frontiers | Frontiers for Young Minds

NEUROSCIENCE AND PSYCHOLOGY
Published: 25 June 2024
doi: 10.3389/frym.2024.1167027

BOOSTING MEMORY THROUGH MAGNETIC BRAIN STIMULATION

Melissa Hebscher* *and Joel L. Voss*

Center for Neurocognitive Outcomes Improvement Research, Department of Neurology, University of Chicago, Chicago, IL, United States

YOUNG REVIEWERS:

LOUIS, MAYA, ISSAC, AND JOSIE

AGES: 11–15

ZOEY

AGE: 11

When you think back to a past birthday party, you can probably remember who was there and what you ate. This might seem easy to you, but memory is a complicated process that scientists are still trying to understand. Memory takes place in the brain, which is made up of billions of cells called neurons. Recent research has shown that memory can be improved safely using a tool called transcranial magnetic stimulation (TMS). TMS works by sending a very strong magnetic field through the skull and into the brain, where it changes the activity of neurons, causing changes in behavior. In this article, we will discuss how the brain remembers, how we can make the brain remember better using TMS, and how TMS could be used in the future to help people with memory problems.

HOW DOES THE BRAIN REMEMBER?

Try to remember the last birthday party you attended. You can probably remember the details of the party like who was there, what you ate, and who you spoke to. It might seem easy to you, but memory is

HIPPOCAMPUS

A curved structure in the middle of the brain that plays an important role in learning, memory, and spatial navigation.

actually a very complicated process, and scientists are still trying to understand how the brain remembers. Scientists have discovered that many parts of the brain are important for memory. The most important brain area for memory is called the **hippocampus**, an area buried deep inside the brain (Figure 1). Without a hippocampus, you would not be able to learn new information or remember much from your past [1]. The hippocampus makes new memories by talking to other parts of the brain that are far away, like areas that are important for hearing, seeing, and feeling emotions. For example, when you are at a birthday party, different parts of your brain will allow you to hear what your friend is saying to you, see what the birthday cake looks like, and feel excited about seeing your friends. The hippocampus stores information about where in the brain these parts of the memory can be found. Later, when you remember that birthday party, your hippocampus tells those parts of your brain to replay what your friend said, what the birthday cake looked like, and how excited you felt. That is why when you remember, it sometimes feels like you are back in the past, re-living the memory again. Your brain is basically your own personal time machine!

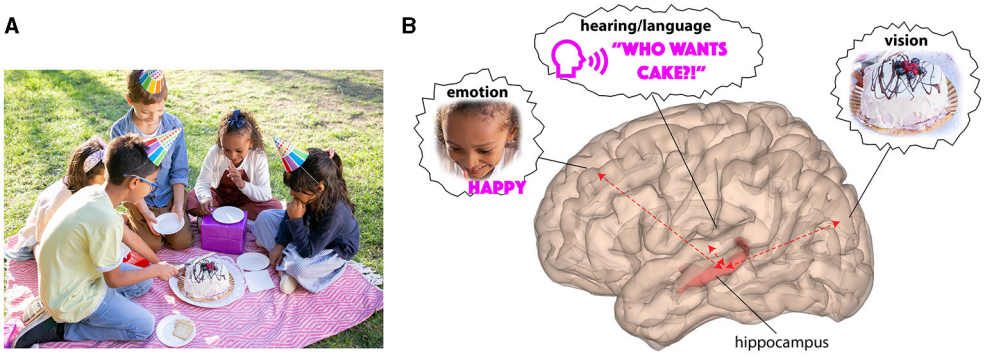

Figure 1

Many parts of the brain are involved in memory. **(A)** When you experience an event like a birthday party, different parts of your brain let you feel excited (emotion), hear what your friend is saying (hearing/language), and see the birthday cake (vision). **(B)** The hippocampus (red), located deep inside the brain, coordinates memory by storing information on where in the brain to find various parts of a memory. When you remember the birthday party, the activity of the hippocampus synchronizes with activity in those other parts of your brain, which many researchers think causes the brain to replay the emotions, sounds, and sights from the event.

BRAIN CELLS COMMUNICATE WITH EACH OTHER

How does the hippocampus talk to areas that are so far away? The brain is made up of billions of cells called **neurons**. Neurons communicate with each other through electrical and chemical signals. When a neuron "fires", an electrical impulse travels through it, causing it to release chemicals called **neurotransmitters**. These neurotransmitters are taken up by the neuron's neighbor, and they cause the neighbor to have an electrical impulse and release more neurotransmitters. Like a chain reaction, this process continues for many neighboring neurons, helping areas that are far apart send signals to each other. When everything is working properly, this process allows the hippocampus to talk to many far-away brain areas, letting us remember things from the past. But this process does not always work perfectly, especially as we get older. This is why people sometimes have a hard time remembering. Researchers are working

NEURONS

Nerve cells that transmit electrical and chemical signals in the nervous system, including the brain, allowing functions like thinking, movement, and sensation.

NEURO-TRANSMITTERS

Chemicals messengers that send signals between neurons, letting different parts of the brain talk to each other, so we can move, feel emotions, and think.

TRANSCRANIAL MAGNETIC STIMULATION (TMS)

A device that uses a magnet to send pulses to the brain to change the activity of neurons in the brain, leading to changes in behavior and mood.

on ways to make memory better in a safe way, by stimulating the brain with magnets.

USING A MAGNET TO CHANGE BRAIN ACTIVITY

A technique called **transcranial magnetic stimulation (TMS)** can be used to change the activity of the brain's neurons and to improve memory. TMS uses a very strong magnetic field that travels through the skull and into the brain, where it causes electrical stimulation of neurons (Figure 2). This magnetic field can reach neurons close to the surface of the brain, but it is not strong enough to reach areas buried deep in the brain. When TMS changes the activity of many neurons, this can lead to changes in behavior. Because TMS is placed on the scalp, it can be used without any medical procedures like surgery, making TMS a safe and painless technique. It feels like being tapped on the head!

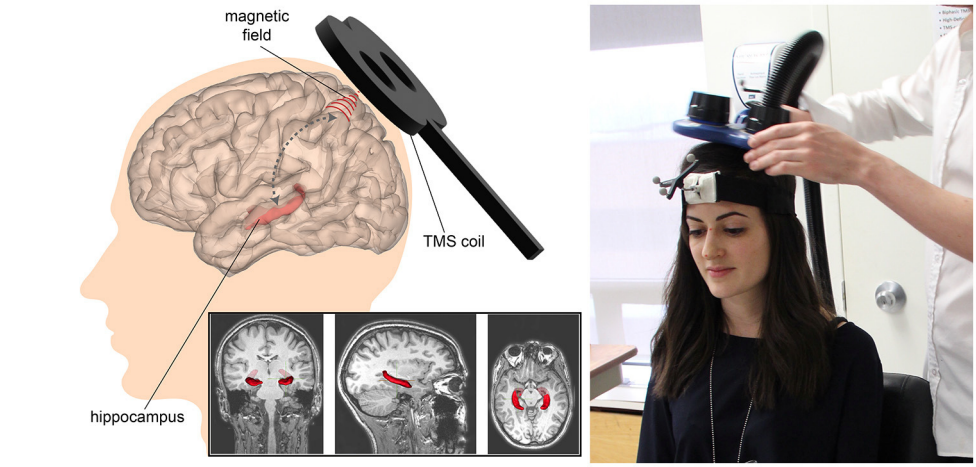

Figure 2

(A) TMS works by sending a strong magnetic field through the skull, where it causes electrical stimulation of neurons. The magnetic field is only strong enough to reach brain parts close to the skull, meaning it cannot reach the hippocampus. The three images on the bottom help you appreciate just how deep the hippocampus is inside the skull. But researchers have recently shown that TMS can hit areas of the brain that *talk to* the hippocampus, and in this way can improve memory. **(B)** A photo of the author receiving TMS.

TMS can change brain activity for a short or long period of time, depending on how often it is used. One session of TMS usually lasts between 1–20 min, and it will change brain activity for around 1 h. In some cases, people will receive one TMS session every day for many weeks, which can cause brain activity to be changed for a much longer time. For example, doctors use TMS to treat illnesses like depression by giving patients 5 sessions of TMS per week for 4 weeks. This treatment causes brain activity to be changed for long time, and it can improve depression.

USING BRAIN STIMULATION TO CHANGE MEMORY

You might be wondering how we can use TMS to affect memory if the hippocampus, the brain's key memory structure, is buried deep in the

brain. As you already learned, the hippocampus talks to brain areas far away through neurons that communicate with each other. But it does not communicate with all brain regions equally. Some parts of the brain have particularly strong connections with the hippocampus, and we call these a "network" of the hippocampus. Some of the areas of the **hippocampal network**, such as areas of the parietal and occipital lobes, are close enough to the surface of the brain to be reached by the magnetic field of TMS. When TMS reaches these brain areas close to the skull, it causes electrical stimulation of the neurons that talk to the hippocampus, which can then indirectly affect the activity of the hippocampus, changing how the hippocampus is involved in memory.

HIPPOCAMPAL NETWORK

A group of brain regions that have strong connections with the hippocampus, including the parietal and occipital lobes, and are important for memory.

To influence the hippocampus with TMS, researchers first need to find a good target for TMS in the hippocampal network. That is, they need to find a brain area close to the skull that has a lot of communication with the hippocampus. We measure this communication using a machine called a **magnetic resonance imaging (MRI)** scanner. This machine takes hundreds of pictures of the brain and can record activity in various parts of the brain. If two brain areas show very similar activity at the same time, we can conclude that these two areas are probably talking to each other. So, using the MRI scanner, we can find an area close to the skull that is part of the hippocampal network. These areas tend to be in the parietal lobe, near an area called the angular gyrus, but the exact location differs slightly for each person because everyone's brain is unique. We then use TMS to apply a magnetic field to the part of the brain that talks the most with the person's hippocampus, hoping that this brain area will let us change the hippocampus' activity (Figure 2A).

MAGNETIC RESONANCE IMAGING (MRI)

A device that takes pictures of the inside of the body, including the brain, to help doctors and researchers see what is going on inside.

Once TMS is over, we give everyone a memory test to see if TMS improved their memory. The type of memory test used can change from experiment to experiment. In some experiments, researchers ask people to memorize a list of words associated with various pictures. Later, people are shown a word and asked to remember which picture went with it. In other experiments, researchers show people short movie clips and later ask them to remember certain parts of the movie clips. The word-picture pairs and video clips measure slightly different types of memory, which lets researchers understand if TMS affects certain types of memory more than others. You can try out a memory test yourself here.

After just a single 1-min session of TMS, we found that people's memory for both word-picture pairs and video clips gets better, but these changes are small and last only around 1 h [2, 3]. After 5 days of TMS sessions, people's memory for word-picture pairs gets about 30% better and these changes last for at least 1 full day after the last TMS session. So far, at least 26 experiments using this method to change memory have been published in scientific journals, and all of the experiments except for one found that TMS enhanced memory.

We can also measure brain activity right after TMS, by using the MRI scanner. Doing this we found that, after TMS, the hippocampus communicates better with the brain area close to the skull that was hit by the magnetic field.

FUTURE OF BRAIN STIMULATION FOR MEMORY

Researchers have only been testing how TMS can change memory and brain activity for a few years. It is therefore not yet fully understood *how* TMS changes the brain to cause memory improvements. The experiments so far have mostly been on young people with good memories, so we are not sure if TMS can be used to improve memory in older people with memory problems. A few very exciting experiments found that TMS can help improve memory in patients with **Alzheimer's disease** [4]. Many more experiments need to be run before we really understand how TMS can improve memory in people with memory problems. Researchers will also need to test whether TMS can help people with memory problems remember more complicated things, like when to take their medication or the names of their grandchildren. With lots of research, TMS may one day be used as a treatment for memory disorders.

ALZHEIMER'S DISEASE

A disease that affects the brain and can cause problems with memory, thinking, and behavior in older people.

While TMS is a promising technology, there are some limitations. First, TMS machines are very expensive and can be complicated to use. While TMS is generally considered quite safe, scientists and doctors must follow strict safety guidelines, like taking a medical history before using and monitoring patients carefully during stimulation. TMS also does not work the same on every person. Some people show big improvements and others do not. Finally, the effects of TMS are temporary and fade over time. Despite these limitations, TMS can still be a very powerful tool for studying, and maybe improving, brain function. If you are interested in learning more about how the brain lets us remember, consider reading more about it in this article. Maybe you will be inspired to think of new ways to use TMS to improve memory!

ACKNOWLEDGMENTS

Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

REFERENCES

1. Scoville, W. B., and Milner, B. 1957. Loss of recent memory after bilateral hippocampal lesions. *J. Neurol. Neurosur. Psychiat.* 20:11. doi: 10.1136/jnnp.20.1.11

2. Hebscher, M., Kragel, J. E., Kahnt, T., and Voss, J. L. 2021. Enhanced reinstatement of naturalistic event memories due to hippocampal-network-targeted stimulation. *Curr. Biol.* 31:1428–37. doi: 10.1016/j.cub.2021.01.027
3. Hebscher, M., and Voss, J. L. 2020. Testing network properties of episodic memory using non-invasive brain stimulation. *Curr. Opin. Behav. Sci.* 32:35–42. doi: 10.1016/j.cobeha.2020.01.012
4. Koch, G., Bonnì, S., Pellicciari, M. C., Casula, E. P., Mancini, M., Esposito, R., et al. 2018. Transcranial magnetic stimulation of the precuneus enhances memory and neural activity in prodromal Alzheimer's disease. *Neuroimage* 169:302–11. doi: 10.1016/j.neuroimage.2017.12.048

SUBMITTED: 15 February 2023; **ACCEPTED:** 31 May 2024;
PUBLISHED ONLINE: 25 June 2024.

EDITOR: Theodore Zanto, University of California, San Francisco, United States

SCIENCE MENTORS: Jonathan B Fritz and Yingying Zhang

CITATION: Hebscher M and Voss JL (2024) Boosting Memory Through Magnetic Brain Stimulation. Front. Young Minds 12:1167027. doi: 10.3389/frym.2024.1167027

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

LOUIS, MAYA, ISSAC, AND JOSIE, AGES: 11–15

Four children read, enjoyed and reviewed this article: Louis, Maya, Isaac, and Josie. Louis (11) is curious about everything, likes to explore places from Atlas Obscura, and for fun enjoys reading comics, and relaxing on the beach. Maya (15) loves science (especially biology and psychology) and the arts (I am a vocalist and also play violin, enjoy performing in musical theater, a dancer and an avid artist). I am fascinated by how actors and musicians and dancers can learn and remember complex sequences of words, music, and movement. Isaac (15). When I am not trying to remember things in school you can find me playing basketball, running, reading, or listening to music. Josie (15) loves math and physics. She is very interested in getting girls more involved in STEM fields and wants to get other girls to share the love for science and math that she has. For fun she loves to play basketball and guitar.

ZOEY, AGE: 11

Hi, my name is Zoey. I like to read fantasy books, play violin, and my favorite subject is science. I would like to become a scientist.

AUTHORS

MELISSA HEBSCHER

Melissa is a staff scientist at the University of Chicago who studies memory using brain imaging and brain stimulation techniques. She earned her Ph.D. and M.A. in psychology from the University of Toronto, and her B.A. from McMaster University. Her research tries to understand how our brains help us remember complex events from the past and how we can improve our memory. *melhebscher@gmail.com

JOEL L. VOSS

Joel is a professor of neurology and director of the Center for Neurocognitive Outcomes Improvement Research (Center NOIR) at the University of Chicago. He earned his Ph.D. from Northwestern University and a B.S. from Eckerd College. His research focuses on human memory and its disorders.