

# THE BRAIN- BOOSTING POWER OF

COGNITIVE SCIENCE

# VIDEO GAMES

→ Shooting zombies and repelling aliens can lead to lasting improvement in mental skills

*By Daphne Bavelier and C. Shawn Green*

## IN BRIEF

**Fast-paced shooter games** did not always grace lists of brain-enhancing activities. For the past 15 years, however, a number of studies have found that playing them frequently changes various aspects of cognition for the better.

**A range of mental skills** appears to benefit from game play, including attention, faster processing of information, flexibility of switching from one task to another and visualizing the rotation of an object. Rigorous testing has provided evidence for these gains.

**Concerns persist** about whether games foster aggression or addictive play. Now that researchers have determined how games help to hone some mental skills, they have begun to design nonviolent action games geared toward people with cognitive deficits.

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**I**N THE LATE 1990S OUR LABORATORY AT THE UNIVERSITY OF ROCHESTER RAN STUDIES TO EXPLORE THE then somewhat unorthodox idea that even the adult brain could grow new brain cells or rewire itself in response to new experiences—a biological process called neuroplasticity. As part of this research, one of us (Green), then an 18-year-old undergraduate assistant in the lab, coded a computerized psychological test assessing how well one can search for a particular shape in a busy visual scene.

Green began by testing himself. When finished, he insisted that there was a bug in the programming that he could not track down. Previously published work on this type of testing suggested that his performance should have been well below perfect, yet he consistently racked up perfect scores. Green's adviser (Bavelier) was becoming worried that the issue had not been resolved. "Why don't you stop running yourself and test naive participants?" she asked.

A few days later Green reported that newly recruited participants also registered flawless performances. Determined to crack the problem that same day, Bavelier asked to be run on the task herself. Her performance was nowhere near perfect. Instead her scores matched almost exactly the expected average. When Bavelier asked whom Green had run as naive participants, the assistant replied that he had tested several close friends.

Our team spent some time considering why Green and his buddies had performed so well on the task. Eventually we settled on one key difference. Every member of the group had spent more than 10 hours a week playing a newly released video game called *Team Fortress Classic*.

The discovery immediately raised an intriguing question: Could "mindless" video-game play—in which the main objective is to overpower zombies, aliens, monsters and villains—really trigger such stunning improvements in a cognitive skill? What had started as a search for a computer bug has led to a new research endeavor to assess the impact of video-game play on both the brain and behavior.

When we began our studies, playing fast-paced "shooter" video games was not high on any scientist's list of brain-enhancing activities. For the past 15 years, however, our investigations, coupled with that of other labs around the world, have established that playing action video games can change some aspects of cognition for the better.

During our research, we and other teams have found that video-game play boosts a variety of cognitive skills. Individuals who regularly play action games demonstrate improved ability to fo-

cus on visual details, useful for reading fine print in a legal document or on a prescription bottle. They also display heightened sensitivity to visual contrast, important when driving in thick fog. Action gamers also mentally rotate objects more accurately—and so are able to judge how an oddly shaped couch might best fit in an overpacked moving van. The multitasking required to switch back and forth between reading a menu and holding a conversation with a dinner partner also comes more easily.

Furthermore, a player's ability to react to events that unfold quickly gets better with regular play. Tests of reaction times of action video-game players show that performance improved by more than 10 percent compared with before they took up gaming. The video game as life coach may even provide a leg up in the workplace. Game playing seems to confer the ability to make correct decisions under pressure—the type of skill sought by employers in many professions. One study revealed that laparoscopic surgeons who were also game players were able to complete surgeries more quickly while retaining the necessary precision in the operating room. Game-playing surgeons appeared to work more efficiently, not just faster.

Video games as learning tools might come as a surprise to those who recall a congressional hearing in the early 1990s that considered negative effects on children who played games such as *Mortal Kombat*. Recent studies have not borne out these fears as far as effects on cognitive function, although concerns persist about whether games foster aggression or addictive play. Now that researchers have begun to figure out how some video games improve cognition in players—by bettering attention and reaction times—they have started to design nonviolent games geared toward people with brain injuries or cognitive deficits. This software may be more effective, in fact, than so-called brain games marketed on television and the Web as cognitive enhancers.

## BOOSTING THE BRAIN

THE STEREOTYPE of the avid player of *Call of Duty* and other action games is of someone who is impulsive and easily distracted. Our

## Game Menagerie

Video games belong to a complex and constantly evolving ecosystem, with more than 10 different commonly recognized genres (action, sports simulation, party, among others). Among these genres, hundreds of distinct subgenres exist (real-time strategy, turn-based strategy and 4X all fall under the broader strategy genre). There are, moreover, tens of thousands of distinct titles among the various categories.

As far as examining effects on cognition, most research has focused on one particular

game genre—action games, which primarily include first- and third-person shooter games, such as the Call of Duty or Gears of War series, but also games that are often labeled as action-adventure (the Grand Theft Auto series), action (the Burnout series) and action-RPG (the Mass Effect series), to name a few.

Whereas action games are best at improving perception, attention or various aspects of cognition compared with other genres, they are not the only ones to yield benefits beyond serving as a fun pastime, as

the list of findings below show. Research on games involving action sports, real-time strategy and action role-playing suggests they may have an impact similar to action games in bettering some aspects of cognition. Furthermore, game genres that do not affect cognition might enhance social behaviors or empathy. Investigators who study social games tend to categorize games differently from those who research cognition, sometimes dividing the game world into violent versus nonviolent kinds.



**ACTION:** Most research on game play for enhancing cognition has focused on action games, a genre that has subgenres, such as shooter and action-adventure games. Action games have demonstrated a range of cognitive benefits that may carry over into work and other activities.



**REAL-TIME STRATEGY:** Playing one of these games, called StarCraft—which has a military science-fiction story line that involves war among several galactic species—produced improvements in cognitive flexibility, the ability to switch from one task to another.



**3-D PUZZLE GAME:** Finding an exit door by using a series of tools—the goal of Portal 2—resulted in players showing a statistically significant advantage in measures of problem solving, spatial skill and persistence over a comparison group that played brain games from the Lumosity software.



**PROSOCIAL:** A 2009 review of studies in the *Personality and Social Psychology Bulletin* found that young people from various countries who played “prosocial” games that involve characters helping one another later cooperated more when interacting with peers.

studies contradict this outdated preconception. Players who immerse themselves in the fast-paced events of digital fantasy worlds derive significant cognitive benefits.

Much of our research has focused on how action games affect a player's attention—the mental processes that lead to finding relevant information in one's environment. Studies of attention have been carried out ever since psychology emerged as a social science in the 19th century. Call of Duty and Medal of Honor have now become tools in research facilities because of their ability to enhance attention. A player must shift between a state of mental focus while monitoring the game scene for potential enemies, switching purposely between what psychologists call focused and distributed attention.

These studies have shown that fighting off waves of zombies requires game players to suppress distracting information or risk obliteration. Specifically, players detect targets better than non-gamers and avoid becoming distracted by any single event that occurs as a fast-paced game progresses. A zombie will always be followed by another and yet another. The player who gets hung up on pursuing any single member of the walking dead risks attack by legions of others.

In one of our studies, we used a well-known psychological test to demonstrate the superiority of an action-game player's attentional skills. The test exposes subjects to a series of letters, interspersed with occasional digits. Each item flashes on the screen at intervals of 100 milliseconds, less than the blink of an eye. Test takers who do not indulge in action video games typically have little difficulty identifying the first digit in the string. But if a sec-

ond digit follows closely thereafter, they often do not notice it—a psychological phenomenon known as attentional blink. Some experienced action-game players, however, barely blink, catching every target digit as it passes by.

Brain scans provide more evidence of the benefits of action games. Widely dispersed regions of the cerebral cortex regulating attention change their activity more in action-game players than in nonaction gamers. Among them are the dorsolateral prefrontal cortex, which helps to sustain attention; the parietal cortex, which switches focus among different targets; and the cingulate cortex, a locus for monitoring one's own behavior.

### FASTER, FASTER

**ACTION VIDEO-GAME PLAYERS** get more out of Burnout and Grand Theft Auto than just better focus. The greater the skill they acquire, the faster they process information in the quick-moving stream of events that makes up each game scene. For psychologists, information-processing speed is a key measure of the efficiency of cognitive functioning—and action games appear to be excellent tools to make a person's reaction time faster. The player must decide whether a moving object is friend or foe and choose which weapon to use, where to aim and when to fire, all in the space of a second or so.

Greater efficiency in controlling attention has a ripple effect on many forms of neural processing. It can ensure that the brain extracts more visual, auditory and other information about a task being performed—and that it excludes sources of distraction or noise. At the highest levels of cognitive processing, an individual

may demonstrate a high degree of flexibility in refocusing attention from one task to another. These are not just lab test results. Better control of attention helps in adapting to new situations and aids, in general, in speeding up learning.

To be able to make a clear statement about the effects of these games, we had to provide a firm demonstration that the benefits of action video games are genuine—and that *playing* these games actually *causes* players' superior concentration and quick reaction times. After all, it may be that these games simply attract players with exceptional attention—which, in turn, leads to stellar performance on both games and subsequent tests assessing players' cognitive functioning.

To show a true cause-and-effect relation, scientists recruit a group of individuals who rarely play video games. After undergoing a pretest of cognitive skills, this larger group is randomly split into two. One group plays an action game, whereas a control group immerses itself in a social game or another nonaction game. Each group is required to play about one hour a day, five days a week for a period of several weeks. A few days after this sustained training, participants are again tested on the same psychological tests they took before playing the games. Groups trained on action games show consistently larger gains in cognition than control groups.

Controlled studies allow researchers to discard factors that might otherwise account for the benefits shown by either group—the possibility, for instance, that someone taking a psychological test tends to perform better when retested. These studies also demonstrate that not all video games have the same effects. Action games that emphasize attention, cognitive flexibility and speed produce clear gains. Nonaction games—which do not recruit these cognitive processes—garner few. Despite the purported benefits of action-game play, the various studies do not provide a license for video-game bingeing. Obsessive hour-after-hour indulgence is not needed. Players achieved cognitive advantages in our study after short, daily intervals of play.

Some other video-game genres—such as action role-playing games (*Mass Effect*) and real-time strategy games (*StarCraft*)—also produce similar beneficial effects on cognition. Ironically, few, if any, of the games marketed explicitly as “brain games” live up to their claims to help people with cognitive deficits or those who wish to improve mental functioning to above-average levels. Early generations of brain games consisted largely of sterile psychological lab tasks “dressed up” with game graphics or engaging sounds that did not actually demonstrate any generalizable cognitive benefit. Indeed, becoming ever better on a specific psychology exercise is unlikely to help the player plan an efficient route at the supermarket or remember where he or she left the car keys.

Even though action video games were never designed as teaching tools, they nonetheless embody many pivotal learning principles. For one, they are fun—a cardinal pedagogical prerequisite that is often given short shrift.

The games' programming also incorporates careful pacing and structuring of the level of play. The number of attackers increases as the game progresses. Players remain absorbed while receiving the right amount of practice to master a game skill. Critically, these games require players to switch between focused and divided attention tasks as the games progress, demanding a high level of attentional control.

The games create a rich environment in which new challenges

## Brain Training or Not?

To determine whether action-game play improves perception and other aspects of cognition—ensuring that gains result from the game itself and not some other factor—researchers compare performance on cognitive tests (shown at right) for a group that plays an action game for a few weeks and for a control group that trains on a nonaction game. Players of action games show greater improvements from pre- to post-testing compared with the control group—and the benefits persist five months later.



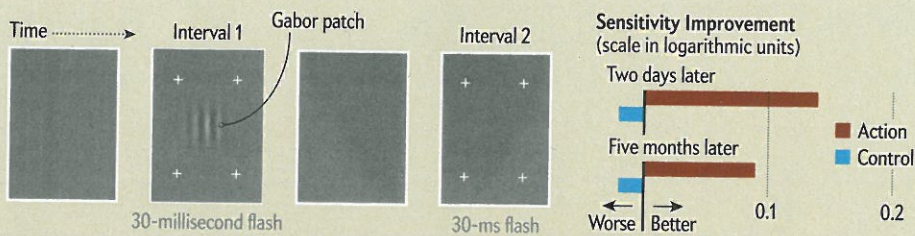
keep arising, always pushing the players out of their comfort zone. Finally, the games also reward players on many different timescales: seconds (defeating a single enemy), minutes (finishing a single mission), hours (finishing a chapter or campaign), days (completing a full game)—all of which promote planning across different time horizons. The games make for a rewarding experience that promotes learning that can be applied to real-life situations: better mental rotation in science or math classes or quick braking of a car if a child runs into the street to fetch a ball.

### A TRUE BRAIN GAME

RESEARCHERS HAVE BEGUN to take lessons from studying commercially available video games and apply them to a new generation of therapeutic games that bears little resemblance to drab psychological tests. Posit Science, Pear Therapeutics and Akili Interactive (disclosure: Bavelier is a co-founding adviser for Akili) are a few names among a growing number of companies looking into using video games as clinical tools, whether for assessment or for actual therapies. Akili, for example, is developing a therapeutic game—derived from a research-based game called *NeuroRacer*—to enhance attention and diminish distraction. This and other games target clinical populations such as children with attention-deficit disorders or older adults experiencing early symptoms of cognitive decline. It will take time to gain acceptance for these games. Ultimately, to be incorporated as clinical tools, therapeutic games and their health claims will have to be evaluated by independent bodies such as regulatory agencies or the broader scientific community.

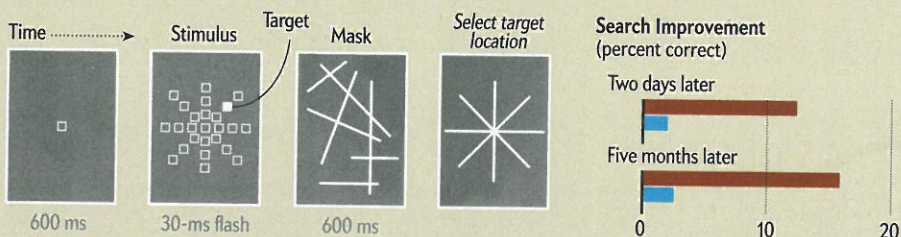
### Can You See It Now?

A contrast-sensitivity task measures the ability to detect slight differences in light versus dark on a computer screen. Participants observe a screen at two time intervals and must indicate when a Gabor patch, consisting of alternating dark and light lines, appears. Patches with varying degrees of contrast are used to determine the minimum contrast the participant can see.



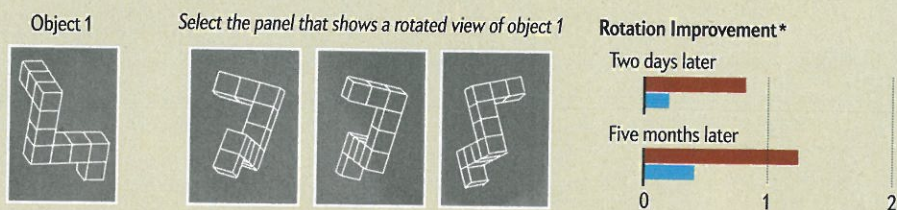
### Find It Fast

The useful field of view task, as it is called, measures spatial attention, or the ability to find target quickly while ignoring distractions in a briefly presented, cluttered scene. Participants in the test must find the solid square (the target) and indicate where it is located.



### Turn It Over in Your Mind

A mental rotation test examines the spatial visualization abilities of players by asking them to determine which rotated object corresponds to the three on the right corresponds to object 1" (far left).



\*Scale expressed as the square root of items correct.

Although action games provide a foundation for developing therapeutic games, a number of weaknesses must be addressed. First, a game needs to be tailored to the needs of the patient. Many individuals with attention deficits show little improvement from playing run-of-the-mill action games, despite the fact that these games enhance attention in healthy individuals. Most players approach the games by using a mental model of how events unfold, which allows them to anticipate what will happen next. People with attention deficits, however, display a more reactive style of play and so run into difficulty visualizing what lies ahead. Developers are now trying to find ways to restructure the traditional action-game format to prod players with attention deficits to take a more active role in strategizing future moves.

A similar revamping will be key for games aimed at increasing the reaction time of older people to, say, improve driving skills. Just downloading a copy of Medal of Honor will not be enough. The furious pace of most action games played by young adults can be overwhelming for the elderly—and they often derive little benefit from off-the-shelf commercial products. Games adjusted to their needs will require a more moderate pacing so that they prove challenging but not impossible.

A less demanding level of play will also be needed for games to enhance vision in amblyopia (lazy-eye) patients—another group targeted by game makers. Finally, the violent nature of many video games must also be scaled back in games targeted at clinical interventions. It may be appropriate for a game to come to a halt when a driver veers off the road, but having body parts flying through the air after the crash is superfluous. To go beyond shoot-

ing zombies to delivering actual therapeutic benefits, scientists with expertise in learning, psychology and neuroscience will have to team up with graphic artists, game producers and designers to create compelling content.

The initial inspiration that our research team derived from Team Fortress Classic holds still untapped possibilities. Games tailored for dyslexic children or head-trauma patients might be further customized by using sensors to monitor brain waves to adjust the level of play automatically. Just as important as the technology itself will be the care taken to align the content and skills of a game with the particular cognitive strengths and weaknesses of its players. A sensitivity to the needs of diverse groups of players will be an essential requirement for next-generation brain games to succeed. ■

#### MORE TO EXPLORE

**Brain Plasticity through the Life Span: Learning to Learn and Action Video Games.** Daphne Bavelier et al. in *Annual Review of Neuroscience*, Vol. 35, pages 391-416; July 2012.

**Video Game Training Enhances Cognitive Control in Older Adults.** J. A. Anguera et al. in *Nature*, Vol. 501, pages 97-101; September 5, 2013.

C. Shawn Green lectures on video games and learning as part of a massive open online course at the University of Wisconsin-Madison; scroll to bottom of page to view the videos: <http://greenlab.psych.wisc.edu>

#### FROM OUR ARCHIVES

**Turbocharging the Brain.** Gary Stix; October 2009.

[scientificamerican.com/magazine/sa](http://scientificamerican.com/magazine/sa)