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## DIGITAL GAMING, BRAIN TRAINING AND COGNITION

### Learning Aims and Objectives

- To introduce the idea that human cognition can be improved or enhanced through the use of digital video games;
- to define the key terms and concepts;
- to explore the evidence for and against the claims associated with cognitive improvements;
- to introduce the concept of brain training or 'cognitive training';
- to explore the evidence presented both for and against the benefits of such programs.

### Overview

One element of the digital environment that has garnered a great deal of attention over recent decades is the impact of video gaming on a variety of cognitive and social skills. The much-maligned debate about the impact of violent video games is not one that will be the focus of discussion here, and there are plenty of other reviews that would do a far better job of this than I can (e.g. Griffiths, 1999). The accumulated research that focuses on the impact for cognitive skills is very broad in its scope, and the results are far from clear cut. Nonetheless many researchers have presented evidence that supports the notion that key cognitive skills can be enhanced when engaging in video game play.

To place this into context, a survey questioning 1102 individuals aged between 12 and 17 found that at least 97 per cent play some form of digital video game (Lenhart et al., 2008). Other researchers have noted that at least 60 per cent of individuals aged between 8 and 18 played video games on at least a daily

basis (Rideout et al., 2010). There have been a variety of attempts to explore how digital gaming can enhance certain skills, with research suggesting the development of problem-solving skills (Adachi and Willoughby, 2013; Prensky, 2012), spatial skills (Dorval and Pépin, 1986; Feng et al., 2007; Green and Bavelier, 2003) and persistence (Shute et al., 2015; Ventura et al., 2013). However, these findings aren't so clear cut, and some researchers have noted that there are a variety of methodological issues associated with some of these findings (Boot et al., 2008) as well as a lack of detailed empirical support (Shute et al., 2015).

### Serious Games: These Are Not Video Games!

You might come across some reference to 'serious gaming' when exploring the impact of gaming on improvements in performance and skill. For the most part these aspects will fall out of the scope of the current discussion, but do warrant some consideration, as there is a cross-over here with our present exploration.

Serious gaming is a more recent development in the context of training and builds upon the use of computer-based training applications. In traditional training applications there is a recognised system of knowledge delivery (on the behalf of the instructor) followed by learning and testing of retention (on the behalf of the trainee). As noted by Greitzer et al. (2007), such a system presents no real opportunity for the trainee to actually engage and utilise the material that is being presented to them. These traditional training systems usually allow the trainee the capacity to access knowledge-testing phases such as quizzes or multiple-choice questions for numerous attempts. Similarly the materials on which such test questions have been based are freely available for the trainees to review over and over again. Therefore such mechanisms fail to fully engage the individual in a state of active learning, which in turn aims to ensure that learners are exploring the functional elements of the material as opposed to a simple knowledge acquisition process.

Serious gaming has been championed as a mechanism to overcome this shortfall in traditional forms of training (Greitzer et al., 2007). Zyda (2005: 26) goes on to define the notion of serious games by linking it directly to the key application areas for such systems: 'Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.'

Serious games have also been used in the context of both investigation and advertisement (Breuer and Bente, 2010; Muntean, 2011; Susi et al., 2007). Serious games have a goal of adapting elements of gaming to engage the individual beyond the basic aspect of 'playfulness'. However, serious games are designed with a specific task or purpose in mind and therefore have little direct application outside of that given environment.

Although serious games can be used to advance aspects of behavioural change, there are some specific disadvantages to such an approach. Primarily the cost of designing, piloting and implementing such systems can be a block to their implementation, especially when the potential user base is small and specialised. Second, as they are usually designed with a specific purpose in mind, the cross-applicability to other areas is limited, making them even less cost effective if further exploitation is a goal. In terms of engagement, serious gaming usually employs game-related dynamics and game environments that could potentially deter those individuals who have no interest in video gaming. There is also some discussion of how effective serious games are in terms of their intended aims and goals, with some indicating that an objective examination of their effectiveness is immensely problematic (Bellotti et al., 2013)

## Defining the Concept of Video Games

According to Prensky (2001), video games typically consist of six key elements which combine to engage the player. These elements include aspects such as

**Table 5.1** Categories of video games

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1. Sport Simulations: This type is self-explanatory. These games simulate sports such as golf, ice hockey, athletics, etc. (e.g. *World Wide Soccer '97*, *NHL Powerplay '97*, etc.).
  2. Racers: This type could be considered a type of sport simulation in that it simulates motor sports like Formula 1 racing (e.g. *Human Grand Prix*, *Speedster*, *Monoracer*, etc.).
  3. Adventures: This type uses fantasy settings in which the player can escape to other worlds and take on new identities (e.g. *Atlantis*, *Star Trek Generations*, *Overboard*, etc.).
  4. Puzzlers: This type is self-explanatory. These games are 'brainteasers' that often require active thinking (e.g. *Tetris*, *Baku Baku Animal*, etc.).
  5. Weird Games: These games are not weird as such except they do not fit into any other category. They would be better termed miscellaneous (e.g. *Sim City 2000*, *Populous 3*, etc.).
  6. Platformers: These games involve running and jumping along and onto platforms (e.g. *Mario 64*, *Sonic*, etc.).
  7. Platform Blasters: These games are platformers but also involve blasting everything that comes into sight (e.g. *Robocop 2*, *Virtua Cop*, etc.).
  8. Beat 'Em Ups: These games involve physical violence such as punching, kicking, etc. (e.g. *Street Fighter 3*, *Tekken 2*, *Mortal Kombat*, etc.).
  9. Shoot 'Em Ups: These games involve shooting and killing using various weapons (e.g. *Blast Corps*, *Mech Warrior*, *Turok Dinosaur Hunter*, etc.).
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Source: Griffiths (1999)

rules, goals/objectives, outcomes and feedback, conflict/competition, interaction and representation or story. Griffiths (1999) presented a review of the literature on video gaming and aggression, and within it highlighted nine distinct categories into which video games can be placed. These categories are presented in Table 5.1 above. Importantly, only the categories puzzlers and weird games are seen to include elements that are directly linked to aspects of education (Griffiths, 1999), although the research literature reviewed below notes the impact of games from wider categories on other cognitive skills.

Eichenbaum et al. (2014) noted that one particular type of video game, that of action video games (or 'shoot 'em ups' to use Griffiths' terminology), has been associated with a wide range of proposed benefits. These games are typified by fast-paced action and a heavy reliance on attention to keep track of many items moving simultaneously. Such games have been notably linked to improvements in aspects of low-level attentional processes as well as aspects of higher-level cognitive functions. The first part of this chapter will focus directly on these types of action video games (AVGs) and explore how they have been proposed to improve aspects of cognition. In the latter part of the chapter I will explore the rise of brain training, which, although it has some links to aspects of video game play, is more specifically designed with the aims of enhancing targeted cognitive skills as well as overall cognitive functioning.

## How Do You Examine the Impact of Video Games on Cognition?

Studies exploring the impact of AVGs on perceptual and cognitive processes usually conform to one of two experimental paradigms. In the first type, researchers will assign participants to groups based on their level of previous expertise with AVGs, this being either novice or expert (Eichenbaum et al., 2014). Researchers will then explore whether there are any specific differences according to a variety of aspects of cognition (e.g. object tracking or a test of visual spatial memory). However, there is an issue with experiments of this type when it comes to making a causative link between the increased accuracy or speed noted in AVG players and their use of AVGs. It could be that those who play such games already have a pre-existing difference in these abilities, hence they are more likely to seek out the challenges that are presented by action video gaming (Eichenbaum et al., 2014). In order to overcome this methodological shortcoming researchers may instead implement the second type of experimental design. In this option they will search for a sample of participants who have no previous experience of playing AVGs. These participants are then asked to complete a battery of cognitive and perceptual tasks to establish a base-rate measure (Boot et al., 2008). Then participants are engaged in a period of

practice where they play AVGs for a period of up to 21 hours, after which they are asked to complete the same tasks that they did in the initial stages of the research. The premise of such experiments is to establish whether practice on AVGs can produce a difference in the skills that have been measured. This performance is contrasted with a similar group of participants who have not engaged in the same practice on AVGs, but who have been typically using something from the non-action video-game genre (something riveting like Solitaire or Minesweeper!). Eichenbaum et al. do point out that in most instances the non-action video game is matched for level of interest, engagement and fun, but lacks the slash/hack/shoot aspect that is integrated into so many AVGs.

### The Early Days of Research: Video Games for Training and Research

In the very early days of video gaming, research focused more directly on basic elements such as improvements in reaction times. For instance Clark et al. (1987) demonstrated that a period of seven weeks of game play significantly improved the reaction times of elderly adults (57–83 years old) in comparison with a control group that did not play video games. A few years later a special issue of the academic journal *Acta Psychologica* was entirely devoted to the exploration of a video game named Space Fortress. Space Fortress was a little different from those games that had traditionally appeared in video game arcades of the time, and perhaps would not have gained the same popularity as others such as Frogger, Pac Man or Donkey Kong. However, Space Fortress was important in one key respect – it had been designed by psychologists for the sole purpose of being a training and research tool (Mané and Donchin, 1989). The objectives behind the game play of Space Fortress were pretty simple in contrast to some of the more contemporary AVGs such as Call of Duty. The task for the player was to shoot missiles at a space fortress in order to destroy it (1989). In addition to this the player must dodge missiles that are being fired by the space fortress as well as avoiding damage to their ship from mines that have been scattered around the playing area.

Researchers used the game in a variety of settings, noting that there was an enhancement in some skills that were not directly linked to video gaming. For example, Frederiksen and White (1989) noted that young adults who played Space Fortress performed significantly better than a control group in a test of physics exploring how acceleration affects the motion of objects. In research by Gopher et al. (1994), Space Fortress was used to explore the transfer of skills in Israeli Airforce cadets. The researchers who implemented this noted that those cadets who played the game as part of their training significantly outperformed

a group who had no experience of the game on tests of flight performance. This again demonstrated that the skills acquired through playing the game actually transferred over into complex visuo-motor skills that were relevant for flight control (Boot et al., 2008; Gopher et al., 1994). Researchers have suggested that this skill cross-over is related directly to the concurrent cognitive demands of the task with the addition of a requirement to engage in fine motor controls. Later research by Stern et al. (2013) showed that engaging older adults (mean age of 65) in the use of Space Fortress for a period of 36 one-hour sessions showed an improvement in a measure of executive control function.

## Enhancement in Visual Perception

It has been noted that there have been improvements in contrast sensitivity which Eichenbaum et al. (2014) define as the ‘ability to detect small incremental changes in shades of grey (p. 56). Li et al. (2009) also noted a significant capacity for AVG players to outperform non-video game (NVG) players in the ability to detect minute changes in shades of grey. These researchers then went on to demonstrate it was actually engaging in AVG play that produced these differences in this perceptual capacity. Green and Bavelier (2007) also noted the superior performance of AVG players on tests of ‘crowded acuity’ or the capacity to pick out individual targets within a display containing a high number of distractors. Eichenbaum et al. (2014) noted that this has an interesting link to the process of reading as we rarely look at the individual letters but rather the word or sentences. Such a suggestion links well to research that has demonstrated an improvement in reading speed without any residual loss of accuracy in children suffering from dyslexia (Franceschini et al., 2013). Work by Appelbaum et al. (2013) noted that AVG players displayed an improved sensitivity to visual stimulus, meaning that they were able to ‘take in’ more visual information in contrast with their NVG player counterparts. However, there was no specific difference in the amount of information that could be retained between NVG players and AVGs, demonstrating that experience only impacts on the initial detection of information.

## Improvements in Selective Visual Attention

Beyond the proposed improvements in aspects of low-level perceptual abilities, AVGs have also been demonstrated to improve aspects of visual selective attention. This is an essential cognitive capacity that allows the individual to isolate key elements from within their current visual environment and to select these for further processing. In this instance AVG players demonstrate a superior capacity to be able to identify critical elements within such displays whilst also being able

to filter out and ignore those elements that are not relevant to the current task (Feng et al., 2007; Green and Bavelier, 2003, 2006b; Spence and Feng, 2010).

A great deal of the work exploring the impact playing video games has had upon aspects of human cognition has focused directly on cognitive skills such as perception and attention. This includes work by Green and Bavelier (2006a), who explored the differences between video gamers and non-video gamers and differences in visuospatial attention. Their work showed that those in the video gaming group showed improved performance in the capacity to pick out the appearance of target objects that fell outside of the central focus of attention. They also noted that video game players adapted this level of focus according to the level of perceptual load (or the amount of items they viewed within the display). In cases where there were few items and perceptual load was low, video game players were more able to attend to the peripheral aspects of the display. This would appear to map onto game play, where a lull in the action would present a prospective moment to gather thoughts and to scan the environment for new potential threats. On the other hand, where perceptual load was deemed to be high and multiple targets were presented on the screen the focus remained central. This would appear to again mimic the action of most video games in instances where attack from multiple enemies would engage the process of self-preservation, hence trying to eradicate the closest and most dangerous threats (Boot et al., 2008).

In other research that has used a paradigm from cognitive psychology termed the ‘attentional blink’ it has been shown that AVG playing improves the capacity of participants to keep track of items over a period of time. In the traditional attention blink paradigm participants are asked to watch a stream of visually presented items that are presented in black. One item, the target, is presented in white (the first target or T1), and in some trials this white target is closely followed by the appearance of a black ‘X’ (the second target or T2). Once the trial has ended participants are asked to indicate whether they have seen the black ‘X’, with the attentional blink phenomenon being the finding that in the majority of cases the participants will miss the appearance of such an object (Shapiro et al., 1997). Oei and Patterson (2013) conducted a number of cognitive tests exploring the link between enhancements in cognitive abilities and video gaming. They noted that for those who had been trained using the AVG, the attentional blink was completely eliminated, a phenomenon which has also been noted by others (e.g. Green and Bavelier, 2003).

The multiple object tracking task (MOT; see Sears and Pylyshyn, 2000) has also been widely used to explore the impact of action video gaming and visual selective attention. There are a number of variations to the MOT task, but the essential premise is that participants are shown a number of identical objects on the screen, of which a sub-set is highlighted as targets to be tracked. These targets



are then moved around the screen alongside the other identical items in the visual display. After a period of time the random movement stops and participants are asked to identify the target items identified at the start of the trial. A variety of researchers have noted enhanced performance on the MOT task by those experienced in AVGs as well as improvements in performance after training (Green and Bavelier, 2003, 2006; Oei and Patterson, 2013). These improvements in the visual element of working memory have also been supported by research that has focused on children. Findings have demonstrated that children who frequently played AVGs had an increased capacity to keep track of target items on screen more accurately in comparison with those who had not engaged in AVG play (Eichenbaum et al., 2014; Trick et al., 2005).

Other researchers have, however, raised issues with the results from these studies, in particular the findings from the original study presented by Green and Bavelier (2003) as well as those presented by Feng et al. (2007). The findings from these studies concluded that video game players exhibited levels of temporal attention, spatial awareness and attentional capacity that were superior to those possessed by non-video game players. However, Murphy and Spence (2009) noted no such differences between those who played video games and those who did not, further suggesting more work was needed to be completed in the area in order to fully understand the impact gaming has on visual attention.

### Improvements in Higher Order Cognitive Functioning

Boot et al. (2008) moved away from the previous narrow focus on the perceptual elements of engaging in video game play. Instead their work looked directly at what are commonly viewed as being higher-level cognitive functions or those which relate to executive functioning. In their study they manipulated the type of game the individuals were playing and then tested them on aspects of performance for a number of cognitive abilities including memory and reasoning. Participants played either a fast-paced first-person shooter/combat game (Medal of Honour), a puzzle game (Tetris) or a strategy/role-playing game (Rise of Nations). The researchers proposed that the first-person shooter would present the best mechanism for an improvement in both visual and spatial attention. On the other hand, the strategy game would aid in improving executive control as this has elements of planning involved within it, and finally the puzzle game would assist in improving spatial skills given the requirement to rotate shapes. The researchers asked participants to complete 20 hours of video game play, with cognitive and perceptual tests being implemented before the practice started, after 10 hours of practice and then after 21 hours. In their results Boot et al. (2008) noted that for many of the tasks tested



there was some level of improvement in the practice groups in comparison with their pre-test scores, but in many of the tests they failed to reach a suitable level of statistical significance. In their comparison between expert and non-expert video gamers they did note that experts were better able to track objects that were moving at speed, could perform more accurately in a test of visual short-term memory, were able to switch between two different tasks quicker and make decisions about the match between rotated objects more quickly and accurately than non-experts. However, the level of practice that was given to participants on each of the three types of games failed to produce changes in performance that could match those of the expert gamers in the initial exploration.

One interesting aspect that was mentioned in the study by Boot et al. was the make-up of the sample for the longitudinal training groups. There was a high percentage of females in these groups, with a potential for such an issue to bias the results. For instance, differences in spatial cognition have been well recognised in the research literature (Geary et al., 2000). In the context of video gaming, earlier work by Feng et al. (2007) noted that females benefitted more than males when engaged in video gaming practice for improvements in tests of spatial cognition. In Feng et al.'s study both males and females were compared before and after ten hours of AVG practice. The findings demonstrated that females improved significantly more in detecting a target object within the display in comparison with males (55–72 per cent for females in comparison with 68–78 per cent for males). This research not only goes to demonstrate the impact video gaming can have upon underlying cognitive processing, but can also obliterate well-observed gender differences.

Aspects of problem solving have also been explored in the context of video gaming with some limited findings. For example, Steinkuehler and Duncan (2008) examined exchanges on the discussion forums related to the role-playing game World of Warcraft (WoW). They were looking for evidence of scientific thought, specifically related to theorising about elements related to in-game play. They found that there was something termed 'social knowledge construction'; the researchers present this as a process of collective development in understanding, usually through a mechanism of joint problem solving. They also found some evidence for aspects of system- and model-based reasoning, which requires an understanding of how certain processes interact and cause an impact on or change in other elements within that system. However, there were some residual methodological problems with the study, with one point being that there was no way of knowing whether this type of specific discussion was linked to the type of game being played or was common across all genres (it should be noted that WoW is more strategy-based, hence doesn't fit directly into the realm of AVGs). Also, it could be that those who are attracted to playing these types of games

already have a higher level of scientific knowledge and awareness, rather than the development of such a skill being fostered through the playing of the game (Steinkuehler and Duncan, 2008).

Other findings have come from research that has used a mechanism of thinking out loud when participants are playing video games. In one study by Blumberg and colleagues (2008) participants were asked to tell the experimenter what they were thinking about whilst they were playing the well-known game Sonic the Hedgehog 2 (terribly addictive, very annoying!). They noted that those participants who engaged in more frequent video game play demonstrated a higher degree of insight (typified as novel approaches to in-game challenges) or more discussion about specific game strategies (such as what type of move is best used to kill off a certain type of enemy). However, other researchers such as Adachi and Willoughby (2013) have questioned the extent to which these problem-based skills could be extended out into wider problem-solving activities that are not specific to the game that is being played.

## **Sustained Attention, Impulsiveness and Vigilance**

These aspects all link to the capacity of the individual to pay attention to elements for a longer period of time, and require aspects of visual working memory to be engaged whilst avoiding the urge to attend to distractions (Evenden, 1999; Logan et al., 1997; Wittmann and Paulus, 2008). Research exploring the impact of video games on the capacity for individuals to remain focused and on task has, however, presented some paradoxical results. As Gentile et al. (2012) noted, exploring the impact of AVGs on these elements requires individual differences to be taken into account before any real differences can be examined. However, they did find evidence to suggest that once these individual differences had been controlled for, those who played AVG demonstrated higher levels of impulsivity and had greater problems in terms of the capacity to focus attention. They also noted that this relationship goes both ways, inasmuch as individuals with issues related to attention and impulsivity will also have a proclivity to spend more time playing AVGs. Gentile et al. (2012) explored the reasons for the link between engaging in AVGs and associated problems with attention. It should be noted that although this work does not specifically mention aspects of Internet use, the association is hard not to make, with other work by Sun et al. (2009) noting similar findings.

The first possible explanation for the attraction to AVGs (as well as digital media in general) is one of excitement. Now let's be honest, being seated in front of any game that is not work is far more attractive when we are faced with the alternative. Indeed, as I am sitting here writing this book chapter, the lure of other

more hedonistic endeavours is a far more appealing thought, but, fortunately for you, I have a great level of impulsivity control. However, the lure of the television, the Internet and AVGs is an obvious one when it is contrasted with the routine of work. There are flashy graphics, excitement, fun and attention-grabbing shiny things that make them a more plausible option compared with the joys of writing yet another report or essay. Many games use the notion of an ‘orientating reflex’ (Sokolov, 1963), something that was previously introduced back in Chapter 4. This exogenous shift means that we will turn and face the direction of something that grabs our attention, particularly in environments of low-level stimulation. The aspects that grab our attention also do something else: they act as an ongoing engagement mechanism, attracting more and more attention from the individual. The suggestion made in the excitement hypothesis is that for many, these features offer the individual a level of interest that sits outside of their normal everyday activities. If the individual is subjected to these exciting and attentionally enticing activities for a period of time, the individual’s expectations for what is a normal level of stimulation will alter. When there is a greater discrepancy between the more interesting and stimulating activities and those that are more mundane and run-of-the-mill, the greater the chance that attentional difficulties will begin to arise (Gentile et al., 2012).

In contrast to these findings, other researchers have noted that AVG players have a greater level of resistance when it comes to preventing distraction from exogenous stimuli. Research presented by Cain et al. noted that when compared with NVG players, those who actively played AVGs could resist the attentional capture of task-irrelevant information in order to focus more directly on task-relevant, goal-orientated information. Such work is also supported by other work that demonstrates AVG players have a greater capacity for cognitive control, perhaps linked to the process of game play which requires focus on concurrent information in order to prevent the player from being attacked (Cain et al., 2012)

### Brain Training: Does It Really Work?

There has been much hype over recent years about the use of digital technology, in particular the notion of brain-training games. There have been some high-profile cases in the media where companies have been fined considerable amounts of money for making a variety of claims that are not substantiated by the research. In 2016 Lumos Labs were fined \$2 million (£1.4 million) for making claims that go far beyond the data. Lumos promoted a suite of 52 games, each one targeting specific cognitive skills. The company published a self-funded report that asserts that the entire suite of exercises is a ‘gym’ for the brain (Shute et al., 2015). The claims made suggest that the program can purportedly train specific areas of the brain, and

if used for a period of 10–15 minutes three or four times per week it could help users maximise their potential in every aspect of their life. Now, apart from the fact that maximising potential appears to be a little bit vague, the company also claimed that the games could also alleviate the symptoms of more serious ailments such as dementia, stroke and brain injury ([www.bbc.co.uk/news/technology-352417780](http://www.bbc.co.uk/news/technology-352417780)).

In this section the aim is to explore the claims that have been made for brain training, and to identify the relevant research that has either found support for or debunked these claims completely.

## What Is Brain Training?

The concept of brain training is more widely viewed as ‘cognitive training’ in the wider research literature. The theoretical perspective follows an analogy linked to learning and improving a particular skill. For example, when you start off doing something like playing darts, you might find it hard to hit the dartboard, but after a period of time you get better, your co-ordination will improve and you will become more proficient.

Brain training relies very heavily on concepts that are directly related to neuroplasticity, something that was introduced in Chapter 3 in relation to the digital immigrant/native debate. To be clear, neuroplasticity suggests that we can bring about changes in the underlying structure and therefore function in the brain as a response to stimulation from the environment (Rabipour and Raz, 2012; Shaw et al., 1994). The attractiveness of this argument means that cognitive training could span a variety of age groups, from the developing brain to one that is in cognitive decline due to old age. The latter is inherently attractive, particularly when the global population is getting older and the potential burden for age-related cognitive decline on already struggling health providers is of central concern for many (Rabipour and Raz, 2012). As we will see in the following section, brain training has been used extensively to explore how cognitive training could be useful in staving off age-related cognitive decline, with Rabipour and Raz (2012) presenting an overview of this research and its ultimate value. Their conclusion is that whilst brain training does improve specific elements of cognitive function, it does not appear to be effective at improving overall global cognitive functioning.

## Transfer Effects

Something that does crop up frequently in the literature on brain training is the notion of transfer effects. The concept of transfer effects has been studied extensively over the past century or so (see Barnett and Ceci, 2002, for a very meticulous review of the research in this area) and refers to how training in one task can benefit or improve another. Transfer effects can be viewed according to

how ‘close’ they are to the original trained skill and are classified in terms of their ‘distance’ from the skill that is the focus of current training. *Near* transfer in cognitive training speak makes reference to the way training impacts on similar types of skills to those being targeted. If we take an example from our daily lives, this might be an improvement in our hand-to-eye co-ordination as a result of training to play tennis. The key here is that an improvement is noted on a similar but not identical skill or task. In contrast, *far* transfer refers to a residual improvement in skills that are outside the current focus of the training, such as finding an improvement in mental arithmetic as a result of training to play tennis.

As we will discuss, the actual evidence for transfer effects is something of a mixed bag, with some researchers finding evidence for this, whilst others have found no such trends. There are a variety of issues that muddy the interpretation of key findings, including aspects of methodological inconsistencies as well as the issues with a clear definition of both transfer effects (Barnett and Ceci, 2002).

## Evidence for the Benefits?

### Brain Training and Its Benefits on the Developing Mind

Miller and Robertson (2010) presented a comparison between three distinct conditions in an attempt to explore the claims that brain training could improve cognitive functioning. In their research they used the popular program *Dr Kawashima’s Brain Training* which was available on the Nintendo DS Lite system. The program itself contained a variety of puzzles that targeted mental calculations and memory retention. However, as Miller and Robertson (2010) noted, there is no evidence from empirical studies examining the objective benefits of such a program. They also included another educational intervention, termed ‘Brain Gym’, which posits that aspects of physical movement facilitate a process of neurological reorganisation. This in turn supposedly promotes ‘whole brain learning’ (Miller and Robertson, 2011; see also Dennison and Dennison, 1994). Brain Gym has gained wide acceptance in an educational context, and according to Miller and Robertson (2011) remains popular in classrooms as a mechanism for enhancing the learning process.

Miller and Robertson’s (2011) study set out to explore which of these two interventions could potentially improve the mental computation skills of children aged 10–11. One group of participants used the brain-training program installed in the Nintendo system, whilst another group engaged in activities from the Brain Gym website. There was also a no-treatment control condition group that essentially did nothing other than their regular daily schoolwork. The results noted a significant difference between pre- and post-test scores on mental arithmetic for both the

brain-training group and the no-intervention group. This would appear to indicate that doing nothing is just as effective as doing something, but when we take a look at the actual level of changes there is a key difference. For the brain-training group, participants showed an improvement that was almost double that in the control condition. This effect was also paired with a similar improvement in time to complete a maths test, with those using the game console to train showing a significant reduction compared with the other two groups. The researchers do, however, note a degree of caution when interpreting these results, given the small sample size of the study and the lack of controls employed related to the expertise of the individual delivering the Brain Gym sessions.

Jaeggi et al. (2011) explored the impact of cognitive training on transfer effects into other areas of cognitive functioning, specifically that of fluid intelligence. Fluid intelligence is often seen as the capacity to engage in aspects of abstract reasoning as well as being able to understand and solve less well-defined problems (Cattell, 1963). As noted by Jaeggi et al. (2011), fluid intelligence is also important in many other respects, predominantly because it can act as a predictor for both educational and professional success (Deary et al., 2007; Rohde and Thompson, 2007; Spinath et al., 2006). The study by Jaeggi et al. (2011) focused on school children aged 8–9 and demonstrated that brain training did work, but there were some moderators. First, the participants only showed beneficial transfer effects to measures of fluid intelligence if they had demonstrated a high training gain in the original working memory task. They also noted that group differences in terms of the benefits of training appeared over time, and in the first three weeks of training no consistent changes were noted. These differences were also persistent, and lasted for at least a three-month period after training had ceased. Such results are supported by earlier findings from Karbach and Kray (2009), who noted that in task-switching training, participants improved on aspects of fluid intelligence alongside aspects of verbal and spatial working memory. However, more recent work by Xin et al. (2014) noted no such improvement in a measure of fluid intelligence for a group of participants aged 60–82, showing how disparate the findings from the research literature in this area can be.

### Impact on the Developing Mind: Using Brain Training to Stave Off Cognitive Decline

As I introduced earlier, part of the push towards the development and use of brain-training activities has been directly related to a potential way of helping stave off cognitive decline, which comes about as a result of old age. Researchers have explored using video games in an attempt to improve the cognitive skills of

older adults with some surprising successes (Basak et al., 2008; Clark et al., 1987; Dustman et al., 1992). For example, Anguera et al. (2013) explored an aspect of cognitive control in older adults, a mechanism that allows us to undertake goal-directed behaviours in complex environments. In their study, participants were asked to play a driving game in which one group had to perform a multitasking activity (keeping track of the car on the road as well as reporting back about information on the screen). For those participants in this multitasking mode, it was found that the residual costs associated with multitasking (in terms of the interference associated with doing both tasks at once) were significantly reduced for those aged 60–85). These gains were also noted for a period of six months after the initial training, with further findings from brain-imaging data showing that the age-related deficits in neural stimulation for cognitive control were reversed through multitasking training. They also found further transfer effects for aspects of enhanced sustained attention and working memory, aspects that were not directly trained for in the original task.

Additional research by Nouchi et al. (2012, 2013) also demonstrated that the use of a specific brain-training program could also improve executive functioning and processing speed. Two groups of participants were asked to play either *Brain Age*, another creation from the mind of Ryuta Kawashima marketed by Nintendo, or *Tetris*. They engaged in playing the game for 15 mins for five days per week over a period of four weeks and were assessed on four key cognitive measures comprising global cognitive status (which included memory for space/time, memory and attention as well as language and visuospatial skills), executive functioning, attention and processing speed. Both groups demonstrated a significant improvement in overall game performance from the first time they played the game up until the end of the training period. For the *Brain Age* group, significant changes were noted in the scores for executive functioning and processing speed, but no such differences were noted for measures of global cognitive status and measures of attention when compared to the *Tetris* group. These findings suggest significant transfer effects for near cognitive skills related to the areas being trained within the game itself.

### Brain Training: When Doesn't It Work?

Just to throw a fly in the otherwise untainted ointment of brain training, there have been some dissenting voices from the world of research. Buitenweg et al. (2012) conducted an extensive review of the literature related to brain training and the senior population and made a variety of broad conclusions. They noted that the results from across the studies they reviewed presented little consistency, and the evidence for transfer effects was limited. Other researchers such as Dahlin and colleagues (2008) noted that transfer effects in the context of working memory training were either small or non-existent.



In one of the largest studies of its kind, Owen et al. (2010) found no consistent evidence for transfer effects from brain training into other skills in a sample of 52,617 participants aged 18–60. Participants engaged in a process of training over a six-week period that included a variety of tasks aimed at improving reasoning, memory, planning and attention. Although the researchers did find a significant improvement in the task on which participants were trained, these effects failed to carry over into untrained tasks even though they shared related cognitive processes. In order to quantify the level of transfer effects elicited, they suggested a partial improvement in memory equivalent to remembering an extra 300th of a digit. Based on their calculations, they suggested it would take an additional four years of training to show an improvement where participants could remember one whole extra digit. The control group actually presented an improvement in memory retention even without any training, demonstrating the issues related to brain training (Owen et al., 2010).

Shute et al. (2015) compared the use of a well-known video game (*Portal 2*) and the software suite provided by Lumos Labs (Luminosity). *Portal 2*, for those who haven't experienced the joy of playing it (and trust me, if you start, be prepared to lose part of your life!), is a first-person puzzle game. The player has to solve a series of puzzles using a variety of tools including a 'portal gun' that can create a portal between two distant points through which the player can travel or transfer objects.

Shute et al. (2015) presented an interesting set of findings from that counter some of the claims made by those who extoll the virtues of brain-training programs. In their study, participants engaged in either an eight-hour period of playing *Portal 2* or the activities presented by Luminosity. They found a significant improvement in three key skills – problem solving, spatial skills and persistence – but for those participants who had been playing *Portal 2* and not those engaged in the activities presented by Luminosity.

## Summary

In this chapter I have aimed to introduce a very broad review of the research that has been conducted into the impact video games and aspects of brain training have on human cognition. As I hope you can see, the findings from research present something of a mixed bag when it comes to making any conclusive statements. One of the key issues that needs resolution if we are to be able to make more direct links between video gaming and subsequent enhancements in cognition is the disparity in methodology between studies (Boot et al., 2011). However, research has noted that those who play video games, or who undergo a period of training

on them, can experience benefits in cognitive skills such as sustained attention, spatial awareness and attentional control to name but a few.

Research has also presented a focus on the potential for video games to be used specifically as a training mechanism to facilitate the improvement of cognitive skills. This focus, stemming from the area of brain training, has presented a number of attractive potential benefits. These relate directly to enhancing cognitive skills in younger children and adults as well as providing a cost-effective mechanism for reversing aspects of age-related cognitive decline in the elderly. However, as attractive as brain training appears, there are the same issues with this type of training as there are for the use of video gaming on more general aspects of cognition. Some researchers have noted that brain training can provide an effective mechanism for training specific cognitive skills as well as presenting far transfer effects in untrained cognitive skills. However, others have noted no such benefits in the context of transfer effects, again demonstrating the importance of more research in this area.