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HOW VIDEO GAMES CHANGE THE BRAIN

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YOUNG REVIEWERS:

AKSHARA
AGE: 13

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TATJANA
AGE: 15

The brain controls how we see, hear, think, learn, and interact with the world. Importantly, the brain is not set in stone. It can be changed over time by the things we do. One of those things is playing video games! Playing video games can lead to a number of changes in the brain, some of which allow us to see, hear, think, and learn better. Crucially though, not all video games are equal. Just like eating different kinds of foods will affect the body in different ways, playing different types of video games will affect the brain in different ways. In this article, we will describe how scientists can measure changes in the brain and how playing video games can change the brain.

COGNITION

An umbrella term encompassing many different sub-functions involved in learning, understanding the world, and making decisions. These include things like perception, attention, intelligence, memory, and the use of language.

THE BRAIN AND COGNITION

The brain is responsible for **cognition**, or the way we process and understand information. Cognition includes things like seeing, hearing, paying attention, learning, remembering things, planning actions, and making decisions. One interesting thing about the brain is that, over time, it can be changed. This quality is called **brain plasticity**. As we experience and learn more things from the world around us,

plasticity allows the brain to physically change, creating stronger connections between certain brain regions. Many of our everyday activities, from daily interactions with others, to things we learn in school, to after-school hobbies, can have an impact on our brains and our **cognitive functions**. Video games are one of those things! The good news is that some of these changes in the brain caused by video games may help improve our cognitive functions. Under the right conditions, video games provide an ideal environment that allows players to exercise various cognitive functions and promote brain plasticity [1].

MEASURING BRAIN ACTIVITY AND COGNITION

To measure how our brains change after playing video games, **cognitive scientists** can use a few types of techniques (Figure 1). One is called magnetic resonance imaging (MRI), which uses strong magnetic fields to show the brain's structure. Using an MRI, scientists can see whether and how the cells that make up the brain have changed after some type of experience [2]. Another technique, called functional magnetic resonance imaging (fMRI), measures how much blood has flowed through specific areas of the brain, which tells scientists which brain areas have been active. A third technique is called electroencephalogram (EEG), which measures the brain's

BRAIN PLASTICITY

The capacity of the brain to change and/or grow. Typically, this occurs in response to experience and results in the brain functioning better when similar experiences are encountered again.

COGNITIVE FUNCTIONS

Mental processes that allow us to carry out tasks, including attention and memory.

COGNITIVE SCIENTISTS

Researchers who study the mind and how it works.

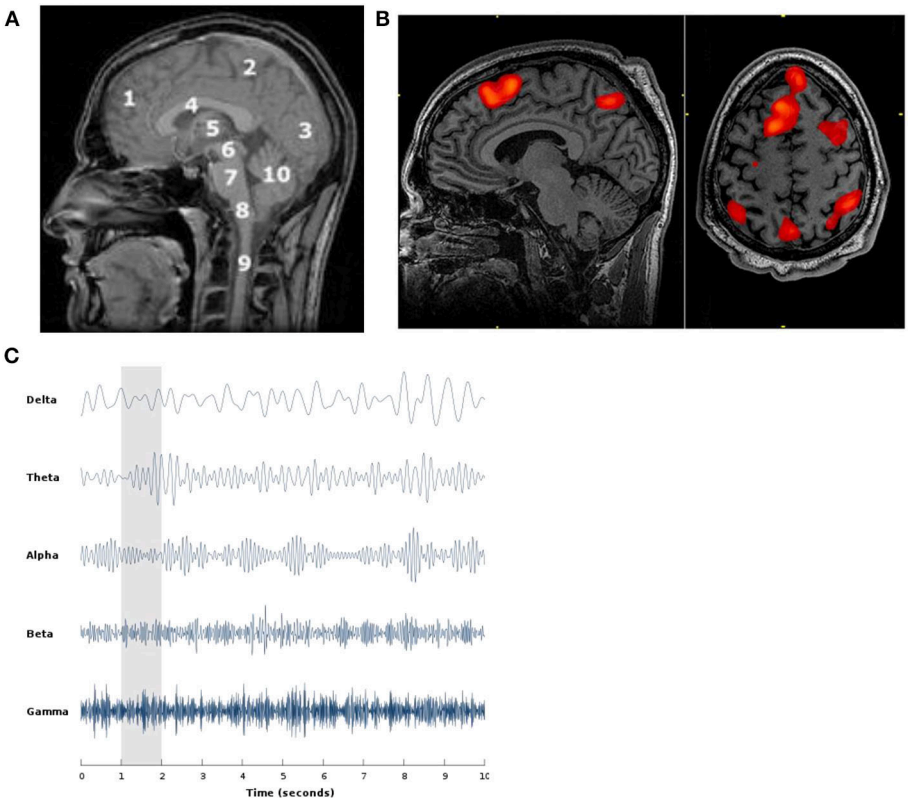

Figure 1

Examples of brain-imaging techniques. **(A)** An MRI of a person's brain, showing brain structures. **(B)** An fMRI showing brain activity in the colored areas. **(C)** An example of EEG signals showing five different types of brainwaves, which indicate different types of brain activity.

electrical signals. This tells scientists how much activity is happening in a given brain region at any moment.

While these brain imaging techniques help scientists to visualize changes in the brain, they also need to know whether video game playing actually changes cognitive functions. To determine that, cognitive scientists developed tasks designed to test various components of cognition, which we will call cognitive tasks for simplicity. These cognitive tasks include tasks to measure how well people can think about and remember information that is constantly changing (called **working memory**), how well they can direct their attention while ignoring distractions, and how well they can problem solve (Figure 2).

WORKING MEMORY

A cognitive function that allows us to hold a small amount of information in a readily accessible form.

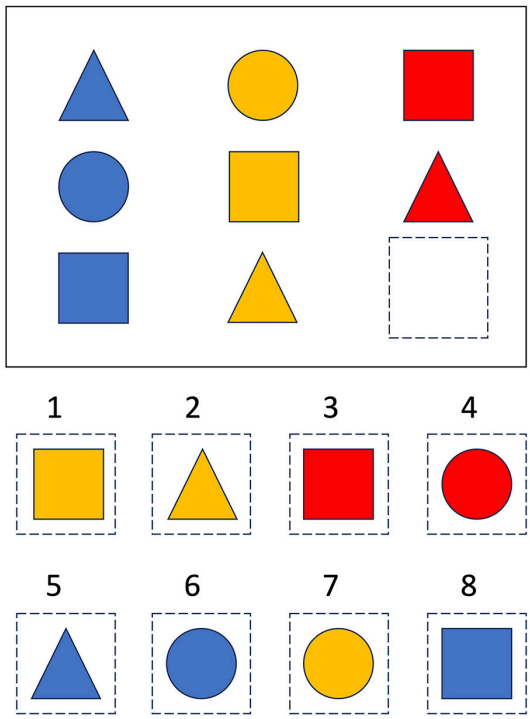

Figure 2

Example of a cognitive task. Raven's Progressive Matrices [3] is a measure of problem-solving ability. The person completing this task sees a matrix of images and must select the image that completes the matrix. Here, the answer is 4.

Using both brain imaging and cognitive tasks, cognitive scientists can conduct experiments to determine whether playing a specific video game changes the brain and/or cognitive functions (Figure 3). For example, maybe they want to know whether playing the video game Fortnite can improve people's brains and cognition. First, the scientists recruit participants and conduct a series of brain imaging scans and cognitive tasks. This is called a pre-test because it tells scientists about participants' brain structure and cognitive performance *before* they are asked to play a video game. The scientists then assign participants to play either Fortnite or a different video game that they do not expect to affect cognition. This second game is called the **control**, and it is used for comparison with Fortnite. Participants then play their assigned video games for an hour a day for several weeks, for example. Then,

CONTROL (OR CONTROL GROUP)

By comparing an experimental group with a control group (that doesn't receive any active treatment), scientists can better tell whether the experimental treatment has benefits.

the scientists conduct the same brain scans and cognitive tasks as in the pre-test. This is called a post-test, because it tells scientists what the participants' brain structure and cognitive performance is like *after* they have played the video game. Finally, the scientists compare participants' brains scans and cognitive task performance between the pre-test and post-test. If the participants who played Fortnite are found to have certain brain changes, such as a greater volume of brain tissue in some brain areas, or if their performance on cognitive tasks has increased more than the participants who played the control video game, researchers can conclude that playing Fortnite positively impacts the brain and cognition more than the control game does.

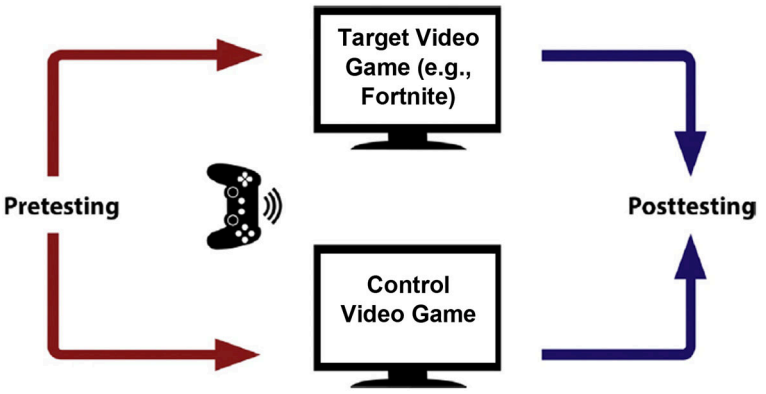

Figure 3

Figure 3

In a typical video game training experiment, participants first take a test measuring their cognitive function (pretesting). They are then assigned to play either an action video game or a control video game for some number of hours (no more than 1 h per day, with the whole thing being spaced out over several weeks). They then return and take the same test from before again (post-testing). If the target video game group improved more from pretesting to post-testing than the control video game group, then we know that playing that game improved cognitive function [Adapted from [1]].

SO, HOW *DOES* PLAYING VIDEO GAMES AFFECT THE BRAIN?

Across many experiments, research has found that playing video games can change many brain areas. As just a few examples, playing certain video games can *increase* the volume as well as the activity in small regions in many parts of the brain (Figure 1) [2]. However, some research has also found that playing video games can *decrease* activity in some of these areas, like the frontal lobe. How can video games both increase and decrease activity in the brain? One explanation is that exposure to a video game may at first increase activity in regions associated with gameplay. Then, as a player's performance improves and playing becomes more automatic, less "brain power" is needed, resulting in a decrease in activity of those brain regions [2]. Thus, depending on the length of training or the timing of the post-test, either increases or decreases in brain activity can be associated with playing video games.

Along with the changes seen in the brain, playing video games has also been shown to improve some aspects of cognition, including the ability to identify information that comes into the senses (like vision and hearing); the ability to understand the surrounding space,

like remembering where objects are located or how to navigate to a specific location; the ability pay attention; the ability to ignore distractions; the ability to multi-task; and working memory [4, 5].

EFFECTS ON THE BRAIN AND COGNITION ARE COMPLEX

The extent to which video game play alters the brain and cognition depends on many factors, such as age, amount of time spent playing video games, and what kind of video games are played. For instance, while playing video games does seem to have at least a small positive effect across all ages, video games tend to improve cognitive functions more in younger adults than in older adults over the age of 65 [4].

Similarly, while any duration of video game play likely leads to some brain changes, research suggests that the more time individuals spend playing video games, the larger the changes will be [4]. Critically though, all the available research suggests that binging on video games (playing for very long sessions) is not a good idea. Video game play most powerfully affects the brain in a positive way when the play sessions are distributed across a wide range of time. For instance, when we are trying to use video games to improve brain function in our lab, we only allow participants to play for 1 h per day.

Finally, not all video games affect the brain equally. In general, cognitive scientists assume that the types of cognitive skills that are required to play a certain game and the brain regions associated with those cognitive skills would be the skills and brain areas to change after playing that game for some time. This is similar to practicing sports. Soccer and basketball require different physical skills. If you practice kicking a soccer ball, you can expect that your leg muscles will get stronger and you will get better at kicking, but you would not expect your arms to get stronger or to get better at shooting a basketball.

Action video games are one gaming genre that has been studied extensively and consistently shown to improve some aspects of cognition. Action video games include first-person shooter games, like Fortnite, and third-person shooter games, like Splatoon. Games like Animal Crossing and Minecraft, however, would not be considered action video games. Researchers have found that action video games improve perception, spatial cognition, and attention more than other parts of cognition [4]. Other video game types, such as puzzle games, like Portal 2, or strategy games, like Starcraft 3, may tap into problem-solving abilities, suggesting that these games could improve those parts of cognition. However, the findings on the effects of these games on cognition have been mixed, so more research is needed [6].

CONCLUSIONS

In summary, the effects of video games on the brain and cognition are somewhat complex. Research has shown that playing video games can positively impact some parts of the brain and cognition, but the impact largely depends on the type of video game being played. Keep in mind that this field of research does not necessarily consider how playing video games affects other parts of a person's life besides cognition. For example, other lines of research have focused on the potential addictive features of video games or how they affect kids' social and emotional development. When thinking about how video games can affect us, it is important to look at their impact on all aspects of our lives.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

AKSHARA, AGE: 13

Science is everything, from the art of brushing to the way we interact with nature. All the information we learn is gathered in our brain. Our brain is not just a heavy load on our neck, it actually helps us to have fun, dream, and live. I am eager to know more about the mechanisms of how it functions. My aim is to understand how organisms interact with their environment to create a healthy society.

MFR DU LIBOURNAIS, AGES: 14–15

We are a group of young people in France. We are very heterogeneous in terms of our backgrounds and our lives, and we love playing video games and sports (cycling, basketball, horse-riding, tennis, boxing, motocross...). We love to laugh and are keen to travel and discover the world. We feel very lucky to be able to join this project and participate into a science project in English! We enjoyed the challenge.

TATJANA, AGE: 15

My name is Tatjana and I am currently 15 years old. In my free time I enjoy playing the piano. I attended the school of mental arithmetic and gained the skill of quick calculation. I would like to gain as much knowledge as possible in the field of information technology. I would like to learn more about how they can help in everyday life and their influence on human thinking.

AUTHORS

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Dr. Parong is a research psychologist who recently completed her postdoctoral work at the University of Wisconsin-Madison in Dr. Shawn Green's Learning and Transfer laboratory. She holds a Ph.D. in Psychological and Brain Sciences from the University of California, Santa Barbara. Her research interests have included how technology and video games can be used to help people learn and to improve their cognition. She is currently a Human Factors Researcher at a non-profit research company studying how people interact with vehicle interfaces and how vehicle technology and automation features impact drivers' safety. *parong.jocelyn@gmail.com

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