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The Impacts of Video Games on Cognition (and How the Government Can Guide the Industry)

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Abstract

Video game play has become a pervasive part of American culture. The dramatic increase in the popularity of video games has resulted in significant interest in the effects that video gaming may have on the brain and behavior. The scientific research to date indicates that some, but not all, commercial video games do indeed have the potential to cause large-scale changes in a wide variety of aspects of human behavior, including the focus of this review—cognitive abilities. More recent years have seen the rise of a separate form of video games, the so-called "brain games," or games designed with the explicit goal of enhancing cognitive abilities. Although research on such brain games is still in its infancy, and the results have definitely not been uniformly positive, there is nonetheless reason for continued optimism that custom games can be developed that make a lasting and positive impact on human cognitive skills. Here, we discuss the current state of the scientific literature surrounding video games and human cognition with an emphasis on points critically related to public policy.

Keywords

video games, brain games, cognitive enhancement

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Playing some, but not all, video games can improve perception and cognition. Many issues remain, though, particularly how to best translate research to produce public good.

Key Points

- Playing some types of video games, particularly "action" video games, results in widespread enhancements in cognitive function.
- There is evidence that other types of games can also lead to similarly positive outcomes—for instance, certain custom designed "brain games."
- Many questions remain as to how to best translate the base science to produce public good.
- Many questions remain as to how to best regulate the industry promoting games for cognitive enhancement.
- Effective governmental regulations would provide an incentive structure for better science to be conducted, in particular, by recognizing that scientific evidence for product efficacy is typically graded, rather than all-or-none.

Introduction

Over the past half century, video game play has gone from being a somewhat fringe activity to a ubiquitous part of modern culture. While the first dedicated video game console (the Magnavox Odyssey, released in 1972) sold only about 300,000 units, the three major consoles released in the mid-2000s (the Xbox 360, the PlayStation 3, and the Wii) sold more than 84 million units each. More than 40% of Americans report playing video games regularly (i.e., more than 3 hr a week), and counter to impressions that video games are the exclusive domain of male children and teenagers, video game use cuts across nearly all American demographics, with 27% of players being above 50 years of age and 44% of players being female. This shift toward gaming has resulted in a concomitant decrease in time spent watching television or movies (Entertainment Software Association, 2015).

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The rising popularity of video games has spurred significant interest in how video games may alter the human brain and human behavior. This is a concern not just for research psychologists but also for politicians, parents, teachers, medical doctors, and many others involved in setting and implementing public policy. Numerous questions surrounding the effects of video games—spanning many psychological domains—have already made their way from the scientific to the public sphere. For example, in the domain of social psychology, a recent Supreme Court case ("Brown v. Entertainment Merchants Association," 2011) grappled with the question of whether certain types of video games (specifically graphically violent video games) represent a sufficient threat to the social-psychological development of children to warrant state-mandated restrictions on their sale.

Here, we examine just one of these domains—the cognitive effects of video game play. Research shows that playing some types of video games produces significant and long-lasting enhancements in a variety of cognitive functions. The scope and scale of these beneficial effects has prompted many research groups to test efficacy of video games in real-world contexts such as in rehabilitative settings or in job-related training (Green & Bavelier, 2012). However, research of video games is fraught with controversy, and questions remain regarding how to translate the science into public policy. Below, we review the science on cognitive effects of video games, including why video games might be capable of altering cognitive function, what types of video games affect cognitive function and which do not, what cognitive effects of video gaming have been observed in adults and in children, and how commercial video games relate to "brain games" in terms of content and cognitive outcomes. We also discuss the real-world and public policy implications of the cognitive effects of video games.

Why Might Video Games Be Effective in Altering Brain and Behavior?

Modern video games have evolved into sophisticated experiences that instantiate many principles known by psychologists, neuroscientists, and educators to be fundamental to altering behavior, producing learning, and promoting brain plasticity (for reviews, see Bavelier, Green, Pouget, & Schrater, 2012; Gentile & Gentile, 2008; Green & Bavelier, 2008). Video games, by their very nature, involve predominately active forms of learning (i.e., making responses and receiving immediate informative feedback), which is typically more effective than passive learning (Michael, 2006). In addition, this active learning usually occurs in a variety of situations, thus promoting generalization of learning (Schmidt & Bjork, 1992). Most video games also use a dynamic degree of difficulty that increases along with player skill, ensuring that players are continuously challenged. Furthermore, many games use a combination of internal reinforcement (e.g., positive social interactions and feelings of competence; Przybylski, Rigby, & Ryan, 2010) and external reinforcement (e.g., points, badges, etc.; King, Greaves, Exeter, & Darzi, 2013). This reinforcement promotes significant time spent on task, which is the best single predictor of positive learning outcomes. In addition, this time is typically distributed over many days, weeks, or even years—a practice schedule that produces more effective learning than when experience is amassed into only a few sessions (Baddeley & Longman, 1978). Finally, video games are highly physiologically arousing and activate reward systems of the brain that drive brain plasticity (Bao, Chan, & Merzenich, 2001; Kilgard & Merzenich, 1998). Thus, there is a strong scientific basis to suspect that video games, when properly designed, have the potential to strongly alter the brain and behavior.

Not All Video Games Are Equal When It Comes to Altering Cognitive Function

Although every well-designed video game incorporates some or all the principles of effective learning mentioned above (as well as many others), and thus will have the potential to shape the brain and behavior, it is the specific content, dynamics, and mechanics of each individual game that determines its eventual effects. Indeed, a common mistake that is made when discussing video games is to lump all games together into a single category. The term *video games* refers to thousands of quite disparate types of experiences, anything from simple computerized card games to richly detailed and realistic fantasy worlds, from a purely solitary activity to an activity including hundreds of others, from a strictly antagonistic/competitive experience to a strictly friendly/pro-social experience, from nothing more than a simple set of rules to a full and highly immersive fiction (see Figure 1 for examples). A useful analogy is to the term *food*, which, like the term *video games*, encompasses an incredibly wide variety of sub-categories and individual exemplars. One would never ask, "What is the effect of eating food on the body?" Instead, it is understood that the effects of a given type of food depend on the composition of the food—the number of calories; the percentage of protein, fat, and carbohydrates; the vitamin and mineral content; and so on. This same fundamental principle is true of video games as well.

In the cognitive domain, perhaps not surprisingly, the types of games that are of interest are those that have complex 3D settings, that feature quickly moving targets that pop in and out of view, that necessitate substantial visual processing of the periphery, that include large amounts of clutter and task-irrelevant objects, that require the player to consistently switch between highly focused and highly distributed attention, and that require the player to make rapid, but accurate decisions. Games that share these features are referred to as "action video games" (Green & Bavelier, 2012; Spence &

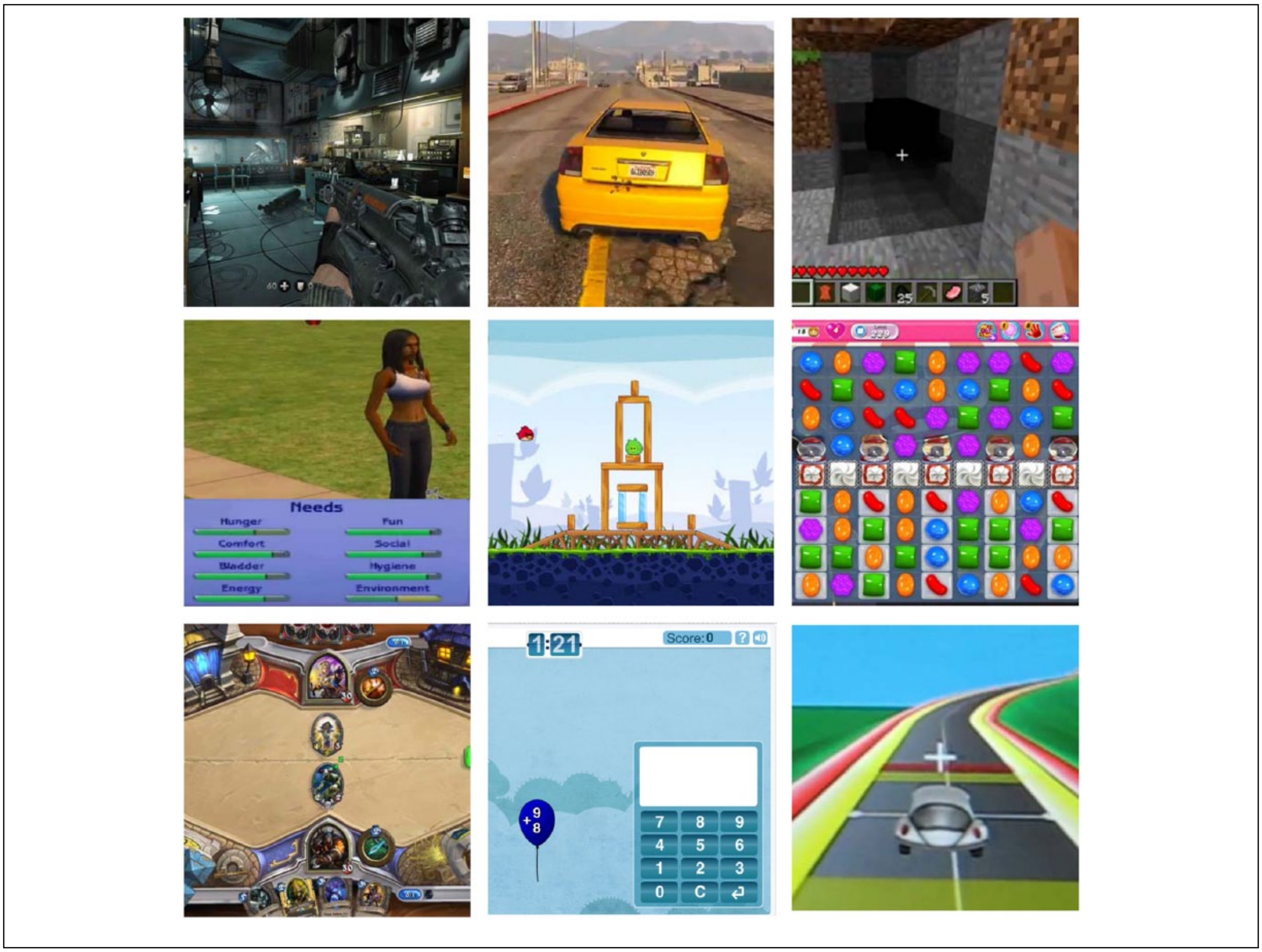

Figure 1. "Video games" encompass a wide variety of experiences.
Note. Video games differ widely in their content, dynamics, and mechanics. As a result, games vary in their effects on cognitive skills. Action games, including many "first-person shooters" (top-left: Wolfenstein: The New Order) and "third-person shooters" (top-middle: Grand Theft Auto V) have been shown to enhance many cognitive functions. Others, including simple building/exploration games (top-right: Minecraft), social games (middle-left: The Sims 2), phone games (middle-middle: Angry Birds; middle-right: Candy Crush), and card games (bottom-left: Hearthstone) lack features believed to be important to the cognitive impact of action games. Even "brain games" have a wide variety—with some being gamified scholastic or lab tasks (bottom-middle: Balloons; Owen et al., 2010), while others layer effective content into interesting game environments (bottom-right: NeuroRacer; Anguera et al., 2013).

Feng, 2010). Playing action video games has been linked with myriad enhancements in cognitive function, from low-level vision through high-level cognitive abilities, while playing many other types of games fails to produce equivalent impact on perception and cognition.

What Are the Cognitive Consequences of Playing Action Video Games?

The consequences of playing action video games have been addressed through numerous studies using several methodologies and examining a wide number of cognitive abilities. Some studies provide more conclusive evidence than others. For example, studies that train non-video gamers to play video games (i.e., intervention studies) can provide causal evidence, as opposed to studies that compare populations that natively play or do not play certain games (i.e., cross-sectional studies). Both types of studies provide useful information, and as a whole, the literature supports the conclusion that playing action video games provides broad-based and consistent benefits on tests of cognitive skills.

Effects on Perceptual Skills

Both intervention and cross-sectional studies have shown that action video game experience is associated with enhancements in numerous basic perceptual tasks including those involving contrast sensitivity (R. Li, Polat, Makous, &

Bavelier, 2009), visual acuity and crowding (Green & Bavelier, 2007), peripheral vision (Buckley, Codina, Bhardwaj, & Pascalis, 2010), and temporal processing (Donohue, Woldorff, & Mitroff, 2010). Collectively, these are consistent with the fact that action games require responding quickly (temporal processing) to important stimuli that are often similar to their backgrounds in their colorations (contrast sensitivity) and features (visual acuity), and typically occur in somewhat cluttered environments (crowding). Although there is increasing evidence that action video game play improves performance on many basic perceptual tasks, much remains to be established regarding the specific mechanisms underlying these performance improvements. Improvements in these tasks can be due to myriad factors (Hung & Seitz, 2014) ranging from optimization of basic visual processes, to improvements in strategies of how the task is conducted, to more effectively attending to task-relevant stimuli.

Effects on Attention Skills

Many studies demonstrate that action video game play improves visual attentional skills, such as the ability to find a particular target from within a large field of view when the target is surrounded by task-irrelevant distracting items (Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003), or to track a small subset of moving items from within a larger field of visually identical moving items (Green & Bavelier, 2006). The fact that action gaming benefits performance in this domain is of particular interest because better performance on some of these same tasks is predictive of real-world consequences, such as fewer driving accidents in elderly populations (Myers, Ball, Kalina, Roth, & Goode, 2000). Thus, while there is still ambiguity regarding the exact mechanisms by which action video game play leads to improved task performance, as a whole, the literature supports the conclusion that action video games can give rise to benefits on a wide array of tasks that rely on perceptual/attentional abilities.

Effects on Higher Cognitive Functions

Action video game play can enhance a diverse set of higher cognitive functions. Several studies show that individuals can switch between competing tasks more efficiently after action video game training (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Strobach, Frensch, & Schubert, 2012). Other aspects of cognitive function improved by action video game training include the ability to multitask (Strobach et al., 2012) and the ability to mentally rotate objects (Feng et al., 2007). Cross-sectional work also suggests that action video game players perform better on tasks of working memory (Sungur & Boduroglu, 2012) and fluid intelligence (Unsworth et al., 2015). However, the latter study failed to find a linear relation between amount of game play and fluid intelligence, and some studies have failed to reproduce effects of gaming on cognition (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; van Ravenzwaaij, Boekel, Forstmann, Ratcliff, & Wagenmakers, 2014), suggesting that more research is required in this domain.

Cognitive Effects in Children

The vast majority of research on the effects of action video games on cognitive function has utilized healthy young adults as research participants. This is at least partially because many action games contain content (e.g., violence) that is not appropriate for children. When researchers have found age-appropriate action video games, however, the similar benefits to perception and cognition have been observed as a result of training in children (Franceschini, Gori, Ruffino, Viola, Molteni, & Facoetti, 2013). Furthermore, cross-sectional studies reveal the same strong associations between avid action gaming and enhancements in cognitive skills in children as have been observed in adult populations (Dye & Bavelier, 2010; Dye, Green, & Bavelier, 2009a; Trick, Jaspers-Fayer, & Sethi, 2005).

What About Other Types of Commercial Video Games?

Most cognitive research on commercial video games has examined action video games. However, other game genres may also benefit certain aspects of cognitive function. For example, training on a difficult version of the strategy game StarCraft resulted in improvements in cognitive flexibility, but not measures of attention, or short-term memory (Glass, Maddox, & Love, 2013). Training on Portal 2, a popular 3D puzzle game, elicited improvements in problem solving and spatial reasoning skills (Schute, Ventura, & Ke, 2015). And training older adults on the real-time strategy game Rise of Nations resulted in significantly greater improvements as compared with controls on measures of working memory, task-switching, visual short-term memory, and mental rotation (Basak, Boot, Voss, & Kramer, 2008). Interestingly, real-time strategy games do share some features with action video games (e.g., the need to monitor multiple sources of information simultaneously, to make decisions quickly and accurately, etc.), which is consistent with the idea that the cognitive effects of games are explicitly due their inherent processing demands.

It is important to note that not all effects of gaming on cognition have been positive. For instance, while some types of games have been shown to enhance the process of "selective attention" (i.e., used when listening to a friend speak in a loud/crowded restaurant and ignoring the other speakers), the effects on "sustained attention" (i.e., the ability to stay on task for a prolonged period) are more mixed. In particular, while action game playing has been associated with either enhancements or no changes to sustained attention (e.g., Dye, Green, & Bavelier, 2009b), one study, which lumped all video games together, found that total amount of video game play predicted poorer attention in the classroom (Gentile, Swing, Lim, & Khoo, 2012). This is a good example of the fact that not all games are likely to affect the cognitive system equally, nor are all the effects likely to be positive (and also attests to the need to differentiate between games as this study does not allow us to determine what types of games specifically are linked with diminished sustained attention).

What About "Brain Games?"

The discussion thus far has focused exclusively on commercial entertainment video games that happen to, as a by-product of their content, dynamics, and mechanics, produce enhancements in cognitive skills. However, commercial video games are (understandably) optimized for entertainment and not mental fitness, and do not intentionally take advantage of neuroscience and psychology research regarding mechanisms and plasticity of cognitive processes (Deveau, Jaeggi, Zordan, Phung, & Seitz, 2015). This is in contrast to the so-called "brain games" (Bavelier & Davidson, 2013), which are designed explicitly to improve cognitive function and that, in the best cases, are closely aligned with an understanding of neuroscience underlying the trained functions (Mishra, de Villers-Sidani, Merzenich, & Gazzaley, 2014; Whitton, Hancock, & Polley, 2014).

The typical brain game "gamifies" existing laboratory tests of cognition by adding interesting graphics and sounds, points, and so on. Examples include games such as Nintendo's Brain Age (Lorant-Royer, Munch, Mescle, & Lieury, 2010) or the games developed for the BBC program "Bang Goes the Theory" (Owen et al., 2010), as well as games sold by a growing number of brain-training companies. While these games can add entertainment value to what are otherwise somewhat sterile psychology tasks, they typically embody few of the qualities of the commercial video games linked with cognitive improvement. This is critical because the cognitive benefits that a video game can yield depend on good game design (Rabin, 2005). Indeed, without proper design, gamification can potentially even impair task performance and learning. For example, Katz et al. (2014) found that motivational features such as scores, prizes, and scene-changes, when added to a working memory training task, led to impaired learning compared with the non-gamified task. A likely reason for this is that gamification involves producing training tasks with "game features" that may be incongruent with, and/or distract attention from, task-relevant features (Leclercq & Seitz, 2012a, 2012b), which then in turn interferes with desired learning outcomes (Seitz et al., 2005). This may be why the cognitive benefits of simple gamified cognitive tasks are often limited (Lorant-Royer et al., 2010; Owen et al., 2010).

A separate broad approach in the brain-training domain works to combine the elements of off-the-shelf video games and standard cognitive approaches that can contribute to cognitive improvement. This approach recognizes that commercial video games are not random assemblages; instead, their levels, challenges, and virtual environments are carefully designed to maintain balance, minimize player frustration, and promote a fun experience. An early example of this new class of brain-training games is the custom designed video game NeuroRacer (which looked like a car racing game rather than a psychological test), which resulted in improvements in multitasking, sustained attention, and working memory in a group of older adults, with improvements persisting for at least 6 months after the cessation of training (Anguera et al., 2013).

There are many reasons why the development of custom designed cognitive training games would be preferable to utilizing commercial entertainment games for the same purposes. This includes the ability to target specific cognitive processes (e.g., a deficit in visual processing, or one in short-term memory). Also, the content of many commercial video games (many of which contain violence) is not appropriate for all ages and/or all individuals.

Video Games Used for Real-World Problems

Given the scope and scale of the positive effects induced by certain types of video games, many groups have explored the potential to utilize video games to address practical, real-world issues. For example, a variety of video games (ranging from Tetris to action video games) have been shown to improve vision in individuals with amblyopia (colloquially known as "lazy eye"; J. Li et al., 2013; R. W. Li, Ngo, Nguyen, & Levi, 2011). Likewise, custom brain-training games for vision have also been shown to improve reading abilities (Deveau & Seitz, 2014), and even on-field performance in Collegiate Baseball (Deveau, Ozer, & Seitz, 2014). Recent research also indicates that action video games may ameliorate developmental dyslexia (Franceschini et al., 2013).

Action video games have also been considered useful to improve performance in jobs that require enhanced cognitive skills. For instance, laparoscopic surgery requires extreme manual dexterity, as well as the ability to use 2D television images to make 3D movements in the real-world and to make decisions quickly. Accordingly, action video game training improves performance of novice surgeons on a laparoscopic simulator (Schlickum, Hedman, Enochsson, Kjellin, & Fellander-Tsai, 2009), and cross-sectional research shows action video game experience is a better predictor of positive surgical outcomes than years of training or number of surgeries performed (Rosser et al., 2007). Action video game play has also been associated with enhanced piloting abilities (Chiappe, Conger, Liao, Caldwell, & Vu, 2013), particularly the ability to fly unmanned drone aircraft (McKinley, McIntire, & Funke, 2011).

Methodological Limitations and Issues Related to Inferring That a Given Video Game Will Produce Cognitive Benefits in an Individual

Some studies provide stronger evidence than others—The types of conclusions that can be supported by a given study depend on the methods used (for a more thorough review, see Green, Strobach, & Schubert, 2014). For instance, "cross-sectional" studies, which take advantage of the fact that some individuals, as part of their daily life, choose to play video games while other individuals do not, do not allow for conclusions of causation (i.e., they do not show that the act of playing the game itself causes enhancements in cognitive skills). Although cross-sectional studies are informative, such evidence needs to be weighed carefully when determining policy. It is because of the various inherent limitations of purely correlational work that cross-sectional studies are often supported by carefully controlled intervention studies (e.g., taking a representative cohort of non-gamers and testing their cognitive abilities before and after an assignment to play a video game). Unlike cross-sectional studies, intervention studies can allow for causal inferences regarding the effects of the games on cognition.

Another issue that affects both cross-sectional and intervention studies are expectancy effects (sometime termed placebo effects). These refer to the possibility that participants will try harder, and thus perform better, on assessments of cognitive function because they believe that playing the video games should have improved their performance. Comparing performance with a control group trained on tasks matched for features of the intervention (e.g., general interest, arousal, motivation, etc.), but critically lacking those features hypothesized to be essential for driving changes in cognitive performance can help address expectancy effects.

It is important to note that the evidentiary basis of a given study depends on many details of the study design and the resultant data, and that there is no one-size-fits-all method of doing science. Not all cross-sectional studies provide less evidentiary basis than all intervention studies (e.g., A well-designed cross-sectional study may provide better evidence than a poorly designed intervention study), and not all research questions allow for intervention studies. For instance, it is inappropriate to force young children to play hours of violent video games for the purpose of measuring causal relationships between game-violence and aggression. The same is true of potential links between video game play and clinical psychological issues (e.g., attention deficit/hyperactivity disorder [ADHD] or major depression), or negative effects on academic performance. Thus, it is necessarily the case that public policy must often be guided by complex and incomplete data. It is therefore extremely important that public policy decisions also rely on the advice of domain experts who have detailed knowledge of the broader literature.

The effect of a game depends on how it is interacted with—A key difference from the action of a drug is that the impact of a video game depends on how that individual interacts with the game, with individual differences in motivation, personality, and nascent cognitive abilities leading to completely different game experiences. At the extreme, it is obvious that having a child with ADHD press random buttons on the game controller will provide an ineffective learning experience. Thus, the results of a given video game intervention can vary widely across individuals. While we have discussed data from many demographic groups (from children to seniors; from those with mental health impairments to athletes and surgeons), showing that video games can positively influence many demographics, there are numerous reasons why a game that helps one individual may or may not have the same effects on another.

If Playing Action Video Games Leads to Many Cognitive Benefits, Should We Encourage More Action Video Game Play?

Most of the public discussion around the topic of regulating game play has centered on the question of whether game play, especially in developing children, should be explicitly limited. For instance, the American Academy of Pediatrics recommends that children and teens should engage with entertainment media, such as video games, for no more than 2 hr per day in total. As far as we are aware, this recommendation of the American Academy of Pediatrics is not based on any actual scientific research showing that less than 2 hr of exposure is acceptable, while more than 2 hr is harmful. Furthermore, the recommendation does not differentiate between types of entertainment media content (i.e., Are 2 hr of watching reality television fully equivalent to 2 hr of playing educational video games or 2 hr of interacting with peers on social networks?). This being said, playing action video games for more than 1 to 2 hr a day is unlikely to provide substantially greater cognitive benefits than what is found in intervention studies, which mostly relies on around an hour a day of training. Almost all learning, utilizing video games or otherwise, is subject to the effect of diminishing returns. This means that doubling the amount of time spent gaming will result in far less than twice as much improvement, and in fact can impair overall gain (Censor, Sagi, & Cohen, 2012; Dosher & Lu, 2007; Heathcote, Brown, & Mewhort, 2000; Stafford & Dewar, 2014). It is also the case that any time spent gaming is time that is not spent doing other activities that society may value to a greater degree (e.g., More time spent gaming may result in less time doing school work, and it is unlikely that the cognitive advantages will make up for the reduced academic achievement; Weis & Cerankosky, 2010). The best policy supported by the science thus far is one in which video gaming is monitored and adjusted as needed. Any explicit guidelines should be reformulated based on empirical scientific evidence. The guidelines should also engage with the fact that terms such as *entertainment media, screen time*, and *video gaming* are exceptionally broad and that different activities within these categories have differential impacts on child development.

How Should Games That Claim to Improve Cognitive Function Be Regulated?

It is difficult to surf the Internet today without seeing advertisements for products that claim to improve brain health and general cognitive function. Many such products claim to be built on the "science of neuroplasticity" or that they are "inspired by work in the neurosciences." In practice, however, the scientific basis for such claims varies widely, with some claims relying on multiple efficacy studies done directly on that product, others that are based on a resemblance to procedures found to be effective in the scientific literature, and others that have virtually no true link to science. At the moment, there is no standard of scientific validity for efficacy claims for such products, and in consequence, it is very difficult for consumers to distinguish which products are more or less likely to be effective.

A first question is what agency is best positioned to regulate the use of video games and the claims made by game companies. In regard to health claims, a natural fit would be the Food and Drug Administration (FDA). Currently, though, the FDA has determined that brain-training games pose no risk to patient safety and thus do not fall under the purview of the FDA. A reasonable analogy in this case might be that of dietary supplements (also not regulated by the FDA) where "a firm is responsible for determining that the dietary supplements it manufactures or distributes are safe and that any representations or claims made about them are substantiated by adequate evidence to show that they are not false or misleading." One glaring issue with this is that there is no provision under the law or FDA regulation that requires a firm to disclose to the FDA or to consumers the information that they have about the safety or purported benefits of their dietary supplement products. It therefore seems unlikely that the FDA is best positioned to regulate the gaming industry.

Another regulatory agency is the Federal Trade Commission (FTC). The FTC has long regulated the advertising of dietary supplements and has begun investigating claims of cognitive benefits from brain-training games. Interestingly, the FTC recently suggested that a company perform double-blind testing to support its claims of efficacy (see "Analysis of the Proposed Consent Order to Aid Public Comment *In the Matter of Focus Education, LLC, Michael Apstein, and John Able*, File No. 122 3153 [https://www.ftc.gov/enforcement/cases-proceedings/122-3153/focus-education-llc-matter]"; note that the FTC is requesting a similar standard of Aaron Seitz, an author of this paper, and his company Carrot Neurotechnology that marketed a vision training program based upon research studies conducted by Seitz [see COI information below]). Such procedures are the "gold-standard" in drug trials, but in the case of cognitive training interventions, there is no true way to perform a double-blind, placebo-controlled study to demonstrate the efficacy of the cognitive intervention. This is because participants will always be aware of what they do during behavioral training (i.e., are not "blind" to their condition). This leaves the possibility that expectation effects can still influence study outcomes.

If cognitive training cannot utilize the same standards as drug trials, what then might be the best practices that any demonstration of scientific efficacy should observe in this domain? A more thorough discussion of these issues can be found in Green et al. (2014), but there is general agreement in the field that proper intervention studies will include random assignment to either an experimental group or a control group. However, the nature of the appropriate control group depends on many different factors and can be very different between cases in which one is trying to determine mechanisms, and those simply concerned with efficacy. In the case of determining mechanisms, controls should be matched to be as similar as possible to the experimental group, while leaving out the hypothesized active characteristics of the intervention so that it can be determined whether those attributes lead to a difference between the treatment and the control. In the case of an efficacy study, however, the most appropriate control is far less clear. In the case of drug studies, there are two rather obvious control treatments: (a) a truly neutral treatment (e.g., a sugar pill) and (b) the existing standard of care (e.g., comparing a new heart medicine to the current standard heart medicine). No such alternatives exist in the case of cognitive training platforms. In fact, it is unclear what the cognitive equivalent of a sugar pill would be (e.g., a crossword puzzle, another video game, an actual sugar pill?). Also, there exist no accepted/standard interventions to address basic cognitive problems (perception, attention, memory, executive function, etc.), and thus the typical standard of care is to do nothing.

Given these deep questions about how the research should be conducted, the current literature does not provide simple answers to serve as a foundation of public policy. Instead, there is real need for regulatory agencies to engage scientists and industry groups to create standards and policies by which to better inform the public of the complex impacts of video games on cognition.

What Is The Best Role For Government?

A clear potential role for government is to create a regulatory structure that incentivizes evidence-based practices in cognitive enhancement products. An incentive system, such as a label indicating a certification level of efficacy (analogous to what is currently done for organic foods and energy efficient products), could provide a market advantage for good science. Rather than directly applying models from drug studies, evidentiary standards need to be developed that respect the fact that video games are within consumers' normal use patterns for entertainment, are safe, and that there is necessarily a continuum of degrees of established efficacy that inevitably involves some ambiguity. The government can play a key role in creating standards to label the various degrees of efficacy by bringing together scientists, industry leaders, and consumer groups to create a system that respects the constraints of the field described above, while considering the potential benefits that these products may have for the public. Such a structure would permit innovation and would allow for well-informed consumers to try out unproven products that may have interesting attributes, while being able to differentiate which products have achieved a stronger evidentiary standard. This would facilitate a market wherein investing in research to design cognitive training paradigms that are more effective will actually result in greater profits (as it is almost certainly the case that the public will gravitate toward games that have been certified as having stronger evidence behind their claims). At the moment, given a lack of clear regulations, it is unclear whether there is any relationship whatsoever between market share and efficacy.

Another obvious role for government is to provide mechanisms through which neuroscientists, psychologists, and educators can collaborate with leaders in the gaming industry. One common criticism of many games designed for positive impact is that such games have historically been designed and implemented by academics rather than game designers (with predictably poor game play resulting). While market forces may be sufficient to drive collaborations around the topic of general cognitive enhancement, there are other domains where additional incentives may be needed. For instance, there are many medical conditions that could potentially benefit from well-designed video game cognitive interventions, but the conditions are rare enough that it would not be a profitable domain for a major gaming company to work in. Government could also incentivize gaming companies to share data with research groups. Game companies collect enormous amounts of data on their players, which would be an incredibly rich source of information through which to better understand human behavior. At the moment, there is no incentive for such data sharing (if anything, it is deincentivized as the data could be used by a competing company to improve their own market share). Thus, overall, we suggest that the best role for the government is to facilitate interactions between stakeholders, encourage good behavior, promote good science, and reward innovation. This will help realize the positive contribution that the games of the future will provide to society.

Conclusion

Video gaming is likely to remain a pervasive part of American culture for the foreseeable future. Given that well-designed video games utilize principles known to effectively drive changes in the brain, there is a real reason for video games to remain the subject of close scientific study. In the cognitive domain, the evidence to date suggests that some, but not all, games are indeed capable of altering basic cognitive skills, and that these changes are of a scope and scale that permit practical applications (e.g., in rehabilitative or job-training settings). Of particular interest for future work will be to determine what game characteristics are most responsible for such benefits, and then to utilize this information to continue to refine custom designed games for cognitive impact (i.e., "brain games"). As the brain-training industry develops, there is likely to be an increasing need for some type of regulatory structure to maintain consumer confidence in the efficacy of these products as well as to incentivize better science. The development of this regulatory structure will require buy-in from many stakeholders, including basic research scientists, game industry leaders, and governmental officials.

Declaration of Conflicting Interests

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