

THIS IS YOUR BRAIN ON FOOD

Neuroimaging reveals a shared basis for chocoholia and drug addiction

By Kristin Leutwyler Ozelli

Mounting evidence shows that compulsive eating and drug abuse engage some of the same brain circuits in similar ways, offering a new angle for understanding and treating obesity. In an interview with SCIENTIFIC AMERICAN, Nora D. Volkow, who is director of the National Institute on Drug Abuse (NIDA) and a pioneer in the study of addiction, explains these recent findings.

KEY CONCEPTS

- Food and illicit drugs both trigger brain circuits involved with reward and pleasure. They create conditioned responses that are subsequently evoked by the mere sight of food or drugs or by the environment in which these substances are consumed.
- These responses exist on the most fundamental neurophysiological level. Obese people or drug addicts may be trying to compensate for an abnormal response to dopamine, the neurotransmitter that mediates reward-seeking behavior. This anomaly may cause them to dose themselves continuously with food or drugs.
- A multifaceted strategy is needed to treat addiction. Pharmaceuticals, biofeedback and group therapy all have their place.

—The Editors

Which brain circuits do food and drugs activate in common?

The system in the brain that both food and drugs activate is basically the circuitry that evolved to reward behavior essential to our survival. One reason humans are attracted to food is because it is rewarding and pleasurable. When we experience pleasure, our brains learn to associate the sensation with the conditions that predict it. That memory strengthens as the cycle of predicting, seeking and obtaining pleasure becomes more reliable. In scientific terms, we call this process conditioning.

Drugs are particularly effective as conditioning stimuli, primarily by virtue of their chemical properties. Natural reinforcers, such as food or sex, take longer to activate the reward pathway. Important for both, however, conditioning links a memory not just to a stimulus but to the environment in which it is found and other related cues. That's exactly what nature intended: if the action needed to attain a pleasurable experience were triggered exclusively by the stimulus in question, the conditioned response would be very ineffective indeed. Once you create a conditioned memory, it's just like Pavlov's dogs; the response becomes a reflex. This conditioned response underlies the drive both in drug addiction and compulsive eating.

For this reason, high-calorie foods—particularly foods that are high in fat or sugar—are more likely to trigger compulsive eating. As

hunters, we didn't always succeed at finding something to eat and so high-calorie foods, which pack a lot of energy, offered a survival advantage. In that environment, it was in our best interest to consume as many foods of this type as we could find. So they are very reinforcing. But today when we open up our refrigerators, we have a 100 percent chance of finding food. Our genes have changed little, but in our environment we are surrounded by high-fat, high-sugar foods, which have contributed to the rise in obesity.

What is going on in the brain during cravings?

Had Pavlov been able to see inside his dogs' brains, he would have likely seen an increase in dopamine whenever the animals heard a sound he had previously paired with offerings of meat. Dopamine serves to tell us what's important: unexpected bits of new information we need to pay attention to in order to survive—alerts about sex, food and pleasure, as well as danger and pain. We've documented that when you show people foods to which they've been conditioned, there is an increase in dopamine in the striatum, a brain region involved with reward and behavioral motivation.

Mind you, this increase is just from smelling and looking at the food, because we tell study participants that they will not be able to eat it. And this is the very same neurochemical response that happens when addicts see a video of other people taking drugs or see anything to do with their drug of choice. The message that you get when dopamine is liberated in the striatum is that you need to get into action to achieve a certain goal. It is a powerful motivator. Overcoming these impulses with sheer willpower is extremely hard.

Also in the brains of both drug addicts and obese people, we typically find a reduced number of so-called D2 dopamine receptors in the striatum as compared with nonabusers and nonobese

subjects, respectively. Perhaps these findings reveal that the brain is somehow trying to compensate for repeated surges in dopamine from continued drug or food stimulation. Another possibility is that these individuals naturally have lower numbers of receptors to begin with, which may put them at increased risk for diseases of addiction in general. Interestingly, we found a negative correlation between the availability of D2 receptors in obese individuals and their body mass index (or BMI); in other words, the more obese a person was, the fewer receptors he had.

Are certain people at greater risk for drug or food addictions?

We know from twin studies that approximately 50 percent of the risk for both addiction and obesity is genetic. But the genes involved come into play on many different levels—from differences in the efficiency with which we metabolize certain drugs or foods to differences in our likelihood of engaging in risk-taking or exploratory behaviors to more specific risks, such as the underlying sensitivity of the reward system.

In obesity, some people may be at a greater risk for compulsive eating because they may be overly sensitive to the rewards of food. One study showed that some obese people have increased brain activity in response to mouth, lip and tongue sensations. Likewise, some people are not very efficient at registering or responding to internal signals of satiety, so they are possibly going to be more vulnerable to cravings triggered by food cues in their environment.

Does the overlap between addiction and obesity reveal any new targets for treatment?

There are pharmacological interventions to explore, such as medications that increase the dopamine response in the brain. One exciting development is the recent synthesis and preliminary testing of an orally administered drug that blocks orexin, a peptide that reinforces the “high” associated with drinking alcohol and is thought to regulate feeding. This drug could be extremely helpful in the treatment of aberrant food and drug consumption. Also, because of social stigma, both obesity and drug addiction can lead to a deep sense of isolation, which is very stressful, and so group therapy can help.

Yet another exciting area the NIDA is researching is the use of functional magnetic resonance

imaging (or fMRI) in real time to train people to exercise specific parts of their brains, just like muscles. By this method, Sean Mackey of Stanford University, Christopher deCharms of Omneuron [in Menlo Park, Calif.] and their colleagues have trained healthy subjects and chronic-pain sufferers to control their brain activity to actually modulate their experience of pain. So we are exploring the possibility that you might use this kind of technique to train people to control a region of the brain called the insula, which has been implicated in food and drug cravings. Smokers who have a lesion in the insula after a stroke seem to lose the desire to smoke.

A distinct obstacle to recovery for compulsive eaters is the obvious fact that you have to eat to survive, whereas if you are addicted to an illegal substance, you are in a way protected because the drug is not going to be environmentally available everywhere. One of the therapeutic interventions for drug addicts is to teach them to avoid places associated with their habit. But how do you do that with food? It's impossible. And these people suffer. In rats, it has been shown that if you give them diets very high in sugar and then administer an opioid antagonist called naloxone, you can trigger a withdrawal that is similar to that in animals given naloxone after repeated injections of morphine. This result indicates that chronic exposure to high-sugar diets generates a physical dependence in these rats. If a similar process happens in humans, then interventions aimed at mitigating withdrawal symptoms may benefit dieters. ■

Kristin Leutwyler Ozelli is a freelance writer based in London.

A patient who observes real-time images of his or her brain activity may be able to alter how neural circuitry functions and gain a measure of control over food and drug cravings.

[THE INTERVIEWEE]

Nora D. Volkow is director of the National Institute of Drug Abuse. Before her appointment in 2003, she held various positions at Brookhaven National Laboratory and also served as professor of psychiatry and associate dean for the medical school at Stony Brook University. In her research, she was first to use imaging technology to investigate neurochemical changes associated with addiction.



NIDA