Simmering, 2003). Similarly, Pan, Cheok, Yang, Zhu, and Shi (2006) noted that the use of XR can help enhance, motivate and stimulate learners' understanding, as well as improve their overall mood. Simulations can be used to mimic real experiments which are important in Higher-level education for many subjects (e.g., Davies, 2008), and understanding has been shown to be equivalent for both physical and virtual experiments (Zacharia & Olympiou, 2011). Experiments and practicals are often important interactive learning tools, and XRs can be beneficial when physical experiments are not practical. Indeed, interactivity and feedback enhance learning by promoting active rather than passive learning. Active learners are more engaged, motivated, and show better learning than passive learners (Benware & Deci, 1984), leading to better student outcomes (Chi, & Wylie, 2014; Cui, 2013).

Markant and Gureckis (2014) noted that according to one explanation active learning improves performance by enhancing cognitive processes related to motivation, attention, and engagement (see also Chi & Wylie, 2014). However, they theorised that the difference between active learning and passive learning comes from a hypothesis-dependent sampling bias which happens when an individual collects data to test their own hypotheses. This explanation is in line with constructivism, which also focuses on the importance of the interaction between experiences and ideas. Thus, VR and MR, which enable active learning (see Chapter 6 for further discussion on active learning), might be more effective compared with some traditional learning methods because they allow one to experience and test such learner-generated hypotheses, compared with traditional passive learning methods (e.g., lectures, textbooks).

Freeman et al. (2014) conduced a meta-analysis of 225 studies which compared student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning conditions. They found that students in classes with traditional lecturing performed worse in the examination and were 1.5 times more likely to fail than students in classes with active learning methods. Similarly, another meta-analysis also found a benefit of using computer simulations for STEM learning (D'Angelo, Rutstein, Harris, Bernard, Borokhovski & Haertel, 2014).

Active learning via the use of XR provides a variety of benefits. However, the costs and benefits of different XRs (VR vs. MR) might differ, as might user acceptance, engagement and experience. For example, VR presents a closed world, so participants might feel more concealed and private, and more comfortable with the simulated reality, which could, in turn, lead to higher user acceptance. Conversely, participants might feel more vulnerable due to being unaware of their real-life surroundings. Similarly, there are two alternatives for MR; participants might feel more comfortable because they can see their surroundings and what is going on around them, or less comfortable because of their awareness of people who can see them using the technology. This user experience will be in part linked to the level of immersion and presence generated by the equipment (see Cheng & D'Angelo, 2018). User-experience and user comfort are important considerations in this study, as even if a technology has a variety of benefits, if individuals are unwilling to use it due to discomfort, it will not be useful. As such, simulator sickness (i.e., motion sickness caused by simulated environments) is also an important factor that needs to be considered.

Although previous work has shown the benefits of VR-based learning over traditional methods, very little previous work has considered the benefits and costs of learning in MR environments. Accordingly, in the present work, we directly compared learning, user experience, engagement and acceptability in a learning context. Overall, based on constructivist principles, we would expect VR and MR to produce better learning outcomes than traditional methods. Furthermore, we would expect VR and MR to result in improved user experience (e.g., in terms of emotion, engagement, and usability) compared with traditional methods (Allcoat & von Mühlenen, 2018). Finally, we would expect that because

VR is fully immersive, it would lead to a higher sense of presence, but it might also lead to more simulator sickness, compared to MR.

Method

Participants

Seventy-five participants (34 female, age range 18-56, mean age 25 years) were recruited from the University of Warwick participant pool. Of these, 25 were undergraduate students, 12 postgraduate students, 23 PhD students, and 15 staff members. Fourteen participants had a background in Engineering, 18 in Science, 16 in Economics/Business, and 27 in other subject areas. All reported normal or corrected-to-normal vision and received £5 Amazon vouchers for their participation. Each gave informed written consent and the study was approved by the University of Warwick Humanities & Social Sciences Research Ethics Committee. Participants were randomly assigned to one of three conditions: traditional, VR, and MR and did not differ in terms of self-reported computer skills, gaming experience, or VR/MR headset experience (see Table 7.1)[6].

[6] Computer skills consisted of two combined questions, where participants were asked to rate on six-point scales their confidence about using computers (from "not at all confident" to "completely confident") and their computer skill level (from "no skills" to "professional skills"). Gaming experience consisted of two combined questions, where participants had to indicate how many hours a week, they were playing video games on average (from "0-1 hours" to "12+ hours") and to what extent they would consider themselves a "gamer" (from "not at all" to "highly"). Headset experience consisted of one question where they were asked if they ever used a virtual or mixed reality headset before (from "never" to "regularly").

Table 7.1. Demographics and Technology Experience (0-5 scale) of each Condition with Results of Comparisons (1-way ANOVA) Between Conditions.[7]

Measure	Traditional	VR	MR	*p*-value
Characteristics				
n (M/F)[3]	25 (10/15)	25 (11/14)	25 (13/12)	-
Age (years)	23.8 (5.2)	27.5 (9.9)	23.7 (4.8)	.101
Prior experience				
Computer	3.0 (1.2)	3.5 (0.7)	3.5 (0.8)	.120
Gaming	0.9 (1.0)	0.9 (1.2)	0.9 (1.3)	.979
VR Headset	0.7 (0.9)	1.0 (0.8)	0.8 (0.9)	.388

Apparatus

The questionnaires and learning material in the traditional condition were presented on a 19” LCD computer screen (1920 x 1080 pixels, 60 Hz) via Microsoft PowerPoint and Qualtrics. Responses were collected through mouse and keyboard. The VR condition used an HTC Vive, which displays a 3D environment via two OLED displays (1080 x 1200 pixels per eye 90 Hz) with a field of view of 100 x 110 degrees. The MR condition used a Microsoft HoloLens, which projects 3D objects on a pair of translucent screens (1268 x 720 pixels per eye, 60 Hz) with a projection field of 30 × 17 degrees (i.e., the 3D objects are seen overlaying the real world). The headsets were of similar weight (Vive 550g, HoloLens 557g) and navigation occurred using the standard handheld controllers. In the XR conditions, participants were tested individually due to the space requirements of the headsets. In the traditional condition, groups of up to eight

[7] All values except for *n* (M/F) are given as means (with standard deviations).

participants were tested in a computer-equipped teaching lab, providing a traditional learning environment.

Learning Material

The learning material was based on a real classroom example covering solar panels for Engineering students. The VR and MR simulations took the material from an existing course that would usually be taught via PowerPoint slides and developed it to be presented in an immersive 3D environment. This topic focused on students' understanding of how different parameters can influence solar-power panel efficiency, such as light intensity, panel mismatching and tilt angle. The existing method of delivering these lectures is to use slides showing graphs describing the relationship between solar-power efficiency and other system parameters.

The simulations for VR and MR were created and programmed in Unity, with some models made with the Blender software package. Both the VR (Figure 7.1a) and MR (Figure 7.1b) conditions allowed participants to interact with the application to experiment with how different characteristics (e.g., type of solar panel, light intensity, shading) impact power output. A video showing the VR and MR environments can be found at https://youtu.be/Jg3gsjVYrKM.

Participants were instructed to interact with the learning environment to find out how solar panels work, so they could answer questions in a subsequent test. They were told verbally how to use the equipment and how to navigate the learning environment. Buttons and sliders manipulated variables, and participants could select information boxes to obtain further details. Both the HTC Vive and Microsoft HoloLens have full head-tracking, so participants were able to look around at the 3D environment/objects at will.

(a)

(b)

Figure 7.1. (a) Screenshots of the VR learning environment, and (b) the MR learning environment.

The Traditional learning condition was implemented in the form of lecture slides adapted from the course, which participants could navigate through, as in a distance learning environment. The researchers worked closely with the course lecturer to ensure each condition was equivalent in terms of its content, material, and amount of information presented. Both the VR and MR conditions presented the same models and written information.

Table 7.2. Characteristics of the Sample with internal reliability estimates based on Cronbach's α.

Measure/Scale/Questions	Scale	NQ[8]	Conditions	α
Phase 1 (10 min)				
Technology experience questions	0-5	6	All	-
Knowledge test I	-	8	All	-
Differential Emotions Scale (DES) I	1-5	10	All	-[9]
Simulator Sickness Questionnaire I	0-3	16	All	.84
Phase 2 (10 min)				
Learning materials (study period)	-	-	All	
Phase 3 (10-15 min)				
Knowledge test II	-	8	All	-
Differential Emotions Scale (DES) II	1-5	10	All	-
Simulator Sickness Questionnaire II	0-3	16	All	.82
Web-Based Learning Tools (WBLT) Evaluation Scale	1-5	13	All	.95
Perceived Quality Scale	1-5	18	VR/MR	.96
System Usability Scale	1-5	10	VR/MR	.90
Unified Theory of Acceptance and Usage of Technology (UTAUT) Questionnaire	1-7	23	VR/MR	.90
Igroup Presence Questionnaire	1-7	14	VR/MR	.83

[8] NQ: number of questions
[9] for a DES reliability measure see Boyle (1984).

Procedure and Design

There were three phases: pre-test, learning, and post-test (see Table 7.2). Participants had approximately 10 minutes for phase 1, at the end of which they put the headset on or were given the lecture slides for the traditional condition. They were given 10 minutes with the learning materials (as determined by piloting[10]) before they filled in the questionnaires of the post-test. Some questionnaires were only presented once, whereas others were given before and after learning, leading to a mixed design with the between-subject factor Condition (traditional, VR, and MR) and the within-subject factor Test (pre and post).

Knowledge Test

Participant's knowledge of the learning material was assessed using eight questions constructed by the lecturer, based on those used in a real classroom course (see Appendix 10). Participants completed the test twice, once before and once after the learning phase. The questions were a mix of formats and tested different types of knowledge in accordance with Bloom’s Taxonomy (Bloom, 1956): four multiple-choice questions tested ‘remembering’ aspects, three short-answer questions and one calculation question focused on the ‘understanding’ and ‘applying’ aspects (see also Anderson et al., 2001). All questions were marked as correct or incorrect using a marking scheme provided by the lecturer.

[10] Piloting was undertaken for all three conditions. Pilot tests were completed with students from the engineering course that the learning material was sourced from. Feedback was given to check the learning materials, length of testing time, and navigation of the VR and MR environments.

User Experience

The Differential Emotions Scale (DES, Izard, Dougherty, Bloxom, & Kotsch, 1974) was used to measure participants' emotions before and after engaging with the learning materials (Appendix 8). The scale included ten emotion categories (interest, amusement, sadness, anger, fear, anxiety, disgust, contempt, surprise, and elatedness), each represented with 3 words (e.g., surprised, amazed, astonished). Participants indicated on a five-point scale (from "not at all" to "very strongly") the extent to which these adjectives corresponded to their current emotional state.

Participants completed Kennedy, Lane, Berbaum, and Lilienthal's (1993) Simulator Sickness Questionnaire, which assesses to what extent individuals experience physical discomfort (Appendix 11). This questionnaire has participants rate whether any of 16 symptoms (e.g., nausea, headache) are affecting them on a four-point scale (from "none" to "severe").

Student engagement was measured via the WBLT Evaluation Scale (Kay, 2011), developed specifically for evaluating the efficacy of web-based learning tools for education (Appendix 9). It consists of 13 questions split into three sections which ask participants to rate on a five-point scale (from "strongly disagree" to "strongly agree") how well they could learn from the learning tools (learning), how well designed the tools were (design), and how engaging they found them (engagement).

Technology Evaluation

The quality of the learning materials was assessed via the Perceived Quality Scale (Pribeanu, Balog, & Iordache, 2017) specifically developed for the evaluation of AR-based learning applications (Appendix 12). It consists of 18 questions which measure participants' perceptions of the quality of the learning materials on a five-point scale (from "strongly disagree" to "strongly agree"). Quality was further split into three different sub-scales: ergonomic quality (perceived learnability and ease-of-use), learning quality (perceived efficiency and usefulness), and hedonic quality (cognitive absorption and perceived enjoyment). Minor changes to the wording of the questions were made to fit the context of the scenario.

The System Usability Scale (Brooke, 1996) consists of ten questions which measure the usability of the learning environment on a five-point scale (from "strongly disagree" to "strongly agree"). Example questions include: "I found the system unnecessarily complex", and "I felt very confident using the system" (Appendix 13).

The Unified Theory of Acceptance and Usage of Technology Questionnaire (Venkatesh, Morris, Davis & Davis, 2003; Akbar, 2013) was used to measure user acceptance and comfort with being in a 3D simulated environment (Appendix 14). 23 of the 31 questions relevant to the scenario of the current study were used (e.g., "Using the system will enable me to accomplish tasks more quickly"). Ratings were provided on a seven-point scale (from "fully disagree" to "fully agree").

Finally, sense of presence is an aspect of immersion which can impact learners in 3D virtual worlds (Mount, Chambers, Weaver & Priestnall, 2009, see also McMahan, 2003) was measured with the Igroup Presence Questionnaire (Schubert, Friedmann & Regenbrecht, 2001). This scale has 14 questions (e.g., "I felt present in the virtual space") rated on a seven-point scale, from "fully disagree" to "fully agree" (Appendix 15).

Results

Knowledge Test

Questions in the knowledge test were marked as correct or incorrect to give a total score of 0 to 8. Learning was represented by the difference between the knowledge pre-test and post-test scores (see Table 7.3). The data from five participants who scored very high in the pre-test (2 *SD* above the mean, i.e., ≥75%) were subsequently removed as outliers from the learning data (Tukey, 1977).

Table 7.3. Knowledge Test Means (with standard deviations) with Results of Comparisons (1-way ANOVA) Between Conditions.

Measure	Traditional	VR	MR	*p*-value
N	25	25	20	-
Pre-test	1.80 (1.3)	1.96 (1.4)	2.25 (1.5)	.451
Post-test	4.48 (1.1)	5.30 (1.8)	4.45 (1.7)	.257
Difference	2.68 (1.2)	3.24 (2.1)	2.20 (1.8)	.127

A mixed-design ANOVA with the between-subject factor of Condition (traditional, virtual, mixed) and the within-subject factor of Test (pre, post) revealed a significant main effect of Test, $F(1,67) = 177.72$, $p = .001$, $\eta_p^2 = .726$; participants' knowledge improved on average by 2.5 points from pre- to post-test. There was a trend for more learning in the VR condition and less learning in the MR condition, however, this difference did not reach significance, 2-way interaction, $F(2,67) = 2.13$, $p = .13$, $\eta_p^2 = .060$. Further analysis of the knowledge data showed that the amount of learning did not depend on prior computer skills (correlation with learning across conditions: $r = -.08$, $p = 51$) or gaming skills ($r = .22$, $p = .07$), nor did it depend on the amount of previous headset experience ($r = .14$, $p = 25$).

Table 7.4. The mean DES ratings for each positive and negative emotion category

	Pre-test			Post-test		
Emotion	Trad.	VR	MR	Trad.	VR	MR
Interest	3.32	3.80	4.04	3.40	3.88	4.04
Amusement	2.88	3.04	3.44	2.92	3.24	3.80
Surprise	1.64	2.12	2.24	1.84	3.08	3.00
Elatedness	2.76	2.52	3.32	2.52	2.88	3.00
Sadness	1.88	2.24	1.44	1.60	1.68	1.16
Anger	1.88	1.60	1.20	1.52	1.60	1.20
Fear	1.56	1.56	1.16	1.40	1.56	1.12
Anxiety	2.32	2.08	1.60	1.84	1.88	1.28
Disgust	1.44	1.28	1.12	1.24	1.44	1.20
Contempt	1.56	1.40	1.12	1.32	1.40	1.16

Emotional and Physical Experience

The ten pre- and post-test DES questions (see Table 7.4) were analysed separately for positive emotions (interest, amusement, surprise, and elatedness) and negative emotions (sadness, anger, fear, anxiety, disgust and contempt). A mixed-design ANOVA for the positive emotions with the between-subject factor Condition (traditional, VR, and MR) and the within-subject factors Test (pre and post) and Emotion (interest, amusement, surprise, and elatedness) revealed a significant three-way interaction, $F(6, 216) = 2.42$, $p = .028$, $\eta_p^2 = .063$. This interaction was further explored with four separate ANOVAs, one for each emotion category (p values of these follow-ups were adjusted using the Holm–

Bonferroni method). Marginally significant two-way interactions were found for elatedness, $F(2, 72) = 4.46$, $p = .06$, $\eta_p^2 = .110$, and for surprise, $F(2, 72) = 3.70$, $p = .09$, $\eta_p^2 = .93$. Participants experienced an increase in elatedness in the VR condition, but a decrease in the MR and the traditional conditions (0.36, -0.32, and -0.24, respectively), and they experienced an increase in surprise (from pre- to post-test) in the VR and MR conditions, but not in the traditional condition (0.96, 0.76, and 0.20, respectively). The equivalent ANOVA with negative emotions showed no significant 3-way interaction, but there was a significant main effect of Test, $F(1, 72) = 11.17$, $p = .001$, $\eta_p^2 = .134$, due to a reduction in negative emotion between the pre- and post-test (1.6 vs 1.4, respectively). There was also a significant main effect of Condition, $F(2, 72) = 3.16$, p = .48, $\eta_p^2 = .081$, due to overall less negative emotion in the MR than in the VR and traditional condition (1.22 vs. 1.62 and 1.66, respectively).

Pre- and post-test scores for simulator sickness were low (overall average: 1.24), and their internal reliability estimates based on Cronbach's α (see Table 2) were acceptable for measures used in the social sciences (Kline, 2013). A 3 x 2 mixed ANOVA with the factors Condition (traditional, VR, and MR) and Test (pre and post) revealed no significant effects. Hence, simulator sickness did not depend on Condition (1.30, 1.20, and 1.21, respectively), and it did not increase from before to after learning (1.23 vs. 1.24, respectively).

Learning Experience

The internal reliability estimates for the WBLT Evaluation Scale with the three constructs (learning, design, and engagement) were acceptable (Cronbach's α: 0.87, 0.87 and 0.93, respectively), and similar to the ones reported by Kay (2011). Figure 7.2 presents the results for the WBLT evaluation scale with the three constructs (learning, design, and engagement), separately for the three learning conditions. Three separate one-way ANOVA's, one for each construct, revealed a significant main effect of Condition for engagement, $F(2, 74) = 4.74$, $p = .012$, $\eta_p^2 = .116$. Post-hoc *LSD* tests showed that the VR and MR groups reported being significantly more engaged than the traditional group (4.0, 4.1 vs. 3.4, respectively). Similar patterns were found for the design and learning constructs, however, they did not reach significance.

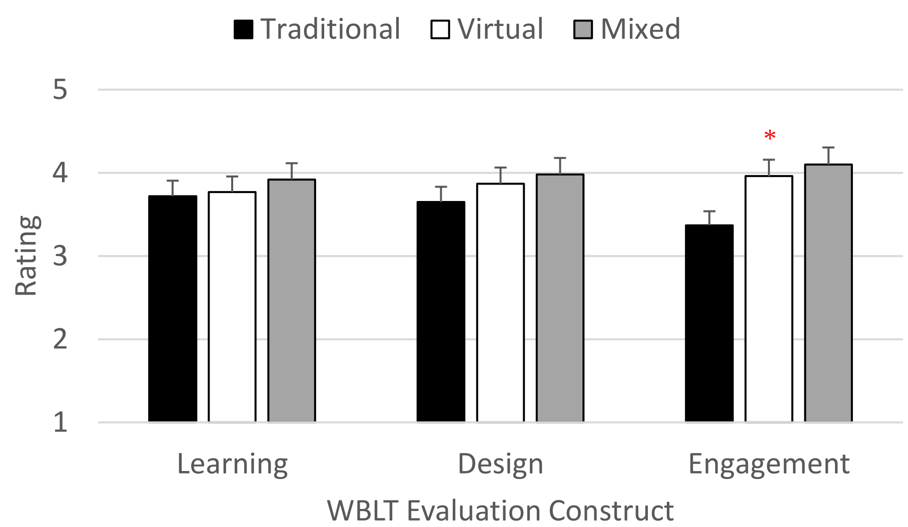


Figure 7.2. Mean rating and SEM (error bars) for the three WBLT evaluation scale constructs, separately for the three learning conditions.

Technology Evaluation

Technology evaluation questionnaires were only given to participants in the two XR conditions. The Cronbach's α for the perceived quality scale and its subscales were acceptable (all > 0.91). Table 7.5 reports the average scores for the three perceived quality dimensions for the VR and the MR applications. There were no significant differences between the two XR conditions. Both systems were generally rated positively on the system usability scale (3.72 in VR and 3.64 in MR, Cronbach's α 0.90), and on the six UTAUT sub-scales (see Table 5). In the Igroup Presence questionnaire, VR participants reported a significantly higher sense of presence than MR participants (4.34 vs. 3.78, respectively), $t(48) = 2.24$, $p = .030$, $d = 0.63$. The internal reliability for the UTAUT and the Igroup Presence questionnaire was acceptable (Cronbach's α 0.90 and 0.83, respectively).

Table 7.5. Technology Evaluation Questionnaire Means (with Standard Deviations) with Results of Comparisons (t-test) Between VR and MR Conditions.

Measure	VR	MR	*t*(48)	p-value
Perceived Quality Scale (5 point)				
Ergonomic	3.85 (0.73)	4.03 (0.86)	0.80	.43
Learning	3.51 (0.79)	3.90 (0.93)	1.58	.12
Hedonic	3.88 (0.80)	2.93 (1.00)	0.18	.86
System Usability Scale (5 point)	3.72 (0.78)	3.64 (0.85)	0.35	.73
UTAUT Questionnaire (7 point)				
Performance	4.60 (1.51)	4.81 (1.40)	0.51	.61
Effort	5.20 (1.45)	5.40 (1.57)	0.47	.64
Attitude to technology	5.41 (1.35)	5.40 (1.57)	0.54	.59
Anxiety	3.19 (1.36)	5.63 (1.52)	0.78	.44
Self-Efficacy	5.08 (1.22)	5.00 (1.67)	0.19	.85
Behavioural Intention	4.35 (2.02)	5.04 (1.79)	1.28	.21
Igroup Presence Questionnaire (7 point)	4.34 (0.88)	3.78 (0.89)	2.24	.03

Discussion

The main aim of the current study was to determine if VR or MR are suitable alternatives to traditional learning methods and if they have any costs or benefits. Significant learning occurred in all three conditions, however, there was no reliable evidence to suggest that VR and MR provide increased learning over traditional methods. As those in the VR and MR conditions performed as well as those in the traditional condition, this does indicate that VR and MR are viable alternatives to traditional learning. This could be beneficial in distance learning situations where traditional learning is not possible.

Although the VR and MR participants did not perform better than those in the traditional condition for learning, there was also no evidence of impairment. Participants had little opportunity to familiarize themselves with the equipment, as they were only given verbal instructions on how to use them. In the same length of time that the traditional group had with standard learning materials, the VR and MR groups were able to learn to use new equipment, acclimatize to a simulated 3D environment, and learn as much from the material. As such, learning could potentially be improved with MR and VR than traditional learning if individuals are familiar with the equipment. Alternatively, VR and MR may be well suited as supplementary learning methods, as our results are in line with those from a meta-analysis which found that e-learning-only situations produced an equal amount of learning compared with classroom-only situations, but blended learning (a combination of both) produced better results than classroom-only instruction (Means, Toyama, Murphy & Bakia, 2013). Moreover, it has been claimed that during lectures attention tends to wane after approximately 10–15 minutes (Davies, 2009; McKeachie & Svinicki, 2013). In these situations, VR methodologies might be particularly effective in generating increased engagement and improved learning outcomes. Currently, VR technologies are also used to supplement – and not to replace learning technologies, with short VR lessons (3-7 min) that are integrated into the classic lesson flow, in order to make the subject more visual and comprehensive (e.g., MEL Chemistry, see Fahrenkamp-Uppenbrink, 2015).

Our findings also suggest that there can be an emotional benefit of learning in VR, as seen by the DES results with VR scoring higher for surprise and elatedness compared with traditional learning. This supports similar previous findings of improved mood as a result of learning in VR (Allcoat & von Mühlenen, 2018). As student satisfaction is considered to be an important concept (e.g., Elliott & Shin, 2002), this could be considered a considerable benefit of using this type of equipment. Indeed, past research suggests that student satisfaction should be an important outcome for teaching institutions and educators, (e.g., Appleton-Knapp & Krentler, 2006; Thomas & Galambos, 2004), both for the learning benefits and for the idea of students as "consumers".

VR and MR both performed significantly better than traditional learning on the measure of engagement. Student engagement has also been proposed to be an important factor in student outcomes (Pascarella & Terenzini, 2005; Trowler, 2010), enhanced learning effectiveness (Zhang, Zhou, Briggs & Nunamaker, 2005), and student success outcomes, such as academic achievements and student satisfaction (Kuh, 2001, 2005; OECD, 2010). Therefore, the observed increased participant engagement in the VR and MR conditions are also benefits of using the equipment in learning contexts.

One potential problem with the use of XR headsets is simulator sickness. Individuals prone to motion sickness or nausea may be wary of using such devices. Our results indicate that neither VR nor MR caused simulator sickness in this context, suggesting that they would be safe to use in-classroom and distance learning. This is likely in part due to the application being well-designed to avoid motion sickness but may also be due to the short sessions with the equipment. Hence, VR and MR may be best suited to shorter, supplementary learning sessions as part of a larger presentation, or for specific activities, as well as distance learning, which can be done at the learner's own pace.

The results from the Unified Theory of Acceptance and Usage of Technology Questionnaire, from the System Usability Scale, and from the Perceived Quality Scale showed no difference between VR and MR, suggesting that the two systems are equally suitable for this learning context. However, the participants in the VR environment had a higher increase for positive emotions, suggesting that participants enjoyed using the VR more than the MR. VR also produced higher reports of presence than MR, suggesting that being in an enclosed virtual environment leads to higher levels of immersion. These results suggest that VR has a few benefits over and above MR for this type of practical learning.

Future research should consider longer durations, as well as longitudinal impacts of the use of this technology, as in this study the headsets were only used for a short period of time. One hypothesis would be that over time the novelty effect of using the equipment would wear off, and the benefits would decrease. On the other hand, the benefits might increase over time as individuals become more familiar with technology and how to use it. As individuals become more proficient with the equipment, they may find the novelty less distracting and be more able to focus on the learning. Therefore, research considering the long-term effects of the technology is an important future focus. VR and MR may produce better retention than traditional learning methods, as it has been found that constructivist learning increases knowledge retention (Narli, 2011), however, this is a question that needs to be considered in future research.

Conclusions

The overall results do suggest that VR and MR are both suitable and safe technologies for learning, potentially enabling new approaches to teaching. Applications for these technologies can also be adapted to suit pre-existing courses, both classroom-based and distance learning. Even when considering possible restrictions of the technology, such as how long it can be used for comfortably, the benefits, such as increased engagement and positive emotions, suggest that VR and MR would be good as supplements to traditional learning methods.

XRs have a myriad of possible uses, as many environments and interactions can be accurately simulated within virtual environments, enabling access to learning materials that may not otherwise be available to learners (Bailenson, 2018). For example, dangerous environments or chemicals can be re-created virtually, or expensive equipment that would be too costly for institutions to purchase. In these cases, XRs can provide learning methods not otherwise available, allowing a more hands-on approach to teaching and learning.

Chapter 8: Overall Discussion

The purpose of this chapter is to summarise the findings of the research conducted. An overview of the results will be presented, including possible limitations of the research. This will be followed by an integrated discussion considering all experiments combined, as well as a section looking at the implications of these results and suggestions for directions for future studies.

Aim of the Thesis

The aim of this thesis was to examine the effects and learning applications of video games and virtual reality.

The research questions that this thesis investigated are as follows:

1) What factors might affect the link between video game playing and cognition?
2) Do we need a more extensive measure of video game experience?
3) How does video game playing affect memory?
4) How does learning in virtual reality differ from traditional learning?
5) Are virtual environments suitable for use in education?

Summary of Results

Chapter 2 – Visual Attention in Video Game Play

This chapter focused on how video game playing might affect visual attention. As previous research has found evidence for video game players performing better on visual attention tasks than non-video game players (e.g., Green & Bavelier, 2003; Dye, Green & Bavelier, 2009; Hubert-Wallander, Green & Bavelier, 2010, Kozhevnikov et al., 2018), but other research has found opposing results (e.g., Boot, Kramer, Simons, Fabiani & Gratton, 2008, Collins & Freeman, 2014; Murphy & Spencer, 2009; Roque & Boot, 2018) the purpose of this study was to investigate this discrepancy. Multiple attentional processes were measured including alerting, orienting, expecting, searching/filtering and executive control, by using three different attention tasks: The Attention Network Task (ANT), the preview search task, and the enumeration task.

For the ANT task those playing never/rarely had a stronger alerting effect than those playing occasionally or frequently. No difference was found between VGP frequency groups for orienting. However, when participants were grouped into action and non-action players, action video game players showed a higher orienting effect than non-action players. Contrary to the findings of Dye, Green and Bavelier (2009), no significant interaction was found between video game playing and executive control.

There was no difference for preview benefit in the preview search task between groups. However, a marginally significant trend ($p = .095$) suggests that frequent players might be more efficient in searching displays than occasional and rare players. A larger sample size may have shown this effect to be more reliable. In the enumeration task there was also no difference found between the groups, for either deflection points or mean percentage errors. It is possible that this is due to the relative low error range (1-13%) in this particular task, providing insufficient room for the group variable to manifest its effects.

These visual attention processes could be looked at in more detail, such as exogenous and endogenous orienting (e.g., Rohenkohl, Coull & Nobre, 2011), or spatial visual short-term memory and object visual short-term memory (e.g., Woodman & Luck, 2004). As such, further research into these when comparing across video game playing experience, may give further insights into the impact it has on visual attention.

In conclusion, to summarize the findings, VGP affected alerting in the ANT task, but not orienting or congruency. However, an orienting effect was found when comparing action and non-action players, demonstrating the importance of video game genre, as well as frequency of play. For the preview search those who played video games rarely/never had slower reaction times, but showed no difference in preview benefit or slope from other VGP groups. For enumeration, there were no VGP group differences.

Chapter 3 – Measuring Gaming Experience

This chapter looked more in-depth at the ways that video game experience is measured. A new questionnaire, the Video Game Experience Questionnaire, was developed in order to more accurately gain an understanding of participants' video game playing history, including extent of playing, genres played, and platforms used. This questionnaire was run on a total 535 participants, with 335 fully complete responses. 50% of respondents classified themselves as a "mid-core gamer", with 24% classifying themselves as a "casual gamer", and 21% as a "hardcore gamer".

An interesting finding of the questionnaire was the differences between gameplay length for mobile games compared to home games. Mobile games were typically being played for much shorter periods of time per session than home games, leading to a much shorter total number of hours played per week compared to home gaming. A multiple regression revealed that the home VGP questions (i.e., session length, playing frequency, weekly hours, and total lifetime games) were much better predictors of the "gamer" rating than the equivalent mobile questions.

PC was found to be by far the most commonly played home platform, with mobile phones being the most common mobile platform. Action and RPG games were the most popular on home platforms, followed by MMOs, adventure games and strategy games. Meanwhile, puzzle games were the most popular genre on mobile platforms, but RPG games, strategy games, and construction/management simulation were also popular.

A second questionnaire was given to professionals in the video game industry regarding the impact of different video game genres and different cognitive skills. This demonstrated that video game genres were rated differently for Critical Thinking, Reaction Speed and Spatial Awareness. The same questionnaire was also given to non-experts and the ratings were very similar for both experts and non-experts.

The genres rated highest for critical thinking were puzzle games and strategy games, followed by construction and management sims. Those rated lowest for critical thinking were driving games and life simulations. In terms of reaction speed, action games, sports games, and driving games were rated highest with construction and management sims and life sims rated lowest. Finally, for spatial awareness action games, MMOs, RPGs, and driving games were rated highest, with life sims having the lowest rating, however the variation of scores was lower than with reaction speed and critical thinking. This indicates that this skill is more similar across genres than either reaction speed and critical thinking, suggesting that it is perhaps a more core component of video game design. A cluster analysis revealed 4 genre clusters: action (action, sports, driving, platformer); adventure (adventure, MMO, RPG); puzzle (puzzle, strategy); simulation (life sim. and management sim.). It was revealed that there was little difference in cognitive skills (i.e., in critical thinking, reaction speed, or spatial awareness) used for each genre between single-player and multiplayer games.

Overall, this chapter showed the importance of distinguishing different genres of, and platforms used for video games. Home gaming was found to be a better predictor of the "gamer" self-rating than mobile gaming, suggesting that this is an important distinction to make. Four genre clusters were found, with each having a different cognitive skills profile.

Chapter 4 – Video Game Playing and Task Switching

The new questionnaire created in Chapter 3 was applied in an experiment looking at executive control. Task switching was chosen as a measure of executive control function. Impulsivity was also measured, as this has previously been linked to executive control (Whitney, Jameson & Hinson, 2004). A measure of personality was included, as it has been linked to video game playing (e.g., Braun, Stopfer, Müller, Beutel & Egloff, 2016; Potard et al., 2019).

Participants were measured on video game playing experience, genres played, and platforms, using the new questionnaire developed in Chapter 3. Personality was measured with the brief 10-item personality questionnaire (Gosling, Rentfrow & Swann, 2003), and impulsivity was measured with the Barratt Impulsiveness Scale (Barratt, 1965; Patton, Stanford & Barratt, 1995). They were presented with digits in a sequence at specific locations of a wheel. Depending on the location of the digit (top or bottom half of the wheel), they switched between parity (odd or even) and magnitude (smaller or greater than five) tasks.

No differences were found for video game playing and task switching, regardless of playing experience, genre or platform. However, a correlation was found between video game playing and the “attentional” impulsivity measure, with video game players rating themselves worse on questions such as “I concentrate easily” and “I am a steady thinker”, and the “non-planning” measure. Those playing video games more often rating themselves worse on questions such as “I plan tasks carefully” and “I am a careful thinker”. Finally, video game playing was negatively correlated with conscientiousness.

A limitation of this study is that the participant sample was not very diverse, leading to a low variation in VGP scores. Further research could recruit more extreme groups, specifically targeting gamers and non-gamers. However, as noted by Boot, Blakely and Simons (2011), this could also lead to participant bias, that is, if participants know they are being recruited because they are VGPs, they may be more motivated to perform better. Alternatively, a training study could be run, separating participants with a similar starting level of (low) VGP experience into and experimental group with a set number of hours playing video games to a control group not playing games. This design could also allow for different genre groups and different platform groups to be directly compared.

Overall, this chapter did not find any task switching differences between video game playing experience, genre, or platform. However, video game playing experience was found to correlate with aspects of impulsivity and personality.

Chapter 5 – Video Game Playing and Memory

This chapter considered the effects of video game playing on learning and memory. Video game playing was split into home (i.e. playing on home consoles and other static platforms) and mobile (i.e. playing on handheld and portable devices). Memory was split into three types of memory: implicit memory, explicit memory, and working memory. Implicit memory was measured with a contextual cueing task, explicit memory was measured with a word recall task, and working memory by a colour sequence task.

This study had four main findings. The first, was that home video game playing showed better memory skills than mobile video game playing, as demonstrated by the data from both the explicit memory and implicit memory tasks. Word recall significantly interacted with the home group, but not the mobile group. Similarly, the contextual cueing effect was shown to depend on home gaming, but not mobile gaming. This finding also supported the prediction that video game players would have improved implicit memory, with those occasionally or frequently playing video games showing more contextual cueing.

Video game players having better explicit memory was partially supported by the data, with a difference for the last two word recall lists for home gaming, indicating that home video game experience can improve encoding and storage of repeated information. This finding supports previous research which found an improvement in explicit memory from video game playing (e.g., Toril, Reales, Mayas & Ballesteros, 2016; Savulich et al., 2017; Yang, Ewoldsen, Dinu & Arpan, 2006). Though the link between video game playing and better memory is not necessarily causal, as individuals with good memory may be predisposed towards regularly playing video games, this would not explain why the link is only found in home gaming and not mobile gaming, as seen in the findings of the present study.

Finally, contrary to the initial predictions, video game players did not have improved working memory, with no significant effects for the colour sequencing task. However, these findings support research by Ballesteros and colleagues (e.g., Ballesteros et al., 2014; Ballesteros et al., 2017) which did also not find an improvement in working memory for video game playing.

A limitation of this study is that the participants had a relatively high level of performance in the word task, with all groups having between 92-98% correct, leaving little room for effects. Future research could address with a more difficult task. In addition, Clemenson and Stark (2015) find differences between 2D and 3D games, but they cannot determine whether their results are due to the complexity, the perspective, the volume of information, or the spatial aspects of the information. The results of the study presented in Chapter 4 suggest that it is less likely to be due to perspective as not all mobile games are 2D, and not all home games are 3D. Therefore, further research into whether these differences are a result of complexity, the volume of information, or the spatial aspects of the information, would be ideal.

Overall, it was found that home video game playing affects both implicit memory and explicit memory, but mobile video game playing does not. This suggests that only home-based video gaming leads to memory improvement. This indicates that more “complex” games, such as those typically played on home platforms, which are usually more powerful in terms of computing power, are more able to improve cognitive processes such as memory (e.g., Clemenson & Stark, 2015). This is in comparison to “simpler” games that are typically played on mobile platforms.

Chapter 6 – Learning in Virtual Reality

This chapter compared learning across three conditions: VR, video, and traditional textbook-style conditions. The experiment demonstrated that participants learning in VR performed better than those learning via video for both ‘remembering’ and ‘understanding’. Furthermore, VR participants were also better at questions that required ‘remembering’ than those in the traditional textbook-style conditions. The improvement of participants in VR condition compared to video implies that the improved performance in VR is not due to the visuals or graphics of the equipment (as they were the same), but instead is due to either the 3D immersion or the interactivity of the VR environment.

The learning was separated into ‘remembering’ and ‘understanding’ questions, as they are different learning stages as defined by Bloom’s Taxonomy (Bloom, Englehard, Furst, Hill & Krathwohl, 1956; see also Anderson et al., 2001). This study looked at the lower ends of the learning hierarchy, but further research into the other stages would be of interest, since differences between VR and traditional methods may be distinct for applying, analysing, evaluating and creating. In particular, the 3D aspects of VR, along with the interactivity it affords, suggest that it may have particular benefit for ‘applying’ and ‘creating’ in multiple subjects.

VR was also found to have a positive impact on mood, as participants had both an increase in positive emotions and a decrease in negative emotions. This is in contrast to both the video and traditional conditions, which showed a decrease in positive emotions. As enjoyment has previously been discussed as an important part of student performance (e.g., Goetz et al., 2006, Valiente, Swanson and Eisenberg, 2012), this indicates that VR could have a beneficial impact on overall student performance in the long term.

Engagement levels were measured by using the results of the WBLT Evaluation Scale. This demonstrated that there are significantly higher engagement levels with VR than with traditional and video learning conditions. Students also self-rated their learning as higher in the WBLT Evaluation Scale, showing that they felt that they had learnt better with the VR.

A limitation of this study is that it compares interactive VR, an active learning method, to passive video watching and traditional textbook-based methods. As such, further studies may benefit from comparing VR to other active learning methods. This is because research suggests that active learning is beneficial to students (e.g., Pereira-Santos, Prudêncio and Carvalho, 2017), therefore, so it could imply that the benefits found for VR are simply down to the benefits of active learning. However, as active learning is not always found to be better than passive learning (e.g., Haidet, Morgan, O'Malley, Moran and Richards, 2004), the benefits shown for VR may also be due to other factors.

Overall, VR was shown to be a beneficial method of learning compared to video and textbook-style methods, with increased student learning, mood, and engagement. Therefore, this demonstrates the need for further research and development in this area, so that going forward the benefits of this technology can be be utilised in educational fields.

Chapter 7 – Learning in Virtual and Mixed Realities

This chapter explored the use of both VR and MR for education, compared to traditional lecture slides. The study found that participants who studied in any of these modalities performed similarly when tested on their knowledge afterwards. However, participants had higher levels of engagement for both VR and MR compared to the lecture slide condition. Additionally, VR participants reported more positive emotions. Neither VR nor MR produced signs of simulator sickness compared to the lecture slide condition, or scored badly for user comfort, indicating that the hardware was comfortable to use.

These results suggest that both VR and MR are suitable learning tools since they improve certain aspects of the learning experience, whilst being safe and comfortable to use. VR did produce higher scores on the presence scale, indicating that it was a more immersive experience, with participants feeling more present in the virtual environment. Depending on the learning environment, this may make VR either more or less suitable than MR for teaching. In an individual learning environment, immersion is likely to be more suitable, to fully capture the student's attention. However, in a group learning environment, it may be more appropriate to have a less immersive environment, so that attention can be split between the virtual environment and other learners or educators.

Overall, the results suggest that both VR and MR are suitable and safe technologies for learning. Applications for these technologies can be designed to suit pre-existing courses, both classroom-based and distance learning, as well as potentially enabling new courses to be designed based on its capabilities. This could result in the development of new approaches to teaching. When considering possible restrictions of the technologies, such as how long they can be used for comfortably, an alternative option would be to use them as supplements to traditional learning methods, which would still allow for the increased engagement and positive emotion benefits.

A limitation of this study is that it does not test the long-term impact of using these virtual environments. This is something that would need to be tested in-depth before full integration into education, as the benefits of using the technologies may decrease as the novelty factor wears off. On the other hand, the benefits may increase over time, as individuals need time to adapt to new technology systems (e.g., Cook and Woods, 1996). Furthermore, research with a more diverse group of individuals should be conducted. This is to establish whether, for example, the technologies are suitable for those with various disabilities or learning difficulties.

However, extended realities do open up a number of possibilities as they have a myriad of potential uses, as many environments and interactions can be accurately simulated within virtual environments. This, in turn, enables learners to have access to materials and environments that they may not otherwise be able to experience, such as dangerous environments or expensive equipment. In these cases, XR can provide learning methods that would not otherwise be available, allowing for more active learning where students can interact with objects as opposed to passive learning where they simply hear or read about them.

Integrated Discussion

The overall outcome of these results suggests that there are some improvements to specific aspects of cognitive processing, and this is dependent on the type of video games played. Each research question that this thesis asked is answered below.

What factors might affect the link between video game playing and cognition?

Research in Chapters 2, 4 and 5 revealed that video game playing affects only certain aspects of visual attention. Not all visual attention processes are the same, and each is affected differently by video game playing. Moreover, some of these processes are only affected by certain types of video game playing, such as action games versus non-action games, other genres, or games played in a home set up, rather than mobile video games.

Specifically, in Chapter 2 multiple attentional processes (alerting, orienting, expecting, searching/filtering and executive control), were measured using three different attention tasks. Those who played never/rarely had a much stronger alerting effect in the ANT than those playing occasionally or frequently. VGPs were also further grouped into action and non-action players. It was found that action video game players had a higher orienting effect than non-action players. No differences were found between groups for the preview search task, or the enumeration task. In Chapter 4, Video game playing did not affect task switching, regardless of genre or platform. This implies that the conflicting results in previous research on whether video games affect visual attention (e.g., Boot, Kramer, Simons, Fabiani & Gratton, 2008; Green & Bavelier, 2003; Green & Bavelier 2007; Oei and Patterson, 2013) can be partially attributed to the type of task used to measure visual attention, and for some tasks, the genre of game played.

In Chapter 5 it was found that differences in memory were dependent only on specific video game platforms. Mobile video game playing found no differences for implicit, explicit or working memory, but differences were found in both implicit and explicit memory for home video game playing. This indicates that the platform played on, something not normally measured in previous video game research, can impact on results. As such, if some participants in previous research included mobile gaming hours in their self-classification, this could impact results.

In conclusion, the link between video game playing and cognition is affected by the type of cognitive task used, and for some tasks, not only video game experience, but also genre and platform. The conflicting research in video game playing on cognition may, in part, be attributed to these other factors which are often overlooked.

Do we need a more extensive measure of video game experience?

In Chapter 3 a new questionnaire, the Video Game Experience Questionnaire, was developed which was designed to more comprehensively measure video game experience. Much of the existing research into video game playing uses only one-dimensional or simple methods to group participants into being either a video game player or a non-video game player.

As discussed, research presented in Chapters 2 and 4 demonstrates that the effects of video game playing do not only depend on the frequency of play, but also on the genre played, and what platform they are played on (the distinction being between home platforms and mobile platforms). As such, this suggests that the simple measures used in much of the previous and current video game research, such as number of hours played per week, are not sufficiently robust to achieve fully accurate conclusions. Rather, these additional measures identified should also be taken into consideration.

Clemenson and Stark (2015) find differences in the effects of 2D and 3D video games. This may be attributed to the spatial complexity of the games, which they used as a grouping measure, rather than the perspective. As such, the difference in results found between home and mobile platforms, as well as different genres, in both my own research and the literature, may be attributed to complexity. Similarly, the results of the skills questionnaire presented in Chapter 3 indicates that each genre utilises different cognitive skills, and that different genres are more commonly played on different platforms.

Overall, this indicates that there is a need for more extensive measurement of video game playing, as this may explain the inconsistencies in results found in previous research.

How does video game playing affect memory?

Chapter 5 considered the effects of video game playing on three different types of memory: implicit, explicit, and working memory. It was found that home video game playing affects both implicit memory and explicit memory, but mobile video game playing does not. On the other hand, working memory was not affected by video game playing. In combination, this suggests that only games played on home consoles lead to memory improvement.

As discussed in Chapter 3, this may be due, in part, to the genre of games played on home consoles. The most commonly played games on home consoles were found to be action games, RPG games and MMOs, as well as adventure games and strategy games. This is in contrast to mobile platforms, where puzzle games and construction/management simulation games were popular, along with RPG games and strategy games. On the whole, this suggests that the most likely genres contributing to these differences would be action games, MMOs, and adventure games. In the genre skills questionnaire, participants rated both action games and MMOs highly for spatial awareness, and action games were rated highly for reaction speed.

Overall, video game playing does have some effect on memory. Specifically, although it does not affect working memory, it does positively affect both implicit and explicit memory.

How does learning in virtual reality differ from traditional learning?

Chapters 6 and 7 both found similar results for the use of VR in learning. Chapter 6 showed that those learning in VR had increased improvement for 'remembering' than those learning via video or textbook-style methods. In addition, they had improved 'understanding' compared to the video condition. Furthermore, emotion self-ratings before and after the learning phase showed an increase in positive emotions and a decrease in negative emotions for the VR condition. This is in contrast to both the traditional and video conditions, which both had a decrease in positive emotions. Finally, the WBLT evaluation scale found that participants in the VR condition reported higher engagement than those in either the traditional or video conditions.

In Chapter 7, learning was equivalent in both virtual and mixed environments, resulting in similar levels of performance compared to traditional learning. However, similar to the results described in Chapter 6, participants reported higher levels of engagement in the Virtual Reality condition (as well as the Mixed Reality condition) compared to the traditional learning condition. Also, as in Chapter 6, higher levels of self-reported positive emotions were found in the Virtual Reality condition after learning.

In conclusion, results indicate that learning in virtual reality leads to some improved performance over learning with traditional methods. Learning in virtual reality also consistently shows improved engagement and mood compared to traditional learning.

Are virtual environments suitable for use in education?

In Chapter 5, implicit and explicit memory were both shown to be improved for individuals who play video games on home platforms. However, unless the video games are developed specifically to be educational, they are not suitable for learning specific material. As such, they are not especially relevant to be used in educational environments, such as classrooms. However, they are not harmful to be played outside of education, and therefore, may be suitable for students to play in their spare time.

VR, on the other hand, is more suited to having specific educational environments developed. Some concerns for using virtual environments such as VR and MR have been addressed, including simulator sickness. In Chapter 7 the programs created for these virtual environments were designed specifically to mitigate simulator sickness. This was done by approaching various professionals in the video game industry who created games for these types of environments and obtaining advice and feedback from them. As video games sales are generally based on how enjoyable they are, mitigating simulator sickness is a high priority for developers. Therefore, they have developed techniques to overcome this issue. Results from Chapter 7 show that there was no indication of simulator sickness for either VR or MR.

Chapters 6 and 7 show that when these environments are developed so they can be safely and comfortably used by the vast majority of individuals, they can indeed be suitable for use in education, since they show benefits for learning, engagement, and mood. This suggests that, in particular, virtual environments such as VR, MR and AR, which are more likely to be developed for education than other virtual environments such as video games, are suitable for use in education.

Implications and Future Directions

The implications of this research are that virtual environments can be used to a great effect for learning, if the learning environment is designed appropriately. Though virtual reality is not necessarily suitable for all learning materials, there are many scenarios where it can be used to successfully supplement current teaching practices.

Technology-enhanced learning is particularly important to higher education institutions, so it is imperative to understand to what extent virtual environments are useful for education. For these institutions, research can have a significant influence on investment into technologies and software.

It is recommended that future research focuses on virtual environments that are designed specifically for learning purposes, rather than using video games to attempt to enhance general cognitive abilities. Video game playing only appears to enhance specific processes, rather than general cognitive improvement. As such, specific learning materials implemented in virtual environments are likely to be far more effective than general video game training.

Future research would benefit from focusing on longitudinal studies that consider how learning in virtual environments changes over time. Specifically, whether students and participants become desensitised to the experience, or if learning improves as they become more familiarised with the learning environments and specific equipment. This type of study would help to demonstrate whether virtual environments are more suited to being occasionally used equipment, or a more fully integrated learning method.

The implications of this research also indicate that dedicated educational software should be designed specifically to mitigate any potential issues with user comfort and experience. Findings in Chapter 7 indicate that simulator sickness does not appear to be an issue when the software is designed to moderate this. However, this should be carefully tested before being integrated into any educational programs.

Further research should consider the learning space required for suitable and safe use of VR and MR. VR, in particular, may require a specific and increased amount of space versus more traditional teaching methods, to fully utilise certain applications. Not all learning spaces can accommodate these requirements, and this is a further consideration for institutions that wish to implement these technologies. Another potential consideration is that in order to operate effectively, some VR equipment requires high-powered computers. However, as the technology improves and adapts, more wireless and stand-alone versions of these headsets are becoming available. Research into optimal learning spaces and also group sizes for this equipment would still be beneficial in order to optimise learning scenarios.

Concluding Remarks

This thesis aimed to look at the effects and learning applications of video games and virtual reality. Video games were found to have some impact on visual attention, when specific combinations of video game playing experience, genre, and platform interacted with particular attentional processes. This suggests that video game playing is not necessarily suitable as a training method for general attentional improvements, as attentional improvements are very specific, rather than generalised. This supports the findings of Simons et. al. (2016) who evaluated the literature and found evidence that brain-training enhances performance on the trained tasks, but little evidence that training improves general cognitive performance. However, playing video games had no negative effects on any visual attention processes. Similarly, improvements to memory and learning from playing video games is very specific and is dependent on particular combinations of types of video games. Again, there were no negative effects of playing video games on memory and learning. As such, this suggests that there is little use of using entertainment video games for training purposes, but they also do not cause harm.

Overall, the research demonstrated in this thesis found that virtual reality has good potential for being a useful tool for learning, increasing benefits such as engagement and positive emotion. Potential problems, such as simulation sickness was found to not be relevant when the software is designed to mitigate this. This would suggest that it would be suitable to fund the inclusion of virtual reality into pedagogic environments, as well as funding the development of educational software for this technology.

In short, virtual environments are indeed helpful, rather than harmful, when applied in the right way.

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Appendixes

Appendix 1

Modified Video Game Play History Questionnaire

Part 1. Demographic Information

1. Sex:

☐ Male ☐ Female

2. Age:

☐ 18 or 19 years old ☐ 20 to 25 years old ☐ 26 to 30 years old ☐ 31 to 35 years old
☐ 36 to 40 years old ☐ 41 to 45 years old ☐ 46 to 50 years old ☐ 51 to 55 years old
☐ 56 to 60 years old ☐ 61 or more years old

3. Vision:

☐ Normal ☐ Corrected (Glasses or contact lenses)

Part 2: Video Game Habits/Experiences (A video game is any game played with a media interface, such as TV, computer, game console, or handheld device).

5. How often do you typically play video games?
☐ daily ☐ several times a week ☐ several times a month
☐ several times a year ☐ rarely or never

6. How long is your typical playing session?
☐ less than an hour ☐ 1 to 2 hours ☐ 2 to 4 hours
☐ 4 to 6 hours ☐ 6 to 8 hours ☐8 to 10 hours
☐ 10 to 12 hours ☐ 12 hours or more

7. How many different video games in any format have you played to date?
☐ none ☐ one - five ☐ six to 20
☐ 20 to 50 ☐ 50 to 100 ☐ over 100

8. How old were you when you played your first video game? (skip if you've never played a video game)

☐ after secondary schooling ☐ grade 10 to grade 12 ☐ grade 7 to grade 9
☐ grade 4 to grade 6 ☐ kindergarten to grade 3 ☐ before kindergarten

9. Which of the following types of video game is your favourite?

☐ First person shooter ☐ Role playing/ Strategy ☐ Driving/Sports
☐ Puzzle/Card/Board ☐ None of the above

10. Which of the following types of video game do you currently play the most often?

☐ First person shooter ☐ Role playing/ Strategy ☐ Driving/Sports
☐ Puzzle/Card/Board ☐ None of the above

11. What platform(s) do you game on? Check all that apply:

☐ Xbox console ☐ Playstation console ☐ Nintendo /Wii console
☐ Personal computer ☐ Handheld game unit ☐ Cell phone
☐ Personal digital assistant

Always	Often	Sometimes	Seldom	Never
A	B	C	D	E

12. How often do you get motion sickness while playing a video game? ______
13. How often do you game online with others, as opposed to playing alone? ______
14. How often do you socialize online while gaming? ______

Appendix 2

Ten Item Personality Measure

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
1	2	3	4	5	6	7

I see myself as:

1. ______ Extraverted, enthusiastic.

2. ______ Critical, quarrelsome.

3. ______ Dependable, self-disciplined.

4. ______ Anxious, easily upset.

5. ______ Open to new experiences, complex.

6. ______ Reserved, quiet.

7. ______ Sympathetic, warm.

8. ______ Disorganized, careless.

9. ______ Calm, emotionally stable.

10. ______ Conventional, uncreative.

Appendix 3

Video Game Experience Questionnaire

Section 1 - Self-Classification

How confident are you about using computers?

	Not At All Confident	Slightly Confident	Somewhat Confident	Moderately Confident	Highly Confident	Completely Confident
Confidence	○	○	○	○	○	○

Which of the following best describes your computer skill level?

- ○ No Skills
- ○ Basic Skills
- ○ Average Skills
- ○ Good Skills
- ○ Expert Skills
- ○ Professional Skills

How regularly do you use computers?

- ○ Daily
- ○ 2-3 Times a Week
- ○ Once a Week
- ○ Fortnightly
- ○ Once a Month
- ○ Rarely or Never

To what extent do you consider yourself a 'gamer'?

	Not At All	Slightly	Somewhat	Moderately	Highly	Completely
Gamer	○	○	○	○	○	○

Which of the following do you consider yourself to be?

- ◯ Non-Gamer
- ◯ Novice Gamer
- ◯ Casual Gamer
- ◯ Core Gamer
- ◯ Hardcore Gamer
- ◯ Professional Gamer

Section 2 - Classic Video Game Experience and Habits

Please answer the following questions in regard to your classic video gaming habits **ONLY**; please do not include your mobile gaming habits.

Classic video gaming is classed as games which you play within a home environment. For example, this could be your own home, a friend's home, or a recreational centre.

Mobile video gaming is classed as games which you play outside of a home environment in a non-fixed location. For example, this could be games you can play whilst travelling or in a public place.

How long do you typically play a game for in one session?

- ◯ 0-1 Hour
- ◯ 1-2 Hours
- ◯ 2-3 Hours
- ◯ 3-4 Hours
- ◯ 4-5 Hours
- ◯ 5+ Hours

How often do you typically play?

- ◯ Daily
- ◯ 2-3 Times a week
- ◯ Once a Week
- ◯ Fortnightly
- ◯ Once a Month
- ◯ Rarely or Never

How many hours a week do you play on average?

- ◯ 0-1 Hours
- ◯ 1-3 Hours
- ◯ 3-6 Hours
- ◯ 6-9 Hours
- ◯ 9-12 Hours
- ◯ 12+ Hours

Approximately how many games have you played in total in your lifetime?

- ◯ Less than 10
- ◯ 10-30
- ◯ 30-50
- ◯ 50-100
- ◯ 100-200
- ◯ 200+

In the last 12 months, how often have you played each genre on average?
(Please refer to genre information at the end of the page for genre descriptions)

	Never	Yearly	Quarterly	Monthly	Weekly	Daily
Action	◯	◯	◯	◯	◯	◯
Role-Playing Game	◯	◯	◯	◯	◯	◯
Puzzle	◯	◯	◯	◯	◯	◯
Adventure	◯	◯	◯	◯	◯	◯
MMO	◯	◯	◯	◯	◯	◯
Strategy	◯	◯	◯	◯	◯	◯
Sports	◯	◯	◯	◯	◯	◯
Platformer	◯	◯	◯	◯	◯	◯
Driving/Racing/Flying	◯	◯	◯	◯	◯	◯
Management Sim	◯	◯	◯	◯	◯	◯
Life Simulation	◯	◯	◯	◯	◯	◯

To what extent do you play video games on each of the following platforms?

	Never	Yearly	Quarterly	Monthly	Weekly	Daily
Xbox 360	○	○	○	○	○	○
PS3	○	○	○	○	○	○
Wii/Wii-U	○	○	○	○	○	○
Xbox One	○	○	○	○	○	○
PS4	○	○	○	○	○	○
PC	○	○	○	○	○	○
Handhelds	○	○	○	○	○	○
Other	○	○	○	○	○	○

How often do you play video games online? (Either cooperatively or competitively)

- ○ Regularly
- ○ Occasionally
- ○ Rarely
- ○ Never

Who do you play video games online with?

- ○ Friends
- ○ Strangers
- ○ Both
- ○ No one

How often do you play video games with others offline (i.e. in the same room)?

- ○ Regularly
- ○ Occasionally
- ○ Rarely
- ○ Never

Genres

Included here are some examples of games from each genre, in case you are unfamiliar with the various genre classifications.

Action: Emphasizes physical challenges, including hand-eye coordination and reaction time. The genre includes diverse subgenres such as fighting games and shooter games. Games in this genre include: Call of Duty, Halo, God of War, Devil May Cry.

Role-Playing Game (RPG): Control the actions of a character/characters immersed in a well-defined world e.g., Skyrim, Fallout, Final Fantasy.

Puzzle: Logic puzzles that require critical thinking to progress. Games in this genre include: Tetris, Portal, Lemmings, Minesweeper, Professor Layton.

Adventure: Assume the role of protagonist in an interactive story driven by exploration and puzzle-solving. Games in this genre include: The Secret of Monkey Island, The Wolf Among Us, Phoenix Wright: Ace Attorney.

Massively Multiplayer Online (MMO): In these games the player interacts with other people from around the world as well the game world. Games in this genre include: World of Warcraft, Destiny, RuneScape.

Strategy: Focuses on skillful thinking and planning to achieve victory, emphasising strategic, tactical, and sometimes logistical and economic challenges. Games in this genre include: Civilization, Total War, Age of Empires, Command & Conquer.

Sports (not including racing): Playing a sport, with physical and tactical challenges, testing the player's precision and accuracy. Games in this genre include: FIFA, Madden, MLB (major League Baseball).

Platformer: Involves guiding an avatar to jump between suspended platforms, over obstacles, or both to advance the game. Games in this genre include: Donkey Kong, Sonic the Hedgehog, Mario, Rayman.

Driving/Racing/Flying: The player operates vehicles, often competitively. Games in this genre include: Forza, Need for Speed, Gran Turismo, Mario Kart, Flight Simulator.

Construction and Management Simulations (Sims): Players build, expand or manage fictional communities or projects with limited resources. Games in this genre include: SimCity, Football Manager.

Life Simulations (Sims): The player lives as or controls one or more artificial lifeforms. Games in this genre include: The Sims, Nintendogs.

Section 3 - Mobile Video Game Experience and Habits

Please answer the following questions in regard to your mobile gaming experience **ONLY**; please do not include your classic gaming habits.

Mobile video gaming is classed as games which you play outside of a home environment. For example, this could be games you can play whilst travelling or in a public place.

How long do you typically play a game for in one session?

- ○ 0-1 Hour
- ○ 1-2 Hours
- ○ 2-3 Hours
- ○ 3-4 Hours
- ○ 4-5 Hours
- ○ 5+ Hours

How often do you typically play?

- ○ Daily
- ○ 2-3 Times a week
- ○ Once a Week
- ○ Fortnightly
- ○ Once a Month
- ○ Rarely or Never

How many hours a week do you play on average?

- ○ 0-1 Hours
- ○ 1-3 Hours
- ○ 3-6 Hours
- ○ 6-9 Hours
- ○ 9-12 Hours
- ○ 12+ Hours

Approximately how many games have you played in total in your lifetime?

- ◯ Less than 10
- ◯ 10-30
- ◯ 30-50
- ◯ 50-100
- ◯ 100-200
- ◯ 200+

In the last 12 months, how often have you played each genre on average?

	Never	Yearly	Quarterly	Monthly	Weekly	Daily
Action	◯	◯	◯	◯	◯	◯
Role-Playing Game	◯	◯	◯	◯	◯	◯
Puzzle	◯	◯	◯	◯	◯	◯
Adventure	◯	◯	◯	◯	◯	◯
MMO	◯	◯	◯	◯	◯	◯
Strategy	◯	◯	◯	◯	◯	◯
Sports	◯	◯	◯	◯	◯	◯
Platformer	◯	◯	◯	◯	◯	◯
Driving/Racing/Flying	◯	◯	◯	◯	◯	◯
Management Sim	◯	◯	◯	◯	◯	◯
Life Simulation	◯	◯	◯	◯	◯	◯

To what extent do you play video games on each of the following platforms?

	Never	Yearly	Quarterly	Montly	Weekly	Daily
DS/3DS	◯	◯	◯	◯	◯	◯
PSP	◯	◯	◯	◯	◯	◯
PS Vita	◯	◯	◯	◯	◯	◯
Mobile	◯	◯	◯	◯	◯	◯
Tablet	◯	◯	◯	◯	◯	◯
Laptop (Or Similar)	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯

How often do you play video games online? (Either cooperatively or competitively)

◯ Regularly

◯ Occasionally

◯ Rarely

◯ Never

Who do you play video games online with?

◯ Friends

◯ Strangers

◯ Both

◯ No one

How often do you play video games with others offline (i.e. in the same room)?

◯ Regularly

◯ Occasionally

◯ Rarely

◯ Never

Appendix 4

Pearson's correlations from Chapter 3. Note that correlations were corrected for multiple comparisons using Bonferroni adjusted alpha levels by dividing 0.05 and 0.01 by the total number of correlations conducted in this study (165), thus the new alpha levels were 0.0003 and 0.00006, respectively. * is significant (0.05), ** is highly significant (0.01).

Table A.1. Correlations between demographics and self-ratings.

	Computer Confidence	Computer Skill Level	Computer Use Frequency	Gamer Rating	Gamer Type
Sex	-.160	-.169	.014	-.152	-.204*
Age	.078	.218**	-.039	-.099	-.073
Education	.029	.173	.026	.049	.053

Table A.2. Correlations between demographics and self-rating with home video game playing (VGP) questions.

	Session Length	Playing Frequency	Weekly Hours	Total Lifetime Games	Home VGP Mean
Sex	.04	.179	-.151	-.249**	-.177
Age	-.039	.101	-.081	.106	-.034
Education	.013	-.013	.004	.016	.015
Computer Confidence	.037	-.062	.057	.165	.105
Computer Skill Level	-.04	.002	.02	.171	.052
Computer Use Frequency	.056	.069	-.032	-.149	-.064
Gamer Rating	.466**	-.653**	.646**	.523**	.738**
Gamer Type	.410**	-.624**	.606**	.519**	.697**

Table A.3. Correlations between demographics and self-rating with mobile video game playing (VGP) questions.

	Session Length	Playing Frequency	Weekly Hours	Total Lifetime Games	Mobile VGP Mean
Sex	.127	-.151	.128	.025	.140
Age	.001	-.06	.045	-.068	.02
Education	.009	-.008	.08	-.047	.014
Computer Confidence	-.044	.07	-.019	.037	-.035
Computer Skill Level	-.067	.062	-.055	.027	-.05
Computer Use Frequency	.002	-.005	-.015	-.011	-.005
Gamer Rating	.153	-.140	.211*	.284**	.241**
Gamer Type	.174	-.074	.139	.228**	.178

Table A.4. Correlations between demographics and video game genres played at home and on mobile.

	Sex		Age		Education	
	Home	Mobile	Home	Mobile	Home	Mobile
Action	-.235**	-.019	-.202*	-.069	-.027	.014
RPG	-.044	.07	-.038	-.029	-.009	.064
Puzzle	.136	.163	.064	.001	-.051	-.088
Adventure	.027	.088	-.151	-.044	.014	.057
MMO	-.056	.035	-.043	.073	.022	.02
Strategy	-.186	.001	-.047	-.013	-.062	-.019
Sports	-.186	-.045	-.006	-.033	-.03	-.02
Platformer	-.013	.07	-.06	-.158	.022	-.032
Driving	-.232**	-.062	-.045	-.04	-.089	-.079
Management Sim	.051	.186	-.07	-.068	-.063	.029
Life Sim	.344**	.267**	-.05	-.021	-.076	-.004

Table A.5. Correlations between the mean of the VGP questions for home to video game genres played at home and the mean of the VGP questions for mobile to video game genres played on mobile.

	VGP Mean	
	Home	Mobile
Action	.462**	.517**
RPG	.491**	.544**
Puzzle	.121	.443**
Adventure	.331**	.554**
MMO	.332**	.424**
Strategy	.391**	.464**
Sports	.072	.118
Platformer	.312**	.399**
Driving	.163	.236**
Management Sim	.166	.342**
Life Sim	.130	.287**

Table A.6. Correlations between home VGP questions and home platforms played.

	Home VGP Mean
Xbox 360	.069
PlayStation 3	.130
Nintendo Wii	.09
Xbox One	.145
Playstation 4	.120
PC	.528**
Handhelds	.209*
Other	.084

Table A.7. Correlations between mobile VGP questions and mobile platforms played.

	Mobile VGP Mean
DS	.369**
PSP	.245**
PSVita	.205*
Mobile	.541**
Tablet	.307**
Laptop	.304**
Other	.186

Appendix 5

Video Game Genre Skills

For this survey you will be asked to rate how important/relevant 3 skills are to game genres.

The scale is 1-10, with 1 being 'not relevant', 10 being 'extremely relevant'.

Critical Thinking: Objective analysis and evaluation to form a judgement on how to respond.
Reaction Speed: The speed at which you respond to the presentation of a stimulus.
Spatial Awareness/Skills: The awareness of where you are in a space and in relation to objects around you. Being able to mentally manipulate 2-dimensional and 3-dimensional figures.

For this first section, please only consider **single player** aspects of games from these genres, the **multiplayer** (split screen and online) ratings are to be given in the following section.

Single Player

Action (e.g. Call of Duty, Halo, God of War, Devil May Cry)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

RPG (e.g. Skyrim, Fallout, Final Fantasy)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Puzzle (e.g. Tetris, Portal, Lemmings, Minesweeper, Professor Layton)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Adventure (e.g. The Secret of Monkey Island, The Wolf Among Us, Phoenix Wright: Ace Attorney)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

MMO (e.g. World of Warcraft, Destiny, RuneScape)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Strategy (e.g. Civilization, Total War, Age of Empires, Command & Conquer)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Sports (not including racing) (e.g. FIFA, Madden, MLB)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Platformer (e.g. Donkey Kong, Sonic the Hedgehog, Mario, Rayman)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Driving/Racing/Flying (e.g. Forza, Need for Speed, Gran Turismo, Mario Kart, Flight Simulator)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Construction and Management Simulations (e.g. SimCity, Football Manager)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Life Simulations (e.g. The Sims, Nintendogs)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Multiplayer (Split Screen and Online)

Action (e.g. Call of Duty, Halo, Team Fortress 2)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

RPG (e.g. Diablo, Dark Souls, Dragon's Dogma)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Puzzle (e.g. Portal, World of Goo, Dr. Kawashima's Brain Training)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Adventure (e.g. Legend of Zelda: The Wind Waker, Catherine)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

MMO (e.g. World of Warcraft, Destiny, RuneScape)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Strategy (e.g. Age of Empires Online, League of Legends)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

<u>Sports</u> (not including racing) (e.g. FIFA, Madden, MLB)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

<u>Platformer</u> (e.g. Sonic the Hedgehog, Rayman, LittleBigPlanet)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

<u>Driving/Racing/Flying</u> (e.g. Forza, Need for Speed, Gran Turismo, Mario Kart)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

<u>Construction and Management Simulations</u> (e.g. Cities XL, Football Manager)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

<u>Life Simulations</u> (e.g. The Sims Online, Nintendogs)

Critical Thinking

1 2 3 4 5 6 7 8 9 10

Reaction Speed

1 2 3 4 5 6 7 8 9 10

Spatial Awareness/Skills

1 2 3 4 5 6 7 8 9 10

Appendix 6

Barratt Impulsiveness Scale

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and put an X on the appropriate section on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

	Rarely/Never	Occasionally	Often	Almost always
I plan tasks carefully.				
I do things without thinking.				
I make-up my mind quickly.				
I am happy-go-lucky.				
I don’t “pay attention.”				
I have “racing” thoughts.				
I plan trips well ahead of time.				
I am self-controlled.				
I concentrate easily.				
I save regularly.				
I “squirm” at plays or lectures.				
I am a careful thinker.				
I plan for job security.				
I say things without thinking.				
I like to think about complex problems.				
I change jobs.				
I act “on impulse.”				
I get easily bored when solving thought problems.				
I act on the spur of the moment.				
I am a steady thinker.				
I change residences.				
I buy things on impulse.				
I can only think about one thing at a time.				
I change hobbies.				
I spend or charge more than I earn.				
I often have extraneous thoughts when thinking.				
I am more interested in the present than the future.				
I am restless at the theater or lectures.				
I like puzzles.				
I am future oriented.				

Appendix 7

Please answer the following questions.

Please read the questions carefully. All answers are possible with the information in the materials you were provided.

Each correct answer will give you 1 point.

After each question please state your confidence in your answer from 1-5.

1: No confidence

2: A little confidence

3: Some confidence

4: Quite confident

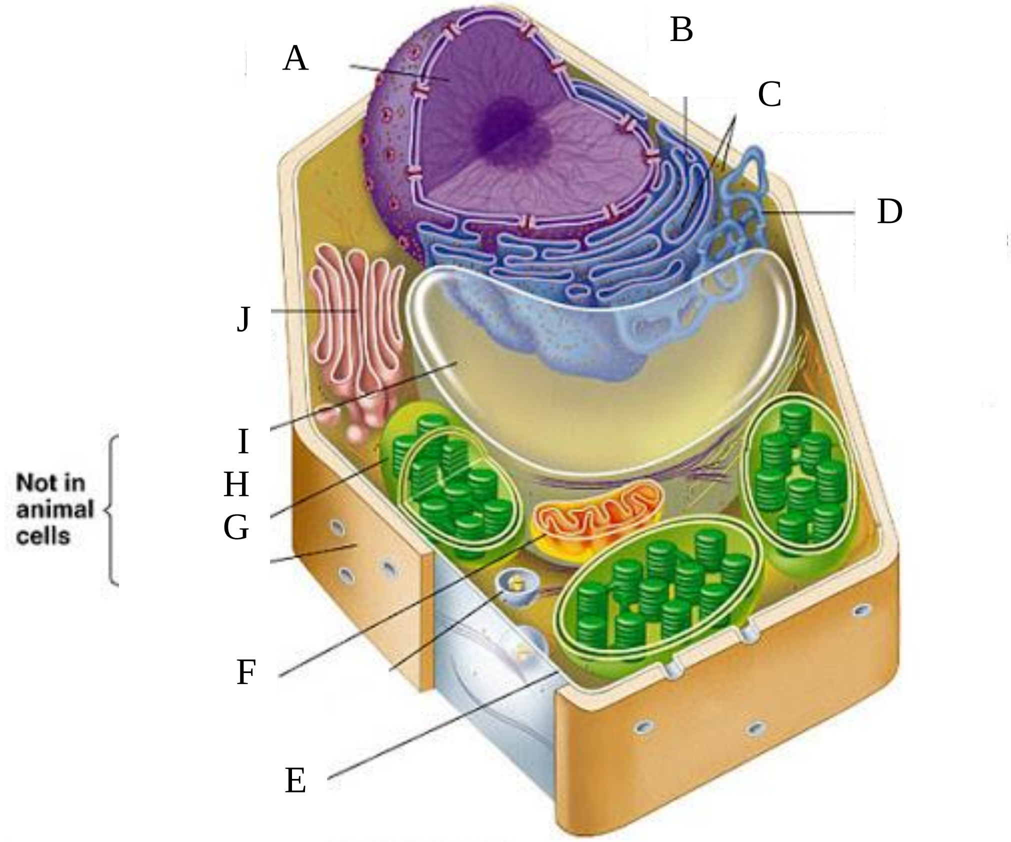
5: Totally confident

For example, a confidence of 5 means you are certain the answer is right, whereas a confidence of 1 means you guessed the answer.

Example:

1 (a) Name part B.

My answer_______________________________________ | 3 |



1 (a) Name part B.

____

1 (b) What is the function of part B?

____

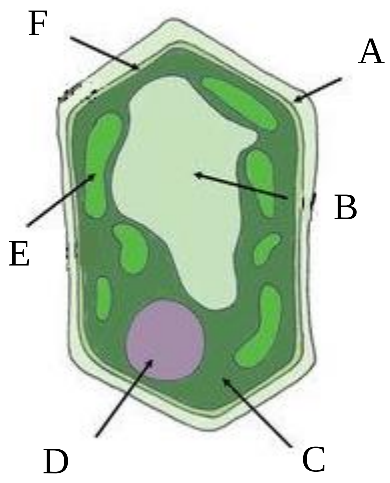
____

1 (c) (i) Name the organelle, crucial to photosynthesis, which is only found in plant cells.

____

1 (c) (ii) Which letter denotes this organelle's location?

____



2 (a) Give the letter of the part of the plant which is filled with liquid.

2 (b) Name the part of the plant which maintains cell structure.

____

Some of the organelles found in plant cells are also found in animal cells. For example, cells lining the bronchi of the lungs secrete large amounts of mucus. Mucus contains protein.

3 (a) (i) Name one organelle that you would expect to find in large numbers in a mucus-secreting cell.

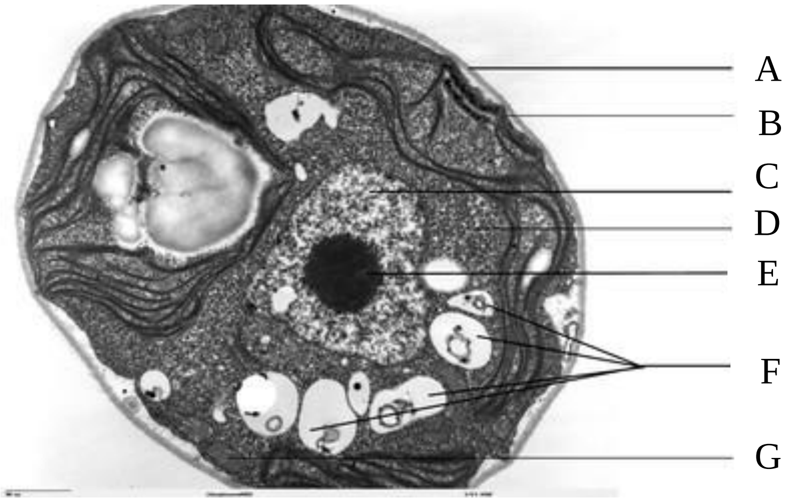
____

Describe its role in the production of mucus.

3 (a) (ii)

____

4 (a) Label the following parts of the cell.



A____

B____

C____

D____

E____

F____

G____

This photograph shows part of the cytoplasm of a cell.

5 (a) Organelle X is a mitochondrion. What is the function of this organelle?

____ ☐

____

5 (b) Name organelle Y.

____ ☐

Appendix 8

Differential Emotions Scale

Please rate on a five-point scale from one ("not at all") to five ("very strongly") the extent to which these adjectives correspond to your current emotional state.

	1	2	3	4	5
Interested, concentrated, alert					
Amused, Joyful, merry					
Sad, down-hearted, blue					
Angry, irritated, mad					
Fearful, scared, afraid					
Anxious, tense, nervous					
Disgusted, turned-off, repulsed					
Disdainful, scornful, contemptuous					
Surprised, amazed, astonished					
Warm-hearted, gleeful, elated					

Appendix 9

WBLT Evaluation Scale

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Learning					
Working with the learning object helped me learn	1	2	3	4	5
The feedback from the learning object helped me learn	1	2	3	4	5
The graphics and animations from the learning object helped me learn	1	2	3	4	5
The learning object helped teach me a new concept	1	2	3	4	5
Overall, the learning object helped me learn	1	2	3	4	5
Design					
The help features in the learning object were useful	1	2	3	4	5
The instructions in the learning object were easy to follow	1	2	3	4	5
The learning object was easy to use	1	2	3	4	5
The learning object was well organized	1	2	3	4	5
Engagement					
I liked the overall theme of the learning object	1	2	3	4	5
I found the learning object engaging	1	2	3	4	5
The learning object made learning fun	1	2	3	4	5
I would like to use the learning object again	1	2	3	4	5

Appendix 10

Quiz

1) What is the relationship between light intensity and solar power efficiency?
    a. Inversely proportional or directly proportional
    b. Inversely proportional
    c. Directly proportional
    d. Inversely proportional and directly proportional

2) With regards to output power, operating temperature:
    a. Positively affects the output
    b. Negatively affects the output

3) How does shading and mismatching affect the efficiency of solar panels?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………

4) Which of the following solar panel silicone structures has the highest efficiency?
    a. Monocrystalline Silicone structure
    b. Polycrystalline Silicone structure
    c. Amorphous Silicone structure

5) Why does the structure you chose in question four have a higher efficiency than the others do?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………

6) Which of the following sentences is correct?
    a. The solar intensity if affected by the change in installation angle of the solar panel cells
    b. The efficiency of the solar panel increases with operating temperature

c. The light intensity increases with shading
d. Mismatching increases power output

7) Why are group 4 elements in the periodic table good at conducting electricity?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………

8) Calculate the required area of a photovoltaic array (solar panel) mounted on a roof with a tilt angle of 45° to meet an annual load demand of 10,000kWh. Assume the module efficiency is 15% and the system performance ratio is 75%.

Tilt Angle (°)	0°	30°	45°	60°	90°
Annual solar radiation (kWh/m^2)	982	1113	1105	1047	794

Solution:

……………………………………………………………………………………………………
……………………………………………………………………………………………………
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……………………………………………………

Answer: ……………………………

Appendix 11

Simulator Sickness Questionnaire

Instructions: Circle how much each symptom below is affecting you right now.

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. Fullness of the head	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. Vertigo*	None	Slight	Moderate	Severe
15. Stomach awareness**	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

*Vertigo is experienced as loss of orientation with respect to vertical upright.
** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Appendix 12

Perceived Quality Questionnaire

Dimensions	Constructs	Variables	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Ergonomic quality	Perceived learnability	Understanding how to use the technology is easy	1	2	3	4	5
		It would be easy to learn how to use the technology	1	2	3	4	5
		It would be easy to remember how to use the technology	1	2	3	4	5
	Perceived ease of use	It would be easy to use the technology for learning Engineering	1	2	3	4	5
		Interacting with the technology was easy for me	1	2	3	4	5
		the technology is easy to use	1	2	3	4	5
Learning quality	Perceived efficiency	the technology would help me to understand the lesson faster	1	2	3	4	5
		the technology would help me to learn more quickly	1	2	3	4	5
		the technology would help me to understand the lesson better	1	2	3	4	5
	Perceived usefulness	After using the technology my Engineering knowledge will improve	1	2	3	4	5
		the technology exercises are	1	2	3	4	5

		useful to test my knowledge					
		the technology helps learning Engineering	1	2	3	4	5
Hedonic quality	Perceived cognitive absorption	Time appeared to go by very quickly when I was using the technology	1	2	3	4	5
		While using the technology I was absorbed in what I was doing	1	2	3	4	5
		While using the technology I was able to concentrate on the lesson	1	2	3	4	5
	Perceived enjoyment	Using the technology is an enjoyable learning experience	1	2	3	4	5
		I like learning Engineering with the technology	1	2	3	4	5
		I enjoyed using the technology	1	2	3	4	5

Appendix 13

System Usability Scale

Variables	Strongly disagree				Strongly agree
I think that I would like to use this system frequently	1	2	3	4	5
I found the system unnecessarily complex	1	2	3	4	5
I thought the system was easy to use	1	2	3	4	5
I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
I found the various functions in this system were well integrated	1	2	3	4	5
I thought there was too much inconsistency in this system	1	2	3	4	5
I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
I found the system very cumbersome to use	1	2	3	4	5
I felt very confident using the system	1	2	3	4	5
I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Appendix 14

Unified Theory of Acceptance and Usage of Technology Questionnaire

Performance expectancy

I find the system useful for the course.	1	2	3	4	5	6	7
Using the system will enable me to accomplish tasks more quickly.	1	2	3	4	5	6	7
Using the system will increase my productivity.	1	2	3	4	5	6	7
If I use the system, I will increase my chances of getting a high grade.	1	2	3	4	5	6	7

Effort expectancy

My interaction with the system will be clear and understandable.	1	2	3	4	5	6	7
It will be easy for me to become skilful at using the system.	1	2	3	4	5	6	7
I find the system easy to use.	1	2	3	4	5	6	7
Learning to operate the system is easy for me.	1	2	3	4	5	6	7

Attitude toward using technology

Using the system is a good idea.	1	2	3	4	5	6	7
The system will make work more interesting.	1	2	3	4	5	6	7
Working with the system is fun.	1	2	3	4	5	6	7
I like working with the system.	1	2	3	4	5	6	7

Self-efficacy

I could complete a job or task using the system…

…if there was no one around to tell me what to do as I go.	1	2	3	4	5	6	7
…if I could call someone for help if I got stuck.	1	2	3	4	5	6	7
…if I had a lot of time to complete the job for which the software was provided.	1	2	3	4	5	6	7
…if I had just the built-in help facility or assistance.	1	2	3	4	5	6	7

Anxiety

I hesitate to use the system for fear of making mistakes I cannot correct.	1	2	3	4	5	6	7
It scares me to think that I could lose a lot of information using the system by hitting the wrong key.	1	2	3	4	5	6	7
I feel apprehensive about using the system.	1	2	3	4	5	6	7
The system is somewhat intimidating to me.	1	2	3	4	5	6	7

Behavioural intention to use the system

If the equipment was available for me to use I would…

Plan to use the system in the next 6 months.	1	2	3	4	5	6	7
Predict I would use the system in the next 6 months.	1	2	3	4	5	6	7
Intend to use the system in the next 6 months.	1	2	3	4	5	6	7

Appendix 15

Igroup Presence Questionnaire

In the computer-generated world I had a sense of "being there"	Not at all	-3	-2	-1	0	1	2	3	Very much
Somehow I felt that the virtual world surrounded me.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
I felt like I was just perceiving pictures.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
I did not feel present in the virtual space.	Did not feel present	-3	-2	-1	0	1	2	3	Felt present
I had a sense of acting in the virtual space, rather than operating something from outside.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
I felt present in the virtual space.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?	Extremely aware	-3	-2	-1	0	1	2	3	Not aware at all
I was not aware of my real environment.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree

I still paid attention to the real environment.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
I was completely captivated by the virtual world.	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree
How real did the virtual world seem to you?	Completely real	-3	-2	-1	0	1	2	3	Not real at all
How much did your experience in the virtual environment seem consistent with your real-world experience?	Not consistent	-3	-2	-1	0	1	2	3	Very consistent
How real did the virtual world seem to you?	About as real as an imagined world	-3	-2	-1	0	1	2	3	Indistinguishable from the real world
The virtual world seemed more realistic than the real world	Fully disagree	-3	-2	-1	0	1	2	3	Fully agree