Video games: play that can do serious good

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Video Games
Play That Can Do Serious Good

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The authors review recent research that reveals how today's video games instantiate naturally and effectively many principles psychologists, neuroscientists, and educators believe critical for learning. A large body of research exists showing that the effects of these games are much broader. In fact, some types of commercial games have been proven to enhance basic perceptual and cognitive skills. These effects are significant enough that educators use these games for such practical, real-world purposes as training surgeons and rehabilitating individuals with perceptual or cognitive deficits. Although many individuals may still consider video games nothing more than mindless fun, the authors argue that games serve also as serious tools for good. **Key words**: job training and video games; video games and cognition; video games and learning; video games and the elderly

Over the last half-century, video games have evolved from crude contests played by a few enthusiasts to richly immersive worlds enjoyed by billions of people around the world. Games have become big business, bringing in more than sixty billion dollars in global revenue annually (Gaudiosi 2012). They are increasingly recognized as an artistic medium too, as institutions such as the Museum of Modern Art (Antonelli 2012), the Smithsonian (*Smithsonian* 2012), and The Strong feature them. Moreover, games have evolved as novel and effective teaching tools (Gee 2003, 2005; Gentile and Gentile 2008). Today's video games are much more than simple entertainment. They also fight against declining mental capacities in old age, promote job-related skills, and offer models of how to teach children complex tasks and abilities. In hindsight, this may not be surprising.

Video game sales thrive because of good advertising, their ready availability in the market, and their relationships to other, familiar game forms. But video games also prosper because players find them enjoyable. The fun in playing video games depends largely on the games' effectiveness in teaching players to

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succeed. More impressively, video games need to teach players to succeed on a set of tasks that are initially quite difficult. Consumers would not want to play video games they have already mastered from the start; nor would they want to play video games they can never master. Essentially, a game designer needs to ensure that players do fail (if they always succeed, there is nothing to learn) but that this failure does not seem insurmountable, that it even seems fun (Juul 2013).

As we present in this article, modern video games instantiate and demonstrate many key principles that psychologists, educators, and neuroscientists believe enhance learning and brain plasticity. This, in turn, has led some scientists to consider the possibility that video game play may produce not just improvements in the ability to play the games but may, in fact, result in more fundamental changes in the way players see the world and process information. It has also led to a burgeoning field that uses video games—even those designed purely for entertainment—in a variety of practical applications, from training individuals with cognitively and perceptually demanding jobs (e.g., military pilots and endoscopic surgeons) to rehabilitating individuals with deficits in particular types of visual or cognitive processing (e.g., individuals with amblyopia or with dyslexia). In all, what began as simple play has become something with significant real-world relevance.

What Makes Games Effective Teaching Tools?

Whether by careful design or simple trial-and-error, modern video games have come to incorporate many of the best practices known to those interested in learning. This starts with creating an environment that encourages users to invest substantial amounts of time in learning. As every educator knows full well, one of the best predictors of learning is time on task (Greenwood, Horton, and Utley 2002). With all other things being held equal, more hours spent on a task means more learning, and, clearly, video games excel at encouraging players to put time on task. Recent surveys suggest that the average player voluntarily spends between ten and fifteen hours a week gaming (Rideout, Foehr, and Roberts 2010). If only high school students could be convinced to voluntarily spend that amount of time on their studies! Although the reasons games produce such dedication are myriad, many—at their root—relate to reinforcement. Like all animals, humans are wired to perform those actions that result in some reward or fulfill some basic need. Indeed, behavioral research shows that games are capable of providing a variety of basic psychological needs. These include autonomy (the belief that one has control over his or her own actions and decisions), competence (the belief that one has the level of skill necessary to achieve goals), and relatedness (the feeling that one is socially connected with other human beings) (Przybylski, Rigby, and Ryan 2010).

Research shows that our brains release in abundance neurochemicals related to reward processing—for example, dopamine—when individuals play video games. These are the same chemicals the brain releases when a hungry or thirsty person receives food or water, as well as when someone takes one of the many commonly abused drugs. In fact, the magnitude of the dopamine release related to playing electronic games resembles that related to some recreational drug use (Koepp et al. 1998). Critically, these same brain chemicals prove essential in permitting brain plasticity and thus learning (Bao et al. 2001). To some extent, we could consider the release of these reward chemicals as a signal to other parts of the brain that an important event has occurred, one that necessitates reorganization to increase the likelihood that the future rewards of the event will also be received.

However, reinforcement alone may not be sufficient to explain the extreme levels of time on task that games produce. Timing, too, is crucial: reinforcement must come at proper intervals and in proper relationship to in-game events. Well over half a century ago, psychologists demonstrated that animals work hardest and longest when they are rewarded in a way that makes them believe there is always a chance their next action will reward them (i.e., a variable ratio-reward schedule). Because the individual never knows exactly when the next reward will come, he or she is strongly motivated to keep at the task. Many video games enhance this effect by layering multiple reward schedules. Therefore, even if one reward is far away, another is almost certainly approaching (e.g., I may need to find one hundred more gold coins to buy the new suit of armor, but I am only two animal furs away from being able to trade for the new sword).

The amount of time on task that playing games encourages will ensure ample opportunity to learn the game skills needed for mastery. Good video games make certain that the player has acquired a sufficient level of expertise in each and every element before administering any cohesive assessment, such as a final boss encounter—similar to the concept of the spiral curriculum in educational psychology (Bruner 1960). Reaching this point of practice beyond perfection (or overlearning) is highly linked to overall retention levels and the ability to access information at a later time (Willingham 2004).

However, time on task can only go so far in stimulating learning if the tasks themselves are poorly structured. All good video games incorporate one crucial learning principle: a proper level of difficulty. If individuals find a learning task too easy, they will not make enough errors to necessitate improvements (i.e., if you make no mistakes, you have nothing to learn). Conversely, if they find a learning task too difficult, the error signals can be uninformative and thus again, they will not learn anything (e.g., a first-grade student would learn very little about quantum physics by receiving graduate-level feedback on exams). Educational psychologists have long believed that the most effective learning paradigms keep individuals right at the edge of their ability in something they call the "zone of proximal development" (Vygotsky 1978). In this dynamic process, the game designer carefully determines the initial level of difficulty of the game and increases it as the individual player improves.

Video games employ a number of methods to ensure that players remain at a challenging level but have tasks they can accomplish. For instance, nearly all games provide several user-controlled difficulty settings (such as "casual" or "expert"), some of which the players can only attempt after they demonstrate proficiency at lower difficulty levels. In the game *Gears of War,* for example, the "insane" difficulty level can be accessed only after the player has mastered the "hardcore" difficulty level. Many games have a series of early "training" exercises that players can bypass by demonstrating a particular level of game competence. Furthermore, some games even manipulate the level of difficulty online depending on current player performance. For instance, in the *Mario Kart* racing video game series, players who are further back in races will often receive more helpful items than players who are toward the front. Or in the video games *Resident Evil 5* and *Left 4 Dead*, player performance is constantly evaluated and used to determine game play elements such as the number of enemies that appear and the level of enemy resistance.

Techniques like these ensure that gamers learn, but it is the last learning principle—variability of training—that allows these players to apply the skills they have learned in more general contexts. As we describe, individuals who are trained on a very limited stimulus-response set learn to perform the exact task for which they are trained, but they find it difficult to generalize those skills to new tasks or contexts. As a classic example, Catalano and Kleiner (1984) had participants view a series of lights arranged in a row. The lights turned on sequentially at a constant rate, starting with the light furthest from the participant and ending with the light closest to the participant. The participant's job was to press a button as close to the onset of this final light as possible. One group of participants trained at just one rate, while a second group trained on a variety of rates. After training, both groups were then given a rate neither had previously seen before. While the group trained on the single rate performed quite poorly (because their learning was specific to the one rate that they experienced), the group trained at more variable rates performed quite well. This basic principle holds for environments like education, where children who master material in just one way (e.g., responding to multiple choice questions) find it difficult to apply what they have learned in new ways (e.g., in an essay format).

Video games typically force the player to learn a task in many different ways. Take, for instance, a race-car game. The player may be asked to drive several different race cars, varying slightly in their dynamics, on a series of different courses, and in the presence of a diverse set of computer opponents. Even a "simple" game like *Super Mario Bros.* requires players to use a small set of actions in a wide variety of contexts (jump over a pit, up a set of blocks, and onto a goomba, for example).

How Does Gaming Change Perceptual and Cognitive Processing?

Game designers want to make sure players learn to play the games they design so that these players will then buy the games they have come to enjoy. But research over the past decade has shown that the effects of learning to play at least some types of video games extend well beyond the market confines of commercial entertainment. One genre of video games in particular, the action video games—which involve lots of fast motion, many items to keep track of simultaneously, and a need to attend to peripheral vision constantly—has been linked to a multitude of benefits from the lowest levels of perception up through the highest levels of cognition.

Before we describe the benefits researchers have found in action video game play, we should briefly discuss how they conduct these studies (see figure 1). Most studies begin with an "experiment of nature." Some individuals spend a significant amount of time playing action video games as part of their daily routines, while others eschew the genre (although they may play other types of games). Thus, researchers first ask whether these self-reported action video game players (AVGPs) outperform nonaction video game players (NVGPs) at a given perceptual or cognitive task (figure 1A). If researchers, indeed, observe such a difference, it is then necessary for them to perform a carefully controlled experiment to establish that it is actually the act of playing action video games that results in enhanced performance. After all, there are countless underlying factors that might explain why some individuals choose to play action video games while others do not, and some of those factors may be related to base perceptual and cognitive skills. That is, it might be the case that people born with good vision are attracted to action video games because their inherent skills enable them to perform well, but individuals born with poorer vision may avoid action video games because their lack of inherent skill ensures they will perform poorly.

To verify that playing video games actually causes an increase in perceptual or cognitive ability, researchers first selected individuals who naturally do very little video gaming, that is, individuals who have no familiarity with any of our training games and who usually play video games rarely, if at all (figure 1B top panel). They are then pretested on whatever measures are of interest (e.g., low-level vision) before being assigned to one of two groups. One group receives extensive training on an action video game (depending on the study, this may be ten, twenty, or even fifty hours of experience spread out over the course of many weeks). Another group receives the same amount of total video game experience; however, group members play a nonaction game instead. Researchers specifically select the nonaction game to be as interesting, engaging, and fun as the action game, but also one that lacks the critical demands present in action games.

At least twenty-four hours after the final training session, the participants are once again tested on the base measures of interest. The delay ensures that any observed effects are not due to short-term changes associated with game play. Indeed, if we are to use video games as a tool for learning, it is critical that we make sure the impact is long lasting (i.e., it is still observable days, months, or even years after the end of the video game play training). If the group trained on the action game shows a larger improvement from pretest to posttest than the group trained on the control game, the researchers can infer that the action games do, indeed, cause changes in perception and cognition (figure 1B, bottom half).

Finally, it is important to note that the beneficial effects observed in this research are no excuse for binging on video game play. In fact, there are literally hundreds of psychological studies showing that "massed practice"—accumulating many hours of training in a short amount of time—will greatly reduce the

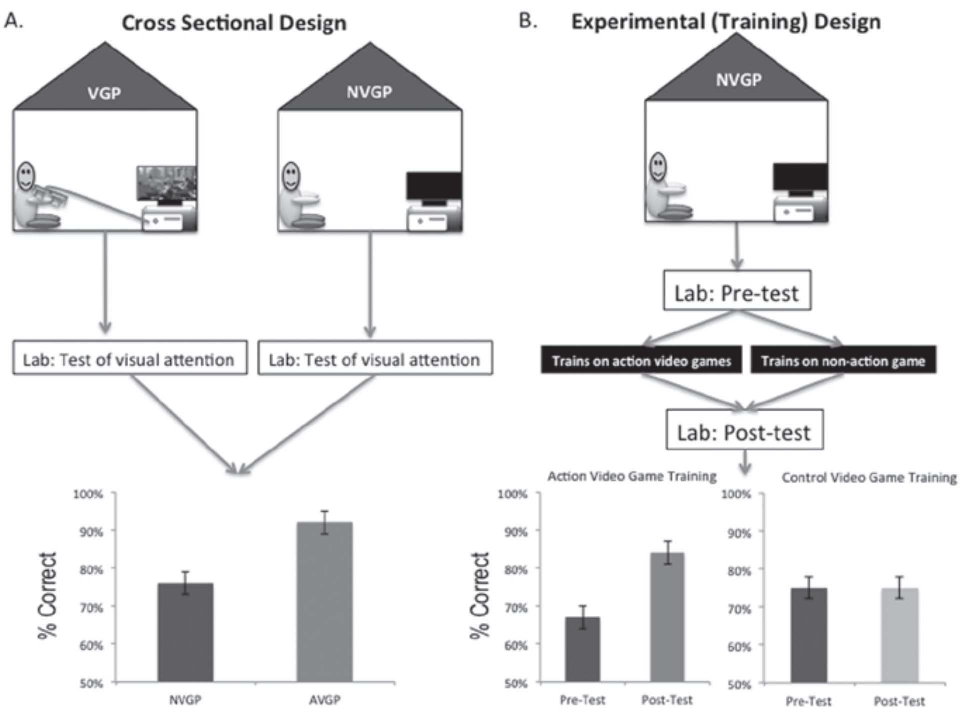

Figure 1. Testing the effects of action video game play on perception and cognition

efficiency of learning (Cepeda et al. 2006). In accordance with this principle, successful training studies have all used distributed practice that requires participants to play only between thirty minutes and seventy-five minutes per day and for no more than five days a week over a period of several weeks. Thus, training in a ten-hour training study would occur over the course of about two weeks, while a fifty-hour training study would require about ten to twelve weeks (Stafford and Dewar 2014).

Vision

Action video game training enhances several aspects of vision. One aspect involves contrast sensitivity, or the ability to detect small incremental changes in shades of gray. This ability is considered one of the primary building blocks of all vision. If an individual cannot detect differences in luminance between two adjacent parts of the visual world, he or she could not detect edges and thus object boundaries, background, and foreground. Li and colleagues (2009) first performed the "natural experiment"—assessing contrast sensitivity in AVGPs and NVGPs. When they found that AVGPs substantially outperformed NVGPs (meaning AVGPs were able to detect smaller changes in gray compared to NVGPs), the researchers then established a causal role of action gaming via a training study. Individuals who underwent fifty hours of action video game training (spaced out over ten to twelve weeks) improved their contrast sensitivity abilities by significantly more than individuals who underwent fifty hours of control video game training. Similarly, Green and colleagues (2007) determined that action gaming improves another key aspect of vision—crowded acuity. Here, action gaming improved an individual's ability to resolve small visual details in the presence of visual distractors. We find this particularly interesting because crowded acuity is linked with performance in higher-level visual tasks such as reading. (When you read, for example, you do not fixate specifically on each individual letter; and thus most letters need to be individuated and identified from among their neighbors in your peripheral vision).

Visual Attention

Beyond low-level vision, action video gaming also improves what is known as visual selective attention. It is important to note that the use of the term "attention" here is not the same as the lay definition (i.e., to pay attention in class). Instead, visual selective attention is the process of choosing which aspects of a stimulus should receive additional neural processing and which should be filtered. For instance, think of making conversation at a noisy party. Although you can "hear" many ongoing conversations, selective attention (auditory attention in this case) enables you to listen to only the voice of your conversation partner and block out the other conversations. This fundamental ability to select task-relevant items and filter out task-irrelevant items improves with action video gaming in a number of distinct domains including across space, across time, and in relation to objects (Green and Bavelier 2003, 2006a, 2006b; Spence et al. 2009; Feng, Spence, and Pratt 2007; Cohen, Green, and Bavelier 2007; Li et al. 2010; Awh, Vogel, and Oh 2006; Mishra et al. 2011; see Green and Bavelier 2012 for a review and Boot et al. 2008 for an alternative view).

In the spatial domain, one well-established measure of selective attention is the Useful Field of View (UFOV) task. This task was originally developed by Ball and Sekuler (1982) as a predictor of driving-accident risk in the elderly (because driving accidents are typically related more to issues of attention such as not noticing a moving car in an intersection with parked cars and other visual clutter than to simple visual acuity or the reading of the bottom line on an eye chart). The UFOV task requires the participant to localize a quickly flashed peripheral target from among a full field of distracting clutter. A number of individual research groups have noted the benefits of action gaming on this task in correlational studies and training studies in several distinct populations of children and adults. The studies indicate that action gaming improves the ability to focus attention on task-relevant information across space (Green and Bavelier 2012).

Another key component of visual attention enhanced by action video game play is the ability to focus on objects across time. For instance, in one common task of temporal visual attention, participants view a stream of letters presented one quickly after another. Although most of the letters in the stream are black, one of the letters is white. The participants know they must watch for the white letter and indicate its identity at the end of the trial. Furthermore, in half the trials, at some point after the appearance of the white letter, a black letter "X" appears. At the end of the trial, researchers ask the participants to tell them—yes or no—whether they saw an "X." Notably, if the "X" appears very shortly after the white letter (e. g. within one hundred to two hundred milliseconds), participants have a tendency to miss it entirely, a phenomenon known as the "attentional blink" (Raymond, Shapiro, and Arnell 1992). Action gaming can substantially reduce the size and duration of this blink. In fact, in a training study performed by Oei and Patterson (2013), twenty hours of training on an action video game was sufficient to essentially eliminate the blink entirely. Clearly, action gaming improves the ability to focus on task-relevant information across time.

And finally, in addition to the ability to attend to distinct spatial locations and distinct points in time, action video gaming also enhances the ability to attend to distinct objects. One common laboratory measure of this capacity is the multiple-object-tracking (MOT) task. In this task, participants are shown a number of randomly moving circles. Initially, some subset of the circles is perceptually distinct from the others (e.g., four moving circles are red, while the remaining twelve circles are green). Then, after a few seconds, the distinct circles change to be perceptually identical to the distracting circles (i.e., the red circles turn green). The participants' job is to keep track of the initially distinct circles for several seconds. Then one circle is cued, and the participants are asked to indicate whether the cued circle was one of the originally distinct circles. Several studies have used this task to show benefits for adult AVGPs and in NVGPs specifically trained on action games in the lab. In addition, several research groups have also used it to assess the abilities of action game playing children. In a study of six-, eight-, ten-, twelve-, and nineteen-year-olds, Trick and others (2005) found that children who frequently play action video games could track significantly more items correctly, across all age groups, than individuals who did not engage in video game play. In 2010 Dye and Bavelier replicated these findings, and in their sample, action game playing children as young as ten years old were already performing better than nonaction game playing adults.

Sustained Attention, Impulsiveness, and Vigilance

While it is clear that action video game play improves selective attention, selective attention is not what psychologists call sustained attention or vigilance (terms that map much more closely to the lay definition of attention, such as paying attention in class). Indeed, there is some concern that interactions with some types of video games or other forms of technology could negatively affect the ability to focus on single (usually, very slowly changing) streams of information for long periods of time (Gentile et al. 2012). However, action gaming seems not to have to any negative impact on this type of attention.

Action gamers and nongamers have been compared on tasks such as the Test of Variables of Attention (TOVA). A common tool for measuring sustained attention and impulsivity, the TOVA is often used clinically to assess Attention Deficit Hyperactivity Disorder, or ADHD (Greenberg 2013). For the TOVA, in each trial, participants are shown one of two shapes. If shape A appears, the test asks participants to click a button as quickly as possible. If shape B appears, the test asks them to make no response (i.e., what is called a “Go–No-Go” task). Two blocks measure sustained attention and impulsivity respectively. In the sustained attention block, there are far more trials with shape B (where participants should make no response) than with shape A (where participants should make a response). The critical measure is thus whether participants are able to stay on task and respond quickly to rare trials where they should respond. The impulsivity block is essentially the opposite. In this block, there are far more trials with shape A (response) than shape B (no response). The critical measure is thus whether participants are able to withhold a response when most of the trials require a response.

In a study by Dye, Green, and Bavelier (2009), AVGPs responded much quicker than NVGPs on both test components (impulsivity and sustained attention) and had either equivalent or greater accuracy, thus demonstrating that the faster reaction times were not simply due to a speed-accuracy trade off. Moreover, in a training study using elderly individuals and a custom-made action video game, Anguera and others (2013) found similar results, providing a causal link between action video game play and both faster processing and enhanced sustained attention. Thus, while it may be the case that some types of games or other new media do lead to issues with sustained attention, it does not appear that this is true of action video games, at least as measured by the TOVA.

Cognitive Flexibility and Executive Functioning

We see the benefits of action video game training not only in basic sensory and attentional capacities, but also in higher-order, executive abilities. We think of executive control loosely as the ability to select and manage multiple cognitive processes, such as attention, memory, and planning. For example, imagine a scenario where you are taking the subway to work and a friend calls just as you are approaching the station. In a relatively short time, there are a number of tasks that must be accomplished. You must talk to your friend, purchase a ticket, and find the right train, all while you are walking around a crowded and distracting subway station. There are a number of executive processes involved in such a real-world situation, including task-switching (e.g., when you temporarily stop talking to your friend to insert money into the ticket machine) and dual tasking (e.g., when you both speak and navigate the station).

We can test executive processes like these by giving individuals multiple laboratory tasks simultaneously and comparing their performance in this multitasking case to their performance when given the same tasks in isolation. In one such study by Strobach, Frensch, and Schubert (2012), a group of NVGPs trained on an action, first-person shooter game for fifteen hours while a control group trained on *Tetris* for the same amount of time. Prior to and following training, participants completed a test in which they had to indicate the frequency of a sound (low, medium, high) and the size of a triangle (small, medium, large) simultaneously. NVGPs who trained on the action shooter game showed significant improvements on the dual-task test while the control group who played *Tetris* or no game at all did not show any improvement. Chiappe and colleagues (2013) found similar improvements in dual tasking in a fifty-hour training study. Specifically, this study examined performance on the Multi-Attribute Task Battery (MATB), which consists of four tasks that subjects have to perform at the same time. The tasks are based on those of aircraft operators such as using a joystick to keep a target centered on screen, monitoring fuel levels, responding to lights on an instrument panel, and listening and responding to radio communications). Thus it is not surprising that performance on the MATB correlates with real-world performance (Comstock and Arnegard 1992). The fact that action video game training led to clear enhancements on the MATB suggests that the multitasking benefits of action video game experience may "scale up" to real-life, complex situations—though more studies are needed to confirm this theory.

In addition to multitasking, executive control can also be measured by testing an individual's performance when instructed to switch quickly between two tasks. For example, in a typical task-switching paradigm, participants are shown a digit from one through nine (not including five). On some trials the subjects are cued to indicate whether the number is even or odd. On other trials they are cued to indicate whether the number is greater than or less than five. Clearly, responses are significantly slower in those trials where participants have to switch tasks (e.g., in the previous trial the participants indicate greater than or less than five and on the current trial they are asked to indicate even or odd) than on trials during which they perform the same task they performed in the previous trial. Researchers refer to this difference in reaction time between switch and nonswitch trials as the "switch cost." There are now several studies showing the benefits of action gaming on task switching (Anderson et al. 2010; Green et al. 2012; Colzato et al. 2014). While action gaming does not seem to eliminate the cost of switching between tasks entirely, it cuts the size of the cost significantly. For example, in one study, the cost was approximately halved after action game training.

Effects of Other Types of Games

While the majority of research performed in this field has focused on action video games, newly emerging research suggests that in addition to action games, other types of video games may also improve certain cognitive functions. In particular, whereas action video games stress the fast allocation of attention to several different objects in the environment and require players to respond immediately to prevent failure, another genre of video games, real-time strategy (RTS) games, places an emphasis on active maintenance of many different units, each having its own timing hierarchy and schedule. Using a methodology similar to those employed in the action video game studies, Glass, Maddox, and Love (2013) showed that forty hours of training on an RTS game resulted in significant increases in cognitive flexibility (including task switching and working memory).

Training on RTS games also helps elderly individuals combat age-related declines in cognitive abilities (Basak et al. 2008). Participants, with an average age of seventy years, who trained on an RTS game (*Rise of Nations*) for 23.5 hours showed greater improvement at posttest than did the control group on measures of executive control—including transfer of improvement to untrained tests of task switching, working memory, and abstract reasoning. Results such as these have recently been achieved by playing action-oriented video games on mobile devices like an iPod Touch and a tablet device (Oei and Patterson 2013). While this literature remains in its infancy, the results thus far are consistent with the overarching idea that games that constantly challenge different aspects of perception, attention, and cognition in a variety of contexts are likely to result in enhancements of these base abilities.

Why Are These Effects Surprising?

While it may seem intuitively obvious that training on perceptually and cognitively demanding video games would improve one's perception and cognition, this outcome is actually very different from those typically described in the perceptual and cognitive-training literature. Here the discussion much more commonly centers on the *specificity of learning*. While it is true that individuals can be trained to improve their performance of essentially any task given appropriate practice (i.e., time on task, spacing between practice blocks, and feedback, if necessary), typically the learning does not transfer to extremely similar new tasks (Fiorentini and Berardi 1980; Ahissar and Hochstein 1997; Fahle 2004, 2005). For instance, one classic learning task studied in the perceptual-training field is the vernier acuity task. For this task, participants view two short vertical line segments one on top of the other. The top line segment is offset very slightly either left or right of the bottom line segment and participants must determine which is the case. Extensive training on this task can produce abilities that are truly remarkable. In fact, the world record for vernier acuity is less than one second of arc—roughly 1/360th of your pinky nail at arm's length or, incredibly, the width of a pencil at the distance of a mile (McFarlan et al. 1991).

However, though long-term training can produce these incredible levels of performance, once the task is changed even slightly, all evidence of learning disappears. This result holds true, for instance, if you change the orientation of the lines (e.g., from vertical to horizontal), the position of the lines (e.g., if you trained on stimuli in the left part of your vision and then move them to the right part of your vision), or even the eye with which you perform the task (e.g., if you trained using only your right eye and then attempt to perform the task with your left eye). Similar specificity is often also seen in cognitive training—such as with some so-called "brain trainers." For example, Owen and others (2010) conducted a large-scale study of the effectiveness of a set of small brain-training exercises. Although subjects improved their performance on the brain-training tasks themselves, there was no benefit on more general tests of reasoning or memory.

Finally, we can observe specificity even after some more complex types of training. Kida and colleagues (2005) tested a sample of baseball players and individuals who do not play the game using both a simple reaction-time task as well as a more complex reaction-time task that better reflected the aspects of a batter at the plate (Go–No-Go decision-making reaction test). In a two-year longitudinal study with high school athletes and nonathletes, baseball practice led to improvement on the Go–No-Go test but not on the simple reaction-time test. Similar results have been found for expert tennis players (Overney et al. 2008) and experienced clay shooters (Abernethy and Neal 1999). Thus, the fact that video games overcome this "curse of specificity" and instead produce quite general benefits to perception and cognition is one of the primary reasons these games are of such interest to the scientific community.

Real-World Uses of Video Game Training

Because video games make such broad improvements in basic processing abilities, researchers have attempted to use these games for practical applications. This is true for retraining individuals with amblyopia (colloquially known as "lazy eye"). Amblyopia typically develops from vision problems during early childhood—for instance, from strabismus (where the two eyes are not properly aligned) or from childhood cataracts (where the lens of an eye becomes cloudy). Because the brain expects two eyes to provide mutually consistent information, when one eye does not, the brain essentially learns to "ignore" input from the bad eye. Critically, ophthalmologists generally consider this process mostly irreversible after a critical point during childhood (Li et al. 2011).

Given that action video game play had proven successful in improving vision in normally sighted adults, Li and colleagues tested the same type of training in adults with amblyopia (see figure 2). The researchers instructed patients (who at pretest had one poor eye) (figure 2, left panel) to play either an action game or a control game for forty hours with only their bad eye (an eye-patch was worn over the good eye; see figure 2, middle panel). At several points in the training, participants completed a battery of visual tests including measures of visual acuity, visual attention, and stereoacuity. Visual acuity for participants in the action game group improved dramatically: some amblyopes became completely normal (i.e., their vision returned to 20/20 or better; see figure 2, right panel). To determine if the effects were due to the patching of the good eye alone, another group of amblyopes wore a patch while engaging in activities such as reading, knitting, and watching television. However, after twenty hours of wearing the patch, there was no improvement in acuity in this group, suggesting that the benefits were indeed due to the influence of the video games (for further evidence see Waddingham et al. 2006; Bavelier et al. 2010; Li et al. 2013).

In the cognitive domain, video games have become an effective means of fighting off the cognitive decline seen with normal aging and potentially even of reducing the probability of Alzheimer's and similar disorders by ensuring that players stay mentally active. Many studies demonstrate the positive effect that video game play can have on the aging population. As we have seen, playing a custom-designed action video game can improve abilities such as information processing and sustained attention. Furthermore, a group of sixty- to eighty-five-year-olds improved on measures of multitasking and cognitive control, benefits that persisted for at least six months following training (Anguera et al. 2013). In all, video game training studies have documented improvements in elderly individuals' ability to perform tests of perceptual, attentional, and cognitive abilities (Allaire et al. 2013; Wolinsky et al. 2013). One study found that in addition to the cognitive improvements following video game training, elderly participants also had a better self-concept and enhanced quality of life (Torres 2011).

Children with dyslexia also seem to benefit from training on action video games. Although researchers typically consider dyslexia (a blanket term for an age-inappropriate ability to read not explained by issues with base intelligence) to be related exclusively to issues unique to language (e.g., phonology), recent studies suggest that, at least in some children, part of the deficits may involve visual attention (because vision is essentially the "front end" that provides information to the language system in reading). One recent study compared the reading, phonologic, and attentional skills of two matched groups of dyslexics after they had trained for twelve hours with either an action or a nonaction video game. Training on the action game resulted in improvements for all measured abilities compared to the nonaction game control group. These improvements

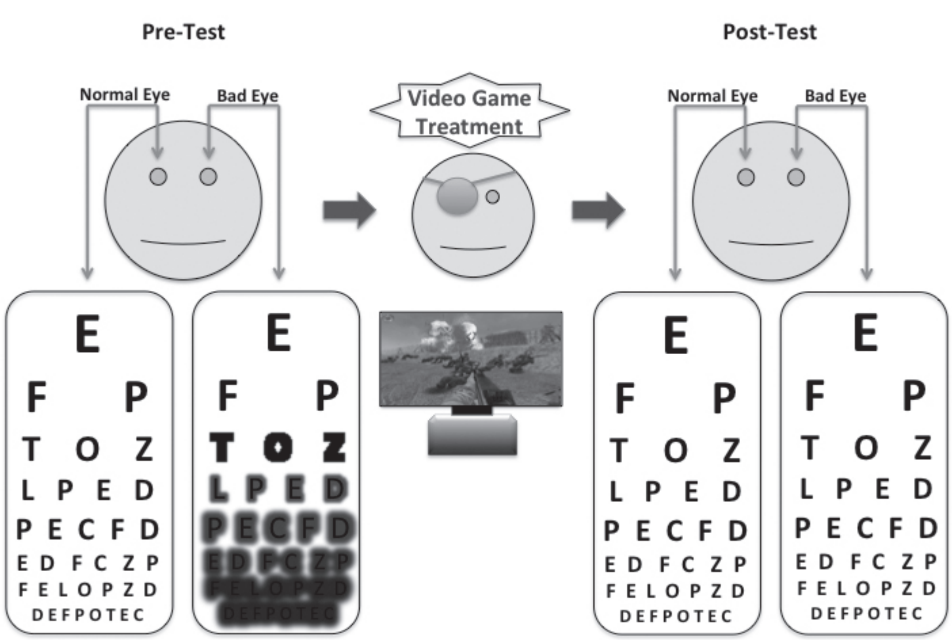

Figure 2. Testing the effects of action video game play on the vision of adults with amblyopia

matched or outpaced highly specific reading regimens commonly used as treatments for dyslexia (Franceschini et al. 2013). While this study will need to be replicated in larger samples and with different languages (the children in the study spoke Italian, which is quite different from, for instance, English), the fact that the improvements in reading scores strongly correlated to improvements in more basic visual attention suggests that it may, indeed, be improvements at this front end that explains the enhancements in reading.

Another practical application of video games involves job-related training (specifically jobs with demanding heightened perceptual, cognitive, or motor skills). For instance, in the early 1990s, researchers linked video game experience to improvements in the flight performance in military pilots (Gopher et al. 1993). More recently, a study by McKinley and his co-workers (2011) assessed the ability of three groups—trained pilots, video game players, and a control group of nonplayers—to fly and land aerial drones successfully. While trained pilots outperformed individuals in the control group on all measures of flight performance, the difference between trained-pilot performance and avid video game player performance was much smaller. In some cases, the video game players' performances were equivalent to those of the pilots.

In a study of medical training, a team from Beth Israel Medical Center noted that young, inexperienced, endoscopic surgeons who were also avid video game players outperformed the most experienced surgeons in their field (Rosser et al. 2007). Endoscopic surgery shares important surface features with video game play, in particular the use of a hand-held device guided by visual feedback. A large number of studies suggest that video game–playing surgeons outperform their nonplaying peers on many measures of surgical performance (see Ou et al. 2013 for a review). In fact, in at least one case, the number of hours per week the surgeon spent playing video games was a better predictor of surgical performance than factors like number of surgeries completed or years of training. Finally, a more recent study found that novice surgeons who underwent video game training performed better on simulations of laparoscopic surgery than a control group of doctors who do not play video games. In addition, those trained on the action video game outperformed a group who played a non-action, cognitively demanding video game on several measures (Schlickum et al. 2009). These studies, again, illustrate the direct link between action game play and impact.

Lastly, there are numerous researchers looking to use video games, not because of the cognitive or perceptual benefits that they engender but, simply, because they are engaging and enjoyable for children. Indeed, there are now many instances where video games have been used to help children through an illness or injury that requires constant maintenance or to distract them from irritating symptoms of their illness. As an example, children with hyperfunctional voice disorders must comply carefully with their physician's instructions to prevent further laryngeal damage and to recover. Understandably, constant focus and maintenance is a difficult task for a child, so the use of video games to hold their attention and educate them about the illness seems obvious. One study found that, through the implementation of an entertainment-based video game, children better followed therapeutic protocol than they did prior to implementation (King et al. 2012). Video games have also been used to aid children with diabetes. In one such study, one group of children played a diabetes-specific education game, while another group did not. After six months of play, the children who experienced the game demonstrated significant improvements in managing their diabetes on their own, greater communication with their parents about the illness, more self-help behaviors, and a decrease in unplanned diabetes-related doctor visits (Brown et al. 1997). Video game usage has also helped children fighting nausea from chemotherapy (Redd et al. 1987), distracted children with asthma (Lieberman 2001), and encouraged preadolescents to avoid smoking (Lieberman 2001).

Conclusion

Over the past half-century, video games have evolved into effective learning tools. Not only do they promote an astounding amount of time on task, the games also use a number of techniques known to promote efficient and transferable learning. Although some researchers express concern about the potential negative outcomes of gaming, others see quite clearly that video game training creates a great number of positive outcomes. A growing body of research demonstrates that some types of games, in particular action video games, promote improvements in a wide variety of perceptual, attentional, and cognitive abilities. These enhancements are of a scope and scale that such games are being used, off the shelf, for a variety of practical purposes. Today's video games are much more than entertainment. They are also weapons in the fight against declining mental capacities in old age. They promote job-related skills. And they are a model of how to teach children complex and difficult tasks and abilities. As with any technology, video games are neither intrinsically good nor intrinsically bad. Instead, the nature of their impact depends upon what users make of them. The research reviewed in this article makes clear that video games represent a form of play that can be harnessed for serious good. The challenge we now face is to determine those game-design ingredients that most efficiently help, for example, an Alzheimer's patient fight cognitive decay or more efficiently teach a twelve-year-old mathematics. Systematic research—including direct collaboration between the video game industry and research scientists—will go a long way to speeding the pace of discovery.

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