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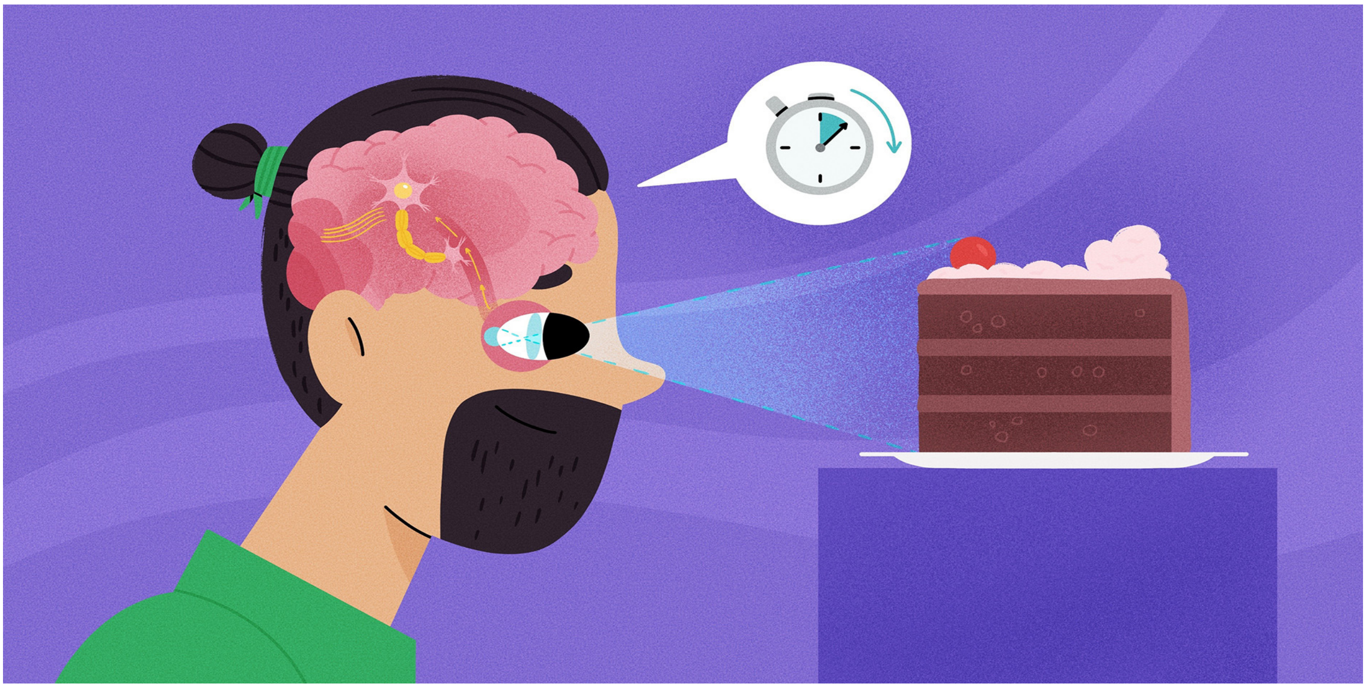
NEUROSCIENCE AND PSYCHOLOGY
Published: 23 August 2023
doi: 10.3389/frym.2023.732405



HOW DOES THE BRAIN ALLOW THE EYES TO SEE?

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YOUNG REVIEWERS:


ADDIE
AGE: 14


ADRIANA
AGE: 14


AMELIA
AGE: 16


BRUNA
AGE: 15


CAROLINE
AGE: 14

Did you know that it is not only your eyes that allow you to see? Your brain functions with the eyes to process and make sense of all things that you see. A part of the brain called the visual cortex is responsible for vision. The brain contains over 100 billion brain cells called neurons, and they work in "levels" to help you see the world—from a basic level in which you perceive simple shapes up to higher levels where you understand complex patterns. When networks of brain neurons do not work properly, brain disorders can result. Doctors and scientists can use various techniques to measure the activity of neurons. For example, unusual patterns of brain waves can tell us about damaged neural networks and brain abnormalities. Computers can also be programmed to "see" visual information, and such computers can help us to learn about the vision process in humans.

ELISHA

AGE: 14

GRACE

AGE: 13

MALCOLM

AGE: 15

HOW DO YOU SEE THE WORLD?

Do you like the world-famous Korean band BTS? In the case of the band, BTS stands Bang Tan Sonyeondan, but in neuroscience, it could also stand for brain transfer stimulus, which is a crucial brain function. The brain recognizes what your eyes see and can interpret those visual information or stimulus, so you can understand what you are reading or seeing. A **stimulus** is anything that captures your attention. When we are talking about vision, you detect visual stimuli, such as light. For instance, when you are at a BTS concert, you see powerful lights flashing with various colors, but this does not surprise you. The brain receives these visual stimuli and processes them with other visual information, so that you know the lights come from the stage. In other words, your brain helps you to recognize things, such as stage lights and a singer at a concert.

STIMULI

A visual signal that captures an attention.

HOW DOES YOUR BRAIN HELP YOU SEE?

Have you ever wondered how your eyes allow you to see? For instance, when you are at a concert, how can you spot a friend in the huge crowd? Even though you see with your eyes, a part of the brain called the **visual cortex** is also responsible for vision, as it processes any visual information from the eyes. This brain region contains several levels for analyzing information [1]. Let us think of the visual cortex as a fabulous, multi-layered cake. On the bottom, you have the primary visual cortex (V1), which interprets dots or any forms without shapes. Surprisingly, it only takes 70 milliseconds (msec, 0.07 seconds) to move signals from the eyes to V1.

VISUAL CORTEX

An area of the brain that processes visual information and has three main layers: primary, secondary, and tertiary.

Next, the secondary visual cortex (V2) recognizes more detailed visual representation than V1, such as geometric shapes. You can think of it this way: as you move up in cake layers, the levels of the visual cortex interpret more complex visual information [2]. With higher levels of visual cortex, you can see different colors or movements. It takes longer to transmit signals from the eyes to “higher” levels of the visual cortex. It takes 100 msec (0.1 seconds) to move from the eyes to V2, about 120 msec (0.12 seconds) from the eyes to V3.

In other words, visual information moves from the eyes through the levels of the visual cortex in a very short amount of time (Figure 1). This explains how you can quickly recognize a friend at a concert. Also, as you are reading this article, you can understand the meaning of each word in a sentence, instead of seeing just a jumble of words. Your brain and eyes work as a team to process visual information.

HOW DO WE KNOW HOW THE HUMAN BRAIN WORKS?

NEURON

A nerve cell that communicates with other nerve cells and forms networks to interpret the information that comes in through our senses, like the things we see.

The human brain has billions of cells called **neurons** [3]. Neurons connect with each other to form networks, and they communicate

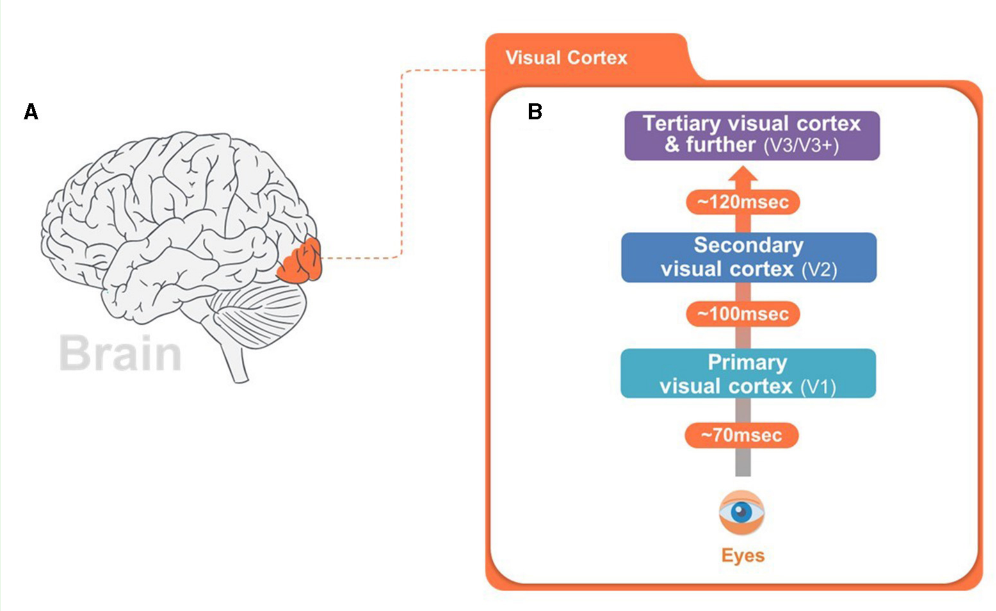

Figure 1

Levels of the visual system and the amount of time it takes them to process visual information. **(A)** The visual cortex, the part of the brain that deals with processing the things we see, is shown in red. It is located at the back of the brain. **(B)** The primary visual cortex, which analyzes very basic visual information like shapes, works the most quickly. The higher levels of visual processing, which recognize more detailed visual information like patterns in V2 and colors and movements in V3/V3+, each take a little longer. Together, visual cortex of the brain receives visual signals from the eyes and tries to make sense of what you are seeing. This is how you can understand a book you are reading or recognize a friend's face.

using tiny electrical signals. If the networks of neurons in the brain are damaged, neurons cannot receive electrical signals from each other. This can negatively affect brain functions, leading to disorders like memory impairment and dementia.

Since we cannot see the inside of the brain, how do we know if there is an issue with brain networks? Scientists and doctors have several ways to analyze the brain! Since neurons communicate using electrical signals, we can measure the brain's electrical activity using small, non-metallic devices called **electrodes** (Figure 2A).

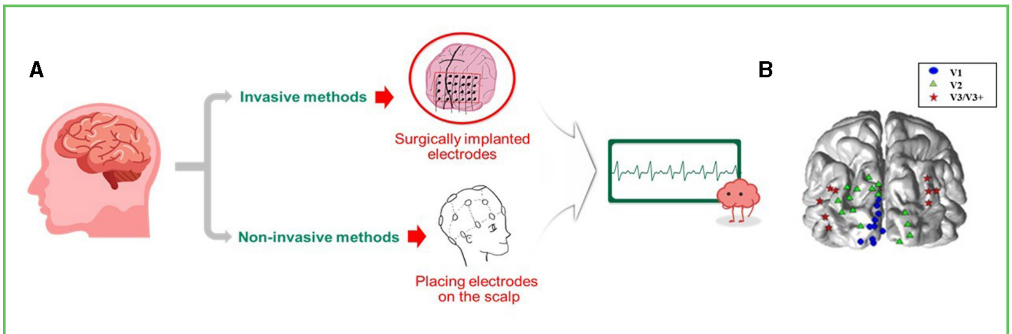

Figure 2

(A) To detect electrical signals in the brain, electrodes can either be placed on the scalp or implanted into the brain during surgery. Electrodes allow us to measure the brain waves. **(B)** The brain response to things we see happens in "levels", with the first level, V1 (blue dots) performs simple visual tasks like recognizing shapes. In an intermediate level, V2 (green triangles) recognizes patterns and colors, and for higher levels, V3/V3+ (red stars) give us complex visual information like colors and movements.

Electrodes help us to see **brain waves** made from the electrical activities of neurons. Just like waves in the ocean, the brain waves look like wavy lines moving up and down. However, if a person has brain damage, the electrodes might show slow and unusual patterns of brain waves. The ability to accurately read brain waves is important in neuroscience because it helps us to identify brain abnormalities or disorders.

To record the brain activity of patients in our study, we placed electrodes into the visual cortex during surgery, and then showed patients pictures of various shapes and patterns. As patients looked at these visual stimuli, the electrodes recorded their brain waves, so we could examine which brain regions became activated and how the brain responded to each shape and pattern (Figure 2B). For simple visual responses like dots or a flash of lights, V1 regions were activated. For intermediate visual responses, like geometric shapes, such as triangles, circles, V2 areas were activated, and for complex visual responses like visual fantasy or an illusion with mixed colors, V3/V3+ areas were activated.

There are other ways to measure brain activity that do not require surgery, such as **electroencephalography** (EEG). In EEG, electrodes can be harmlessly placed on the patient's scalp. EEG is widely used to look at brain activity and identify brain disorders [4].

Today, computers also help us to understand brain abnormalities. Using **artificial intelligence (AI)**, computers can mimic the networks of neurons in the human brain (Figure 3), which allows these computers to function similarly to the brain. For instance, AI-based computerized "vision" allows computers to recognize and interpret visual stimuli, kind of like they are "seeing". This computer-based "seeing" is similar to human vision, but computers can identify things more quickly and accurately. Thus, whenever we have difficulties in finding brain disorders in patients, we can use AI networks to gain more insight into disorders and treat patients more efficiently [5].

ELECTRODE

Small non-metallic devices that measure brain electrical patterns are used in both invasive and non-invasive brain imaging techniques.

BRAIN WAVES

Recordings of electrical signals of the brain.

ELECTROENCEPHALOGRAPHY

A non-invasive brain imaging method that measures electrical activities of the brain by placing electrodes on a scalp.

ARTIFICIAL INTELLIGENCE (AI)

A computerized system that mimics the networks of neurons in the brain and can perform human-like tasks.

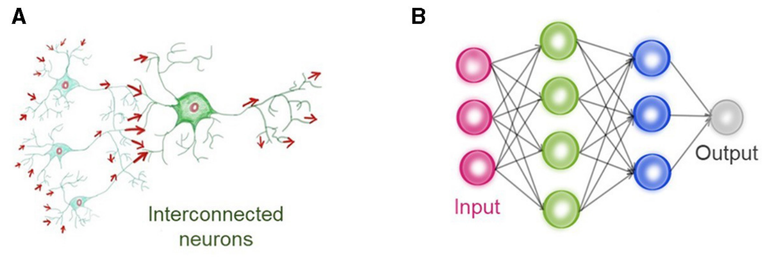

Figure 3

Figure 3

(A) Networks of interconnected neurons in the brain work together to help us see. Electrical information flows from one neuron to another. **(B)** AI can simulate the networks of neurons in the human brain, with information flowing between signals (colored circles). In this case, input is a visual stimulus, such as image, and output recognizes what the image is. In fact, artificial neurons in AI look similar but also serve a similar function as neurons in human brain.

SUMMARY: WHY IS THIS WORK IMPORTANT?

In this article, we told you about how the visual cortex functions in vision and how scientists and doctors can monitor brain activities by measuring brain waves. Now you know that the brain must work with the eyes to allow you to see! Networks of brain cells in the visual cortex communicate to process "levels" of visual information, from simple to complex. When brain networks do not work properly, brain disorders like memory impairment and dementia can result. Computerized neural networks, like those used by AI, can help scientists to understand what goes wrong in brain disorders. With our work, we hope to inspire many bright young scientists to show interest in **neuroscience** and help to answer more fascinating questions about vision someday!

NEUROSCIENCE

The study of human brain and the interaction of brain cells involved in memory functions and behaviors.

ACKNOWLEDGMENTS

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. Part of this work was invited to present at Frontiers for Young Minds through Organization for Human Brain Mapping (OHBM) 2021. The paper was supported by the RP-Grant 2021 and 2022 of Ewha Womans University (SEK). The study was supported by grants of the Basic Science Research Program, Convergent Technology R&D Program for Human Augmentation, BK21 Plus Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, Information and Communication Technologies & Future Planning [NRF-2018M3C1B8016147, 2019M3C1B8090803, and 2020R1A2C2013216], and Institute of Information & Communications Technology Planning & Evaluation (IITP) funded by the Korea government (MSIT) [No. RS-2022-00155966], and Artificial Intelligence Convergence Innovation Human Resources Development from Ewha Womans University to HL.

ORIGINAL SOURCE ARTICLE

Kim, S. E., Kim, W. S., Kim, B. G., Chung, D., Jeong, J., Lee, J. S., et al. 2013 Spatiotemporal dynamics and functional correlates of evoked neural oscillations with different spectral powers in human visual cortex. *Clin. Neurophysiol*. 124:2248–56. doi: 10.1016/j.clinph.2013.04.341

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SUBMITTED: 12 January 2022; **ACCEPTED:** 04 August 2023;
PUBLISHED ONLINE: 23 August 2023.

EDITOR: Elizabeth Johnson, Northwestern University, United States

SCIENCE MENTORS: Hengameh M. Taraz and Soyeon Jun

CITATION: Kim SH, Cho EJ, Kim YJ, Kim SE and Lee HW (2023) How Does the Brain Allow the Eyes to See? Front. Young Minds 11:732405. doi: 10.3389/frym.2023.732405

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

ADDIE, AGE: 14

I am a 9th grader who enjoys fashion design and math. I am passionate about the performing arts. I love to act! When I am not rehearsing for a play or musical, you can usually find me crocheting. My favorite color is purple and my favorite food is chicken wings. Some day I hope to be on broadway. If that does not work out, I would like to be a clothing designer.

ADRIANA, AGE: 14

I am a freshman in high school who enjoys songwriting and playing the piano, as well as writing short stories. I enjoy biology and literature. I maintain high grades in school and pride myself in my ability to learn things quickly. I love riddles and puzzles, as well as video games-the more challenging, the better!

AMELIA, AGE: 16

I am a high school student who enjoys drawing fun comics, learning about cosmology, and the science of quantum physics. I like sleeping in on the weekends and sometimes procrastinate.

BRUNA, AGE: 15

My name is Bruna. I am a student of On A Beam of Light class. I love science because it's so vast and complex. Science provides solutions to many problems so I think that when science is studied, we are able to gain much more knowledge about the world we live in. A few other facts about me is that aside from liking science, I love reading, studying history, and traveling. Also, I was born in Brazil; my first language is Portuguese.

CAROLINE, AGE: 14

I enjoy writing, specifically poetry. I have been writing since I was 6 years old, writing lyrics for songs. No matter what my age is, I would always tell stories through my writing. Having the ability to tell stories has helped me learn more about science! All science has a story behind it and the more attention you pay to the details of the story, the more secrets you uncover.

ELISHA, AGE: 14

I enjoy reading, creative writing, and making art. I have been playing the violin and learning taekwondo for over seven years now, and continue to advance to more challenging skills! I like musical theater as well as acting; my favorite musical so far is Hadestown. My favorite color is olive green and I love understanding how the world functions, including science!

GRACE, AGE: 13

Grace enjoys reading books, exercising, and playing sports. She likes cake, sandwiches, cheese, and mushrooms. She is good at studying, drawing, doing presentations, and P.E. She is naturally curious and likes to experience different activities, cultures, and whatnot.

MALCOLM, AGE: 15

Yo! My name is Malcolm and I am 15 years old. My favorite subjects in school are Japanese and Physics. I enjoy learning about various STEM topics (especially aerospace), participating in robotics competitions and playing Volleyball. In my free time, I like to play video games and bike around my town. I'm super excited to be a Young Reviewer and learn more about STEM along the way!

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Soo Hyun Kim is a 4th-year medical student at Ewha Womans University School of Medicine in Seoul, Korea, and she was a speaker for Organization for Human Brain Mapping (OHBM) Korean team in 2021. She graduated from Ewha Womans University with a degree in computer engineering and worked as a developer for 2 years. Her research interests focus on brain imaging or other advanced technologies using computers. She hopes to use her career in research to diagnose and treat brain diseases.

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Yu Jin Kim is a 2nd-year medical student at Ewha Womans University School of Medicine in Seoul, Korea. Her research interests vary, so she is working on several studies and chasing her dream through those experiences. With her passion for children's psychiatric health, she held the Teddy Bear Hospital Program at the Ewha Womans University Medical Center, which was well received. She wants to help children and adolescents to overcome their traumatic events and live healthy and positive lives.

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Dr. Kim is currently a research professor at Ewha Womans University School of Medicine in Seoul, Korea. She received her Ph.D. in medical science from Ewha Womans University School of Medicine, and participated in variety of human and clinical research. Her main research topics include various brain disorders, such as epilepsy, sleep disorders, and brain aging. She is also interested in biological and behavioral changes in brain disorders and brain aging process in population data by using different brain imaging and recording techniques in human.

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