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WHY IS IT SO HARD TO RESIST MARSHMALLOWS?

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YOUNG REVIEWERS:

KYLE

AGE: 13

THANUSRI

AGE: 13

Have you ever wondered why it is so hard to resist soft, sweet, and melty marshmallows? There are two brain processes that play a role in situations like this: cognitive control and reward. Cognitive control helps us to make choices, and rewards are things we want to have because they make us feel good—like eating a marshmallow! The brain has complex systems to control both these processes. The systems can communicate with each other and with the rest of the body using tiny chemical messengers. When one of the two systems speaks louder than the other, this can cause all kinds of problems! Understanding how cognitive control and reward work, and how we can influence these brain processes, can help us make better choices in the future.

HOW DO WE CONTROL THE TEMPTATION TO EAT MARSHMALLOWS?

Do you sometimes hear a little voice in your head saying that you should not eat another marshmallow? Or that you should start your homework, even when you do not want to? Imagine a world in which these internal controlling thoughts did not exist. You would never be able to stop eating marshmallows, even if your stomach hurt from eating too many. You would stay up all night watching your favorite TV show, even if you were really, really tired. And your parents would not complain, because the little voices in their heads would not exist either!

When you see a soft, sweet, and melty marshmallow in front of you, you probably hear a little voice telling you to eat it. That voice is focused on what makes you feel good. When you experience something that makes you feel good, scientists call this a **reward**. For example, if you like marshmallows, eating one is a reward. The controlling voice in your head telling you not to eat too many marshmallows is called **cognitive control**. Everyone hears this little controlling voice, although its loudness is different for everyone, and the voice gets stronger as you get older.

In this article, we explain how and why people experience reward and control. We will also discuss how reward and control work together and how you can use this knowledge to make good choices.

REWARD

Something the brain associates with a good outcome. The more rewarding an experience is, the more likely we are to do it again.

COGNITIVE CONTROL

The brain's ability to regulate and direct a person's thoughts, attention, and actions. It helps people make good choices, solve problems, and achieve goals effectively.

TO EAT OR NOT TO EAT MARSHMALLOWS: IT IS ALL IN YOUR BRAIN

Rewards and cognitive control are two specific functions of the brain. The brain pathway related to pleasant feelings is called the reward system. This system becomes activated when you experience pleasure, for example, the good feeling you experience when you eat a marshmallow. The reward system helps people to survive, because eating and drinking make you feel good and are needed to stay alive [1]. The reward system in the brain is like a happy button that gets pushed when we do activities that we enjoy. When this button is pushed, the brain starts to link activities with positive experiences. This is then stored in the memory system, which makes the brain remember that we did something we liked. At a later moment, we would then be motivated to keep doing these activities again, to experience the same pleasure. For example, when you eat a yummy marshmallow, you probably want another one because it tasted so good.

Two brain areas play an important role in the reward system: the ventral tegmental area (VTA) and nucleus accumbens (Figure 1A). The VTA contains brain cells called **neurons** that produce a chemical called **dopamine** [2]. Dopamine is sent from the VTA to other brain areas

NEURON

A specialized brain cell that carries electrical signals to transport messages—both between brain areas and from the brain to other parts of the body.

DOPAMINE

A chemical in the brain that communicates with the body, also known as the "pleasure hormone". Dopamine is released when people do something that makes them feel good.

when we engage in fun activities. Dopamine release starts even when we expect to eat a marshmallow, and this explains why just seeing a marshmallow can already make you happy, before you even eat it. When you expect or eat a marshmallow, the VTA sends dopamine to the nucleus accumbens [3]. The nucleus accumbens makes you feel good. Dopamine also communicates messages between the brain and the rest of your body, kind of like a postman. That is why you can experience good feelings in your body, for example, you might feel butterflies in your belly when riding a rollercoaster.

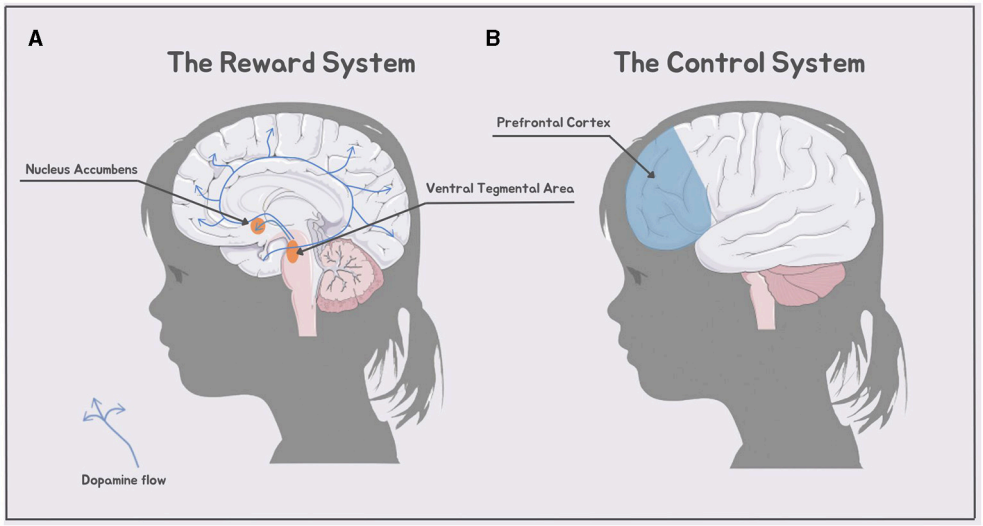

Figure 1

Figure 1

The brain has multiple layers. Some parts are closer to the surface, while other parts are hidden in the middle. **(A)** In this image, the brain is cut in half down the center, so you can see the brain layers and parts of the reward system within. The blue arrows show how dopamine flows around the brain. **(B)** Here you can see the surface of the brain, including the prefrontal cortex, which is located behind the forehead and makes up part of the control system [parts of the figure were drawn by using Servier Medical Art, licensed under a Creative Commons Attribution 3.0 Unported License (https://creativecommons.org/licenses/by/3.0/)].

The brain's control system enables people to control their behavior, such as the ability to resist an extra marshmallow. This system helps people make the right choices by considering the consequences of their behavior before they do something [3]. For example, if you want to eat marshmallows but you just brushed your teeth, your control system will tell you it may not be a good idea. One of the major brain parts involved in the control system is called the prefrontal cortex, which is located behind your forehead (Figure 1B).

DEVELOPMENT OF CONTROL AND REWARD

Researchers used to think that the brain was fully developed by adulthood, but now they know that the brain keeps on developing for a person's whole life. The reward system is fully developed at a young age, but the control system (prefrontal cortex) takes more time to develop [4]. In adolescence, people respond more strongly to rewards because the parts of the reward system may overrule the prefrontal cortex. This explains why, when people are young, they might sometimes make the wrong choices—they are focusing more on the reward than on the best outcome. For example, you might get very excited from eating a lot of marshmallows, but as you get

older, you will probably learn to control these feelings and not eat marshmallows every day!

THE BATTLE BETWEEN REWARD AND CONTROL

The reward and control systems interact with each other. Imagine you were offered one marshmallow immediately or, if you wait 15 min, you can have two marshmallows (Figure 2). This experiment is often used in research. It was created at Stanford University and is called the marshmallow test [5]. The little voices in your head would probably start negotiating with each other. The voice of your reward system wants you to eat the one marshmallow right now, for the immediate reward. Receiving an immediate reward rather than waiting some time for a larger reward is called **immediate gratification**. This response requires much less control, so it is often easier to reward yourself right now instead of waiting for a bigger reward. At the same time, the controlling voice would tell you to wait and get the two marshmallows later. Waiting some time for a larger reward is called **delayed gratification**. If you achieve this goal, it will feel much more rewarding. However, it will also require a lot of control to not immediately eat that one delicious marshmallow in front of you.

IMMEDIATE GRATIFICATION

When a person choses to receive an immediate reward rather than waiting some time for a larger reward.

DELAYED GRATIFICATION

When a person choses to wait some time for a larger reward rather than receiving an immediate smaller reward.

Figure 2

In the marshmallow experiment, the boy has the option to eat one marshmallow straight away. Or, if he is willing to wait 15 min, he will receive two marshmallows. This experiment helps scientists to see how well children can exercise self-control and delay gratification, by seeing whether the children can wait longer to get a bigger reward rather than eating a smaller reward right away. Parts of the figure were extracted from: https://www.vecteezy.com/free-vector/student, Student Vectors by Vecteezy, under a free license.

So, who "wins"? Your decision tells you! The best outcome would be a balance between rewarding activities and controlling ourselves. For instance, it is important to enjoy marshmallows once in a while. But you must control yourself so that you do not eat marshmallows if you have just brushed your teeth.

LOSS OF CONTROL

Sometimes the reward system continuously overrules the control system, or the control system is not functioning properly. In severe

cases, people can experience loss of control, which is one of the characteristics for developing an **addiction**. People with addictions cannot stop a behavior, even though it is harmful to themselves or others. This happens when the brain becomes dependent on the release of high amounts of dopamine from the VTA [2]. Research has shown that people can get addicted to substances like alcohol or cigarettes, but some scientists also believe people can become addicted to their phones, food, or exercise [6].

ADDICTION

Not having control over doing, taking or using something to the point where it could be harmful to you.

By gaining more knowledge about how the brain works in healthy people, researchers can also start to see how the brain changes in people with addictions or **substance use disorders**. This knowledge can hopefully help to prevent, identify, or treat brain diseases, improving the lives of people suffering with these disorders.

SUBSTANCE USE DISORDER

A disease that affects a person's brain and behavior and leads to an inability to control their use of a legal or illegal drug or medicine.

TOO MUCH CONTROL

Sometimes the control system continuously overrules the reward system. In severe cases, people want to stay in control of everything in their lives. This can cause them to overthink their day-to-day actions, resulting in extreme worry and anxiousness about the possible consequences of their behaviors. Extreme control can limit people's lives quite a lot because they cannot go to school or play with a friend without feeling extremely anxious.

HACKING YOUR OWN BRAIN

Luckily, the brain is very flexible. If people put in time and effort to learn something new, the brain adapts. You can hack your brain by doing things that make you feel happy. Rewarding yourself can help you do the things you do not like. For example, doing your homework becomes easier if you reward yourself with a marshmallow afterwards. Of course, you will need your control system to make sure you do not eat the marshmallow *before* you finish studying. You can also train your control system. For example, waiting a while to eat a second marshmallow after you have just eaten one will take more effort in the beginning, but it becomes easier with practice. Think about some of the things you like and that you could use as rewards as you practice these skills (Figure 3)!

NOW YOU KNOW...

In summary, the brain's reward system motivates us to do the things that make us feel good, while the control system helps us to resist temptation. The reward system consists of the VTA and nucleus accumbens, and they talk to each other using dopamine. The prefrontal cortex is responsible for cognitive control. It is important

Figure 3

On the "dopamine menu" in the figure, you can see a list of activities that might be rewarding. Look at the examples and give them a score between 1 and 5, depending on how fun they are for you. Can you come up with some additions to the list? Maybe you can also think of an activity that might not be rewarding right now but will be good for you in the future.

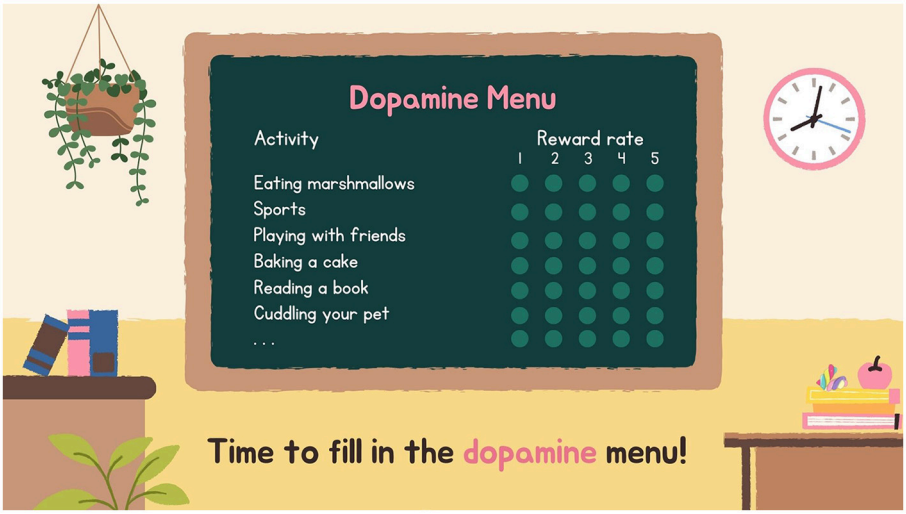

Figure 3

that these systems are in balance, so that you can reach your goals and have fun at the same time. In young children, these systems are not in balance yet. Now you know why it is so hard to resist marshmallows!

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REFERENCES

1. Gearhardt, A. N. 2018. "Chapter 6: Role of reward pathways in appetitive drive and regulation", in *Pediatric Food Preferences and Eating Behaviors* (Academic Press). p. 111–26. doi: 10.1016/B978-0-12-811716-3.00006-3
2. Koob, G. F., and Volkow, N. D. 2016. Neurobiology of addiction: a neurocircuitry analysis. *Lancet Psychiatry* 3:760–73. doi: 10.1016/S2215-0366(16)00104-8
3. Goldstein, R. Z., and Volkow, N. D. 2011. Dysfunction of the prefrontal cortex in addiction: neuroimaging findings and clinical implications. *Nat. Rev. Neurosci.* 12:652–69. doi: 10.1038/nrn3119
4. Colyer-Patel, K., Kuhns, L., Weidema, A., Lesscher, H., and Cousijn, J. 2023. Age-dependent effects of tobacco smoke and nicotine on cognition and the brain: a systematic review of the human and animal literature comparing

adolescents and adults. *Neurosci. Biobehav. Rev.* 146:105038. doi: 10.1016/j.neubiorev.2023.105038
5. Ebbesen, E. B. 1970. Attention in delay of gratification. *J. Person. Soc. Psychol.* 16:329–37. doi: 10.1037/h0029815
6. Alavi, S. S., Ferdosi, M., Jannatifard, F., Eslami, M., Alaghemandan, H., and Setare, M. 2012. Behavioral addiction versus substance addiction: correspondence of psychiatric and psychological views. *Int. J. Prev. Med.* 3, 290–294.

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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

KYLE, AGE: 13
Kyle likes marshmallows, but in a s'more the best!

THANUSRI, AGE: 13
I enjoy running and swimming. I love animals, particularly dogs. I like to learn about the brain and its functions. It is amazing to see how the brain works. It controls all our activities—how we perceive the world, talk, and feel the world around us. I enjoy reading fiction and would like to write books one day. I also enjoy good food and cooking. I want to experiment with cooking different dishes.

AUTHORS

KARIS COLYER-PATEL
Karis Colyer-Patel is a Ph.D. candidate in the Department of Psychology, Education and Child Studies at Erasmus University Rotterdam. She is interested in understanding how the developing brain is linked to risk and resilience to addiction. To understand this, she scans people's brains and measures aspects of brain functions, such as memory ability. When she is not doing her research, she is usually playing sports or hanging out with her dog. *colyerpatel@essb.eur.nl

SAMMIE MARIE BACK
I am a master's student in psychology. What I love about my field of study is that I get to explore so many different things: why do we think, feel, and act the way we do? What happens in our brains? What kind of influences do our parents have on us? What are the best ways to help people with problems like depression or addiction? When I grow up, I would like to combine teaching and writing with being a psychologist and a researcher!

MARC ANDRE REBOUILLON
Hey, my name is Marc, and I am currently completing my master's in clinical psychology at Erasmus University Rotterdam. The field of psychology that I am most interested in is addiction and substance use disorders. In the future I plan on becoming a therapist, treating individuals suffering from substance use disorders. I hope that my future job will have a positive impact on many individuals seeking help.

ROOS VAN OEVEREN
I study neurobiology at the University of Amsterdam, in the Netherlands. Neurobiology is all about the brain and how it functions. The brain is responsible for so many things, but exactly what happens in the brain is often still a mystery to scientists. What I like most is trying to solve this puzzle and discover more and more about our own bodies, thoughts, and actions. I hope to use this knowledge in the future as a researcher, to learn more about diseases in the brain and hopefully how we can cure them!

JILL VÉRONIQUE VIS
I am a master's student in clinical psychology at the Erasmus University Rotterdam. Over the years my interests in the psychology field have varied a lot. I find mental disorders, depression, and addiction very interesting. I have gained more interest in what influences the brain has on everything. What I find most interesting is learning how everything is related and can have an influence on us, from growing up, to the brain, to significant life events. In the future, I am looking forward to integrating various aspects of my knowledge to develop comprehensive treatment plans that address both the psychological and neurological aspects of mental health issues, as well as to implement HR strategies that foster a supportive and healthy work environment.

HANAN EL MARROUN

I am a professor in biological psychology (focused on substance use and brain development) at the Department of Psychology, Education and Child Studies at the Erasmus University Rotterdam. I studied biomedical science, epidemiology, and neuroscience, and that is when I got fascinated about brain development. The brain is such a complex organ, and every day I learn new things about its structure, function and development. Next to science, I love to play board games and, as you may guess from this article, I have a "sweet tooth"!