
video games

Video Games

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Introduction

Whether or not certain mentally stimulating activities can improve cognition, enhancing our ability to perform important tasks in our everyday lives, is a controversial topic. In 2014, more than 70 scientists signed a consensus statement arguing that there is little or no compelling evidence that "brain games" can improve cognition (Stanford Center on Longevity 2014). A counter-consensus statement was released a few months later signed by 133 scientists and practitioners. While this counter statement acknowledged that many claims regarding the efficacy of brain training programs have been overstated by companies marketing products, it ultimately concluded that there is a solid and growing body of evidence in support of the effectiveness of some types of brain training, including commercial brain games currently on the market (Cognitive Training Data 2014). Consistent with the claim that the effectiveness of brain training programs is often exaggerated, the U.S. Federal Trade Commission recently fined Lumos Labs, maker of the brain training program Lumosity, $2 million for deceptive advertising (Federal Trade Commission 2016).

This chapter will focus on the evidence for one type of brain training that has received a great deal of attention, and appears to be one of the more promising routes to boosting cognition. Specifically, we examine the role video game training, utilizing commercially available games designed for entertainment purposes, might play in enhancing cognition. While initial findings are promising, the degree to which video game training transfers to other tasks and can improve the performance

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of everyday tasks is debated. The aim of this chapter is to present the evidence for (and against) the idea that video game play can improve cognition, examine this evidence critically, and to present recommendations for more definitive tests of the potential relationship between gameplay and superior perceptual and cognitive abilities.

What Is a Video Game?

In the United States, 65% of households own a device used to play video games, and there are about two gamers in every U.S. household (Entertainment Software Association 2016). In 2015, video game-related sales reached $23.5 billion in the United States alone. With this medium rapidly proliferating across our technological, economic, cultural, and social landscape, it is not surprising that researchers have spent a great deal of time and effort trying to understand the possible positive and negative consequences of video game play.

Esposito (2005) provides a simple, short, and comprehensive video game definition: "A video game is a game in which we play thanks to an audio-visual apparatus (e.g., electronic computers, gaming consoles, mobile phones, interactive peripheral devices) and which can be based on a story." It is clear from this definition that it makes little sense to talk about the effects of "video game" play on something (e.g., cognition, aggression). What counts as a video game is far too broad to expect homogenous effects. Definitions of what a "game" is make it clear that games (including video games) are capable of varying along several important dimensions. Zimmerman (2004) defines a game as "a voluntary interactive activity in which one or more players follow rules that constrain their behavior, enacting artificial conflict that ends in a quantifiable outcome." Video games can differ in the degree and nature of player interactivity, the number of players, game rules, the specific behavior or set of behaviors of the player being constrained, and the nature of the conflict that must be overcome (and the skills necessary to do so). Based on the dimensions along which games can vary, video games can be organized into different genres based on gameplay (Konzack 2014). For example, action games typically require fast responses and place high demands on hand–eye coordination, with common subgenres including fighting games and first-person shooters, while strategy games are slower paced and involve components of planning and decision-making, and often involve play across a large map in which resources must be collected and allocated.

A great deal of research has specifically examined the potential effects of action video game play on perception and cognition, and this will be the primary focus of the current chapter. Within this literature, action games are "characterized by complex 3D settings, quickly moving and/or highly transient targets, strong peripheral processing demands, substantial amounts of clutter, and the need to consistently switch between highly focused and highly distributed attention, all while making rapid but accurate actions" (Green and Bavelier 2015). The most commonly studied action video game subgenre is the first-person shooter. Common to these games, players must navigate 3D environments and shoot enemies while avoiding being shot (often with many enemies attacking at the same time). A number of published studies have found associations between the amount of action video game play a person engages in and their performance on tests of perceptual and cognitive abilities, and training studies that have asked people to play action games or non-action games have provided converging evidence that action video game play can improve these same abilities.

Evidence for Action Game Effects

In 1980s and 1990s, a number of studies were published finding a relationship between video game play and cognition, and a few training studies found that participants randomly assigned to play fast-paced video games improved more on perceptual and cognitive tests compared to participants who were not assigned to play video games (see Boot 2015; Simons et al. 2016). These studies often relied solely on non-experimental designs and experimental designs that did not include strong control groups (e.g., control groups that did not engage in some alternative activity). For these reasons they are not a major focus of the current chapter. However, in 2003 Shawn Green and Daphne Bavelier published an extremely influential paper in *Nature* that reinvigorated interest in the potential of video games as a tool for perceptual and cognitive enhancement (Green and Bavelier 2003). First, the performance of non-gamers (who reported minimal video game usage in the past 6 months) was compared to the performance of action video game players (who reported at least 1 h of action gameplay on 4 days per week over the past 6 months). Action gamers outperformed non-gamers on all reported measures of attentional breadth, flexibility, and capacity (as measured by classic laboratory paradigms including Useful Field of View (UFOV), attention blink, enumeration, and perceptual load tasks). In a separate study, non-gamers were randomly assigned to receive 10 h of experience playing *Tetris*, a puzzle game, or *Call of Duty*, an action video game. Action game assigned participants improved significantly more on the UFOV, attention blink, and enumeration tasks, providing evidence for a causal relationship between action gameplay and superior visual and attentional abilities. Results were notable because of the relatively strong control group (an active control group that played a different video game), the fact that improvements were observed after just 10 h of gameplay, and the fact that improvements were observed on the UFOV task, a task that correlates with automobile crash risk (Ball et al. 2005).

It was subsequently reported that action game training has the potential to improve visual acuity, contrast sensitivity, and the ability to track multiple fast-moving objects (e.g., Green and Bavelier 2006, 2007; Li et al. 2009). Many of these later studies report using significantly more game training, often ranging between 30 and 50 h. Action game effects do not appear to be restricted to visual processing. At least two studies have demonstrated that action game training appears to improve the ability to keep two tasks in mind and rapidly switch between them (i.e., task switching ability; Green et al. 2012; Strobach et al. 2012). Studies comparing gamers and non-gamers have found similar effects (e.g., Colzato et al. 2010; Steenbergen et al. 2015). Another study has reported that action game training can improve visual short-term memory (Blacker et al. 2014), and action game experience is also associated with working memory benefits (Colzato et al. 2013). Action game-trained participants appear to be better able to quickly extract the information necessary to make accurate decisions (Green et al. 2010). Some have even suggested that action video game training can address the root causes of dyslexia in children (Franceschini et al. 2013). While a complete review of the action video game literature is beyond the scope of the current chapter, the reader can refer to Bavelier et al. (2012) and Green and Bavelier (2015) for a more detailed discussion.

Mechanisms of Action

A variety of mechanisms of action have been proposed linking action video game training to improvements in perceptual and cognitive performance. A "common demands" hypothesis claims that many different skills are exercised within action video games (Oei and Patterson 2015). Multiple objects (enemies) must be tracked simultaneously, targets must be detected in the periphery, and attention must be switched rapidly depending on the changing demands of the game environment. Practicing these skills in the varied contexts of action games repeatedly, often under time pressure, allows these skills to then transfer beyond the game itself. This view is in contrast to the proposed "learning to Learning to " hypothesis (Bavelier et al. 2012). This hypothesis claims that action video game experience enhances the ability to extract task-relevant information from the environment to learn new tasks. This is consistent with the finding of Bejjanki et al. (2014) that gamers initially show no advantage, but exhibit a more rapid rate of learning compared to non-gamers. This parsimonious explanation can account for the broad transfer observed to many different perceptual and cognitive outcome measures. While this explanation is appealing, it is also unsatisfying in some respects. It is still unclear from this account what the "active ingredient" is within action games that facilitates the ability to learn more rapidly. Finally, some accounts propose that instead of changing fundamental aspects of cognition, game experience may change how gamers approach tasks (i.e., strategy; Clark et al. 2011). Even short-term game exposure appears to influence whether individuals adopt a strategy prioritizing speed or accuracy (Nelson and Strachan 2009).

Understanding mechanisms of transfer may require a more detailed study of not just transfer task performance, but also game performance. Much might be gained by developing a more detailed understanding of what participants are doing and learning during gameplay (Towne et al. 2014, 2016). Process tracing approaches such as verbal protocol analysis and eyetracking may help link performance changes within action games to performance changes within laboratory tasks of perception and cognition.

While initial evidence suggests that action game training can transfer to a number of other tasks, the mechanisms of this transfer are not well understood yet. Additionally, some researchers have questioned whether part or all of previously observed game effects may be due to methodological confounds. These critics have also suggested that game effects may not be as large and robust as initially thought. These criticisms have major implications for whether or not gaming interventions can be recommended as means to boost cognition.

Failures to Replicate

It is well known that null results are difficult to publish, and that in psychology, medicine, and other research domains there is an excess of positive findings in the literature (Francis 2012; Ioannidis 2005; Rosenthal 1979). Past and recent meta-analyses confirm that the video game literature is no exception. For example, a meta-analysis of cross-sectional game studies conducted by Powers et al. (2013) found that estimates of effect size were reduced from moderate-large to small when correcting for publication bias (see Ferguson 2007; for a similar, earlier finding). For game training studies, estimates of a small-medium effect were reduced to small when accounting for bias. These analyses suggest that if video game play does have an impact on perceptual and cognitive abilities, this effect may be smaller than initially thought.

Further, there have been failures to replicate studies finding an association between gameplay and cognition. Unsworth et al. (2015) examined the relationship between previous video game experience (including action video game experience) and a variety of cognitive abilities in samples of participants 10–20 times larger than the typical video game study (Study 1: $N = 252$; Study 2: $N = 586$). The authors explored the relationship between game experience and cognition at the latent construct level by having participants complete multiple tests tapping the domains of attentional control, working memory, and reasoning ability. In both studies, few robust relationships were observed between gameplay and cognition, and the few effects that were observed were small. Unsworth et al. (2015) ultimately conclude that that video game experience is weakly, if at all, associated with cognitive ability.

Additional cross-sectional studies have tried to replicate and extend previous findings of a gamer advantage. Donohue et al. (2012) conducted an experiment with the aim of exploring whether gamers might multitask better compared to non-gamers. Gamers and non-gamers played a racing game, performed a multiple object tracking task, and performed a visual search task, both under single-task and dual-task conditions. The dual-task condition involved also answering trivia questions. Not only did gamers fail to exhibit evidence of superior multitasking, they failed to perform significantly better than non-gamers on the multiple object or visual search tasks under single-task conditions. Perhaps not surprisingly, habitual gamers outperformed non-gamers on the racing video game. Gaspar et al. (2014) similarly tested gamers and non-gamers in multitasking situations. In this case, participants had to cross a busy simulated roadway as a pedestrian under single- and dual-task load (a working memory task). Again, there was no relationship between multitasking performance and game experience, and there was also no difference between gamers and non-gamers on any of the other tests in a cognitive battery. Tests included measures of UFOV, visual short-term memory, and attentional control. Each of these has been found to be sensitive to game experience in the past.

Game training studies have also failed to find differences between action game training and non-action game training. Green et al. (2010) proposed that action game experience can speed visual information processing. Van Ravenzwaaij et al. (2014) tested this claim in two training studies (one involving 10 h of training, another 20 h). The outcome measure was a visual discrimination task in which participants had to detect coherent motion, a task very similar to the one used by Green et al. (2010). Participants either played the action game *Unreal Tournament* or the non-action game *The Sims*. Unlike the results of Green and colleagues, Van Ravenzwaaij et al. (2014) found no hint of an advantage for participants who played the action game.

Boot et al. (2008) conducted a fairly close replication of the original Green and Bavelier (2003) training study. Rather than 10 h, Boot and colleagues had participants train for 20 h, and also tested double the number of participants per condition compared to the original study. Despite increased training duration and statistical power, action game-trained participants did not improve more than non-action game-trained participants on any of the collected outcome measures, including measures of UFOV, multiple object tracking, visual short-term memory, and executive control.

Inconsistent findings might suggest that other factors may be important in determining whether or not game effects are observed (i.e., moderators). Cardoso-Leite et al. (2016) found little support for an action gamer advantage on four tasks that tapped attention and memory (i.e., few significant main effects of game experience). However, interactions were observed between game experience and the amount of media-multitasking participants engaged in. Media multitasking refers to the tendency to consume multiple forms of media simultaneously, such a reading a book and listening to music at the same time. Action gamers who were high and low media multitaskers exhibited no advantage over non-gamers. However, for intermediate media multitaskers, action gamers outperformed non-gamers.

Hartanto et al. (2016) report that the association between game experience and task switching performance may depend on the age an individual started actively playing video games. Switch costs, for example, did not differ significantly between non-gamers and active gamers who began playing after the age of 12, but did differ between non-gamers and gamers who began playing before the age of 12. On average, participants were 22 years of age, meaning 10 years of gameplay may be necessary before some associations between game play and cognition are observed.

If one assumes that there are indeed causal mechanisms at play, this has significant implications for using games to improve cognition.

Methodological Issues

A number of methodological issues have been raised calling the validity of studies linking gaming and cognition into question. Many studies simply report an association between the amount of gaming a person engages in and his or her perceptual and cognitive performance. Although this pattern is suggestive of the benefits of action video game play, directionality and third-variable problems prevent this evidence from being interpreted as providing a causal link (Boot et al. 2011; Boot and Simons 2012; Kristjánsson 2013). It has also been suggested that recruitment materials for these types of studies that highlight action game skill may bias gamers to be more motivated once they enter the laboratory. Participants know they are being sought for their expertise in fast-paced, visually demanding games, which may influence how they approach the fast-paced, visually demanding outcome measures researchers ask them to perform (but see Green et al. 2014; for a counterargument). However, these concerns appear to be partly justified as recruitment materials have been found to bias how participants perform in brain training studies (Foroughi et al. 2016).

While in principle, training studies allow for causal conclusions to be drawn regarding the efficacy of video game experience, the strength of the control group also needs to be considered. A proper control group adequately addresses the problem of placebo effects, which are observed improvements not due to the power of the intervention itself, but to participants' expectation that the intervention should work. "Sit-and-wait", or no-contact control groups that receive no treatment are insufficient to rule out placebo effects. It is unlikely that doing nothing will generate expectations of improvement as strong as doing something. Any video game training study that compares the effect of a video game to a control group that does nothing is obviously suspect. Active control groups, in which both the intervention group and the control group perform some type of task can better address the problem of placebo effects.

Recently, however, the idea that an active control group in and of itself is enough to control for placebo effects has been challenged. Boot et al. (2013) had participants view a video of a fast-paced action game (*Unreal Tournament*) or a slow-paced non-action game typically used as the control condition in gaming studies (*Tetris* or *The Sims*). Participants were then shown the most common cognitive measures used in these studies and asked about their expectation that the game they saw would improve performance on each cognitive task. Critically, expectations matched the outcome of game training studies in the literature perfectly. Since expectations matched the outcome of action game studies, Boot and colleagues interpreted this as action game effects being indistinguishable from placebo effects. Unfortunately, few video game training studies at this point have measured or controlled for expectations (though see Blacker and Curby 2013).

Conclusion

In this chapter we have reviewed the growing body of evidence suggesting that action video game training is capable of improving perceptual and cognitive abilities. Action game training appears to be one of the most promising means of "brain training." However, we also raise a number of issues that need to be considered before definitive conclusions can be drawn. In addition to evidence that game effects are less robust than initially thought, it is important to note that almost no studies have examined video game transfer beyond abstract laboratory tasks. It is unclear if action game training might, for example, help someone avoid an automobile crash, or make better financial decisions. These are critical questions that need to be answered before game training can be recommended to anyone hoping to gain a cognitive edge.

Where do we go from here? Replication in science is crucial, thus large-scale replications of originally reported action game effects would be beneficial to the field. Larger samples (ideally, with 100 participants per condition or more) can help uncover whether individual difference factors might be important in moderating previously reported effects. These moderating effects might provide insight into previous failures to replicate game effects. Preregistration of intervention designs, outcomes, and analyses can boost confidence that results are robust and are not the result of selective reporting or p-hacking. Future studies might also measure expectations or manipulate expectations directly to help rule out placebo effects, and also assess potential benefits to important everyday tasks such as driving. Finally, a great deal might be learned by comparing game training conditions that are more similar. There are thousands of differences between an action game like *Call of Duty* and a puzzle game like *Tetris*. Any one of those differences might be crucial for producing game transfer effects. Game training studies that compare action game training to training *on the same game*, but with certain game elements removed, might help definitively link perceptual and cognitive improvements to an active ingredient within the action game.

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