



TREATING ADDICTION BY STIMULATING THE BRAIN WITH POWERFUL MAGNETS

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Have you ever wondered why some people cannot stop smoking, even when they really want to? Addiction happens when someone cannot stop using a substance, like cigarettes, even though they know it is harmful and want to quit. This is because of a strong urge that is hard to resist, called a craving. Simultaneously, people with addiction have less control over their actions. These changes in craving and control result from changes in the activity of certain brain areas. Researchers have found a way to restore activity in these brain areas from the outside, using a technique called transcranial magnetic stimulation (TMS). Studies have found that more activation in certain brain areas reduces smoking, but not necessarily craving. So, TMS helps to bring back healthy behavior and can be helpful in treating addiction. Researchers continue to investigate ways to make TMS work better.

ADDICTION

When someone cannot stop doing something, even if it is bad for them, because their brain gets used to it and craves it a lot.

CRAVING

When you really, really want something, like your favorite candy or toy, so much that it is hard to think about anything else.

COGNITIVE CONTROL

It is like your brain's "boss", helping you make good choices, focus, and stop yourself from doing something you know is not right.

WHAT IS ADDICTION?

Imagine that you really love chocolate and you want to eat it all the time. Even when you feel full from all the chocolate you ate, you still find it hard to stop eating more. So, you eat a little more, even though you know it will make you feel sick if you do. If you do this a lot, it can also be bad for your health. For example, you might become overweight or develop diabetes.

Addiction works the same way, but instead of chocolate it involves things like alcohol, cigarettes, or other drugs. A person is addicted when they cannot do anything without using their drug. People with an addiction often know that using drugs is bad for them, but they find it very difficult to stop. Cigarette smoking is a common addiction for many adults and sometimes even teenagers. Did you know that **28,300,000 adults in the U.S. smoke?** That is more than 1 in every 10 people! You probably know that smoking is bad for you. It damages the heart and can cause lung cancer. In fact, 1 in every 5 deaths in the U.S. is due to smoking. This is a big problem because most people start smoking at a young age, without knowing it is bad for their health. Smoking does not only affect people's health, but it also changes how the brain works.

Two behaviors that are different in people with an addiction are **craving** and **cognitive control**. You can think of these as the gas and brake pedals of a car. When someone craves smoking, they feel a strong urge to smoke a cigarette. So, craving makes someone do things like smoke (using the gas pedal). Cognitive control is like being the boss of your own actions: it is what helps a person control and think about their behavior. Cognitive control is like using the brake pedal on a behavior. When someone becomes addicted, for example to cigarettes, the craving becomes stronger and cognitive control becomes weaker. This is why people keep smoking even when they no longer enjoy it: they cannot resist the urge to smoke. Because it is so hard to stop smoking cigarettes, most people need help to quit successfully.

CHANGING THE BRAIN FROM THE OUTSIDE

When someone is addicted to something, there are ways to help them quit. These can include talking to a therapist about why they want to keep using a drug and how they can learn to resist the craving to use it. Medication is another option. Certain medicines can help people resist the desire to use the drug, or make them very sick when they do use it. But these treatments do not always work for everyone, and sometimes people start smoking again even if they did stop smoking before, which is called relapse. It is very important to keep finding

PREFRONTAL CORTEX

The front part of your brain that helps you make smart choices, solve problems, and control your feelings.

INSULA

Like a “feelings detector”, this brain part helps you feel things like hunger, pain, or emotions.

Figure 1

(A) This left side view of the brain shows the locations of the anterior insula, posterior insula, and prefrontal cortex. These brain areas are responsible for craving and cognitive control. (B) With addiction, there is more craving and less cognitive control. If you could put these factors on a scale, craving would weigh more than control. Created with [BioRender.com](#).

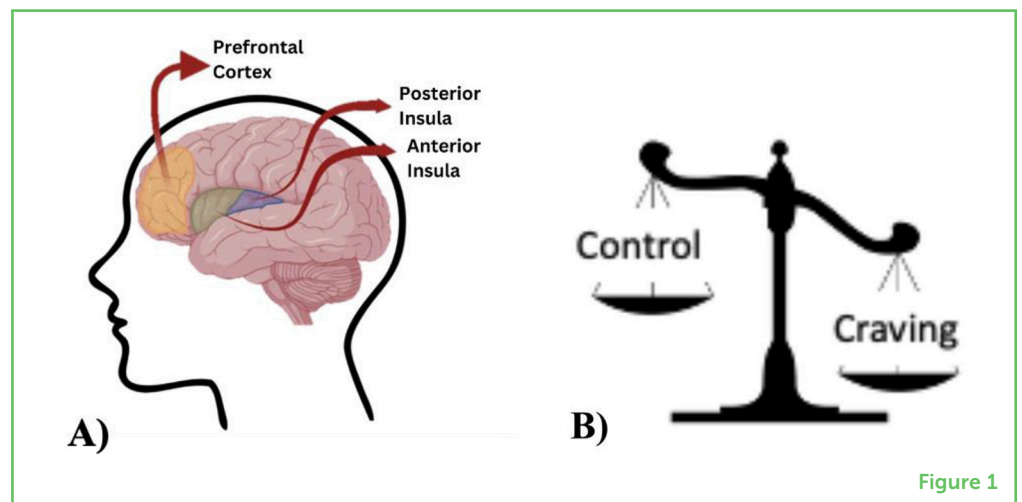


Figure 1

DEEP BRAIN STIMULATION

A treatment that improves how your brain works by putting tiny wires in your brain to send signals.

TRANSCRANIAL MAGNETIC STIMULATION

A treatment that uses a special magnet outside your head to send signals to your brain, helping it work better.

MAGNETIC FIELD

An invisible force around a magnet that can pull or push metal objects, like when a magnet sticks to your fridge.

Stimulating the brain can change its activity. There are two ways to stimulate the brain: invasively (meaning from inside the skull) and non-invasively (meaning from outside the skull). Stimulating the brain invasively involves surgery to open the skull and put a stimulator in the brain. This is called **deep brain stimulation** [1]. You can read more about deep brain stimulation in [this Frontiers for Young Minds article](#). But deep brain stimulation can be dangerous because surgeries have potential risks, like bleeding and infections. Non-invasive methods do not have the risks associated with surgery, because they stimulate the brain from outside the skull. One of these methods is called **transcranial magnetic stimulation** (TMS). Can you guess what this means? The name actually describes exactly what the method does — “trans” means through, and “cranial” means skull. So, it means magnetic stimulation that goes through the skull! TMS has already been used to help people with problems like depression (feeling very sad). If you want to read more about how TMS is used, you can read [this article](#).

How does TMS work? Brain cells can be stimulated using a **magnetic field** that goes through the skull. This stimulation can increase or decrease the electrical activity of the brain cells in a specific brain area.

Typically, these brain cells are close to the skull. In a new type of TMS, areas that are further away from the skull can be stimulated, like the insula. This is why it is called deep TMS (Figure 2). Similar to typical TMS, deep TMS can also change the activity of brain cells in certain areas. It can target the deeper brain areas responsible for more craving and less cognitive control in addiction. In this way, TMS can help restore the brain's activity and potentially become a useful way to treat addiction. TMS is not as risky as invasive stimulation, but it may cause side effects like dizziness or headaches after treatment.

Figure 2

(A) Deeper areas of the brain, such as the insula, can be targeted using deep TMS. (B) A participant wearing a TMS coil designed to specifically target the insula. [BioRender.com](https://www.biorender.com).

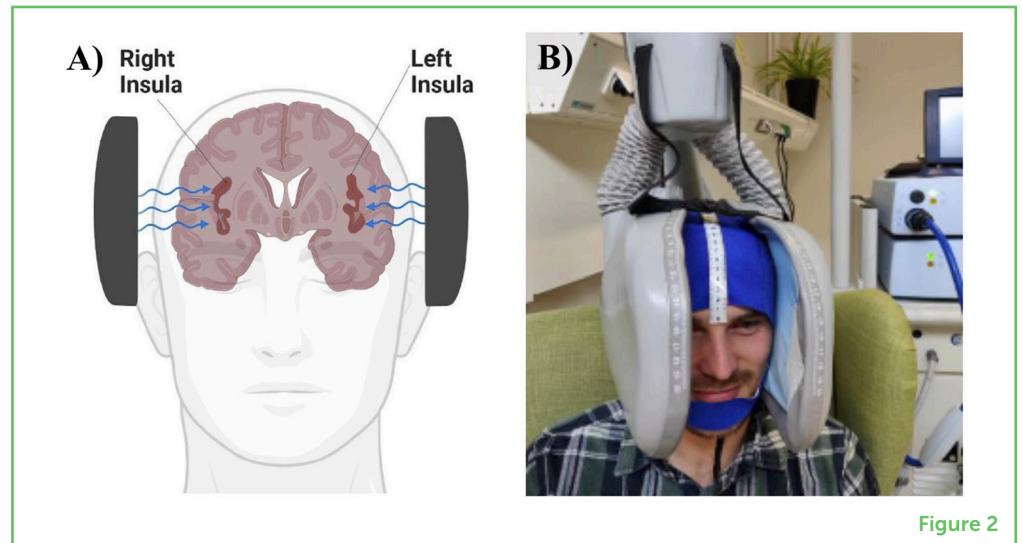


Figure 2

DOES DEEP TMS HELP PEOPLE WITH SMOKING ADDICTION?

Remember that people with smoking addiction might really want to stop smoking but find it hard to do so because they have more craving and less cognitive control? These symptoms of addiction are caused by changed activity of the PFC and insula. Scientists found that this brain activity can be changed by stimulating these brain areas non-invasively, which can change how much craving and cognitive control someone has. This is how we can use deep TMS to help people to stop smoking. Researchers have done several scientific studies to find out if deep TMS really works.

For example, in one study, researchers worked with 262 people who had tried to quit smoking at least three times before but could not [2]. For three weeks, half of the people got the real deep TMS to increase their brain activity, and the other half got fake stimulation that feels and sounds the same but has no effect on the brain. The two groups got the treatments every day for three weeks, and then once a week for three more weeks. The treatments were given after making the participants want to smoke by showing them things related to smoking.

Researchers checked if the participants had stopped smoking by asking them to write down if they smoked each day and testing their urine to see if they had smoked. The main goal of this study was to see how many people stopped smoking for 4 weeks straight by the end of 18 weeks. Researchers found that after real deep TMS, people smoked less and had less craving compared to fake TMS.

Some studies showed that deep TMS helps reduce craving, while others showed that it does not make a big difference [3]. Although researchers are still investigating the effects of TMS on craving and smoking, one explanation could be that TMS affects cognitive control. If you think back to the scale analogy, when cognitive control becomes heavier, craving becomes weaker in comparison. This could lead to TMS being effective for stopping smoking without a change in craving. However, some scientists combined the results of a bunch of studies and concluded that TMS is a promising treatment for quitting smoking and reducing craving [4].

WHAT DO WE KNOW SO FAR?

Addiction is a long-lasting problem in which people keep wanting to use the substance they are addicted to despite the negative consequences and the desire to quit. Although some treatments for addiction exist, people often start using drugs again after trying to quit. So, new and better ways are needed to help them stop.

People with an addiction have more craving to use a drug and less cognitive control over their behavior. This is because the activity of the brain areas responsible for these functions has changed. Normal brain activity can be restored by stimulating the brain from outside the skull with TMS. Changing the activity of these brain areas could reduce craving and restore cognitive control. In smokers, researchers have found that activating these brain areas helps people quit smoking. In future studies, researchers should find out how to make deep TMS work better, by both reducing craving and increasing cognitive control.

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We would like to thank Vanessa (18 years old) from Beijing for her contribution in reviewing the article. She is a biology lover and enjoys reading therapeutic methods for human diseases. She is also an amateur popular science writer herself and owns a little biological science blog! She dreams of becoming a scientist who writes, and feels deeply honored to be involved in Frontiers for Young Minds!

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YOUNG REVIEWERS

HANGZHOU DIPONT SCHOOL OF ARTS AND SCIENCE, AGES: 12–14

Hello! We are a group of Grade 6–8 students interested in neuroscience, craving for brilliant resources! We are on a mission to inspire more young minds to be empowered by brain science and advancement!





JASON, AGE: 14

My name is Jason, I am 14 years old, and I am a junior high school student. I enjoy participating in outdoor activities, such as basketball. I think my current English level is not good enough, and I hope to improve my English skills. I also like some leisure activities, and in the future, I hope that through my efforts, I can bring more leisure time to people.

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I completed my Bachelor's degree in Psychology, and following my Master's degree in Clinical Psychology at Erasmus University Rotterdam. In my Master's thesis, I focused on impulsivity differences, namely sensation seeking and behavioral inhibition, between cannabis users and controls, and explored how initiating cannabis use at different life stages influenced the relationship between cannabis use frequency and impulsivity. I am now working as a clinical psychologist in an inpatient unit for substance-induced psychosis in a psychiatric hospital in Turkey. When I have time off, I like to cook and walk while listening to nice music.



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I completed my Master's degree in Clinical Psychology Research at Erasmus University Rotterdam, where I studied changes in cognitive control that are associated with addiction. My focus lies in understanding the complexities behind drug addiction and its impact on the human brain. Now, I am working on a large data set with brain activity to study how initiation of addiction is related to cognitive functions in 17-year-old children. When not studying, you can find me playing the piano, enjoying a nice book, or cooking a delicious meal with friends.



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I am an Assistant Professor in the Clinical Psychology Department of the Erasmus University Rotterdam. During my PhD., I studied cognitive control in people with mental problems like addiction. I learned a lot about analyzing brain activity in children and adults. I continue to study how the brain is involved in cognitive control in children and young adults and how this is related to the start of mental problems. In my spare time, I teach swimming lessons to kids, cuddle with my two lazy cats, make puzzles and play outside in the woods with my two daughters and husband.



MIEKE H. J. SCHULTE

I am an Assistant Professor in the Clinical Psychology Department of the Erasmus University Rotterdam. In my research, I investigate how impulsivity is involved in the development, maintenance, and treatment of addiction. By combining behavioral and brain measures, I try to develop innovative treatment strategies for addiction that target impulsivity and the involved brain areas (such as "deep" TMS), so people can receive the best treatment for their addiction. In my free time, I like to spend time with my family and friends, crochet, run, and work in my vegetable garden on my balcony. *schulte@essb.eur.nl