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Is dopamine to blame for our addictions?

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Damn you, dopamine. Credit: Photographee.eu

Most researchers agree that the key difference between human brains and those of other animals is the size and complexity of our cerebral cortex, the brain's outer layer of neural tissue. We therefore tend to focus our attention on this area, believing that our unique mental life is due to this masterpiece of evolution.

But we often ignore the bits that are nearly identical between humans and animals, such as the tiny group of brain cells that use the chemical dopamine to communicate with other brain cells.

A rewarding experience

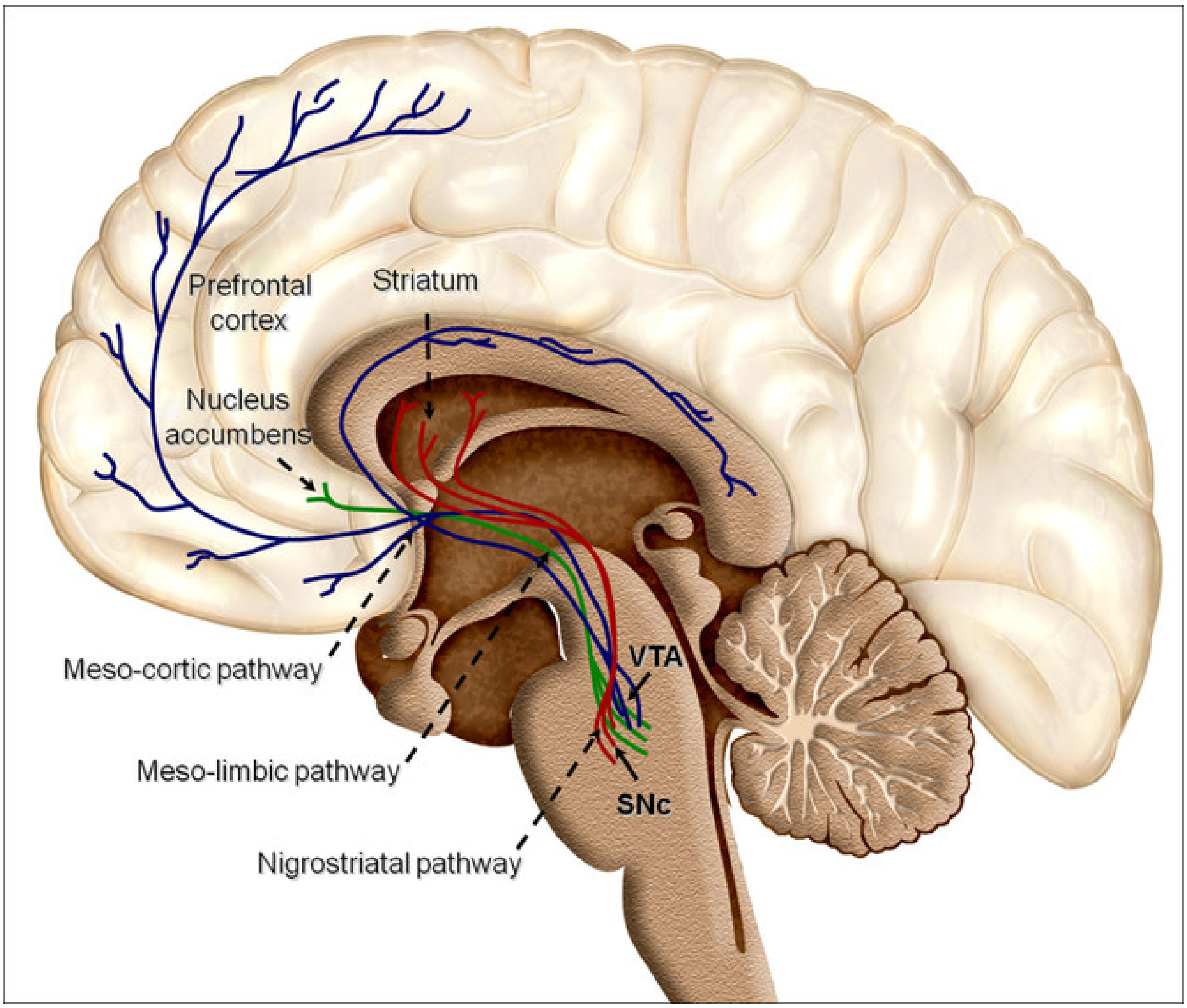
Dopamine is often described as the brain's "pleasure chemical", but it is actually involved in a large number physical and mental processes. It is used by a cluster of neurons in the midbrain to transmit messages to other neurons. The dopamine neurons are small in number (~0.0006% of the neurons in the human brain) and they are observed in all mammals and even "simple" animals such as turtles.

In the 1950s, researchers discovered that rats appeared to enjoy the stimulation of the nerve bundle that links the dopamine neurons with their targets in the forebrain. The rats would learn to press a lever for this kind of stimulation, and, left unchecked, would do so thousands of times in a day.

A similar (and wholly unethical) experiment was performed in 1970 on a human patient. Like the rats, the patient learned to press a button to stimulate the dopamine nerve bundle, pressing the button up 1500 times over the course of a three-hour session and reporting feelings of pleasure during the stimulation.

Since then, studies have shown that the dopamine system can be activated by a wide range of pleasant experiences, such as eating, having sex, getting revenge, winning video games, listening to music, earning money and reading funny cartoons. The dopamine system also responds robustly to addictive drugs, including opiates, alcohol and cocaine. These drugs can evoke stronger activation than natural rewards and, unlike natural rewards, they do not cause satiety.

A straightforward interpretation of these facts is that the dopamine system is a pleasure pathway in the brain. This potentially explains why animals and people would be willing to press buttons or push levers to activate the dopamine neurons. It might also explain why some drugs are so addictive. The strong and prolonged activation induced by drugs can act as a "super-reward", making drugs even more desirable.



Dopamine pathways in the human brain. Credit: Was a bee/wikimedia, CC BY-SA

However, many mental events occur near the time of a reward, including changes in motivation, arousal, attention, emotion, and learning. For example, imagine passing by a vending machine that offers sweets. If you are motivated by hunger, your attention will be drawn to the machine and you will become more alert as you approach it. Once you have eaten the sweets, you experience pleasure, your brain learns to associate the vending machine with reward, and your hunger decreases. It is likely that the dopamine system is involved in many of these processes rather than just pleasure per se.

Dopamine versus willpower

One of the most important aspects of dopamine function is learning. Researchers believe that dopamine neurons change their activity when expectations about reward do not match the reality, signalling a 'reward prediction error' that drives learning. For instance, dopamine neurons are activated by unanticipated rewards, but they are suppressed when expected rewards fail to materialise.

Events followed by increases in dopamine activation become associated with reward, and those that are followed by decreases are linked with disappointment. If the environment is unchanging, all our brains need to do to obtain reward is to engage in actions that activate the dopamine neurons and avoiding the ones that suppress them.

It is highly unlikely that we have much awareness of the learning that dopamine activation induces, such as making us attached to things we unknowingly associate with dopamine activation. This lack of awareness might explain why people often make seemingly irrational or maladaptive choices.

Imagine a drug addict taking cocaine. Because the pleasure from cocaine does not satiate like a natural reward, the dopamine activation, and hence drug-induced learning, occurs with each puff of the crack pipe, making the actual pipe an object which the addict is drawn to.

Our chemical master?

Can brain research be used to overcome the effects of dopamine in addiction? Neuroscientists are actively pursuing the creation of drugs that block the learning induced by dopamine in addiction. However, they have had limited success, for it is difficult to create a drug the blocks the learning without also blocking other functions of dopamine, such as feeling alert, motivated and happy.

Dopamine-induced learning is certainly not the whole story behind addiction, but it does suggest that we should consider whether addiction is something that human reasoning on its own can overcome. The same might very well also apply to other everyday failures of willpower, such as overeating.

Our special cerebral cortex may be in control of our actions, but our primitive dopamine system may very well serve as its teacher.

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