Pyramid-shaped brain cells provide algorithm for us to recognize, categorize food

October 4 2018

Dr. Joe Z. Tsien, neuroscientist in the Department of Neuroscience and Regenerative Medicine at the Medical College of Georgia at Augusta University. Credit: Phil Jones, Senior Photographer, Augusta University

Brain regions best known for recognizing the potential horror of a hurricane also help us recognize, appreciate and categorize our food, scientists report.

They found that a group of large, triangular-shaped neurons, in two almond-shaped structures on either side of our brain, form cliques that help us enjoy the total food experience, from recognizing a banana to anticipating its taste and texture, placing it correctly in the category of food and maybe even the subcategory of a breakfast food.

"Our knowledge is categorical," says Dr. Joe Z. Tsien, neuroscientist in the Department of Neuroscience and Regenerative Medicine at the Medical College of Georgia at Augusta University and Georgia Research Alliance Eminent Scholar in Cognitive and Systems Neurobiology.

"You are not only creating a specific experience memory about a banana but, almost like a library, you are putting those memories in categories like you would comic books or science fiction," says the corresponding author of the study in the journal *Neurobiology of Learning and Memory*.

The cells are pyramidal cells and the brain regions the two amygdala. Most research that has be done on the amygdalae is about fear, and Tsien's team also was looking at their role in fear. But while examining neuronal response, they decided to also look at potential roles in positive emotions like the food experience.

"It's the pyramidal cells that help distinguish a banana from a cake and put it in categories like breakfast or lunch," Tsien says. "They provide structural organization for knowledge from a specific food, to a category of food to the general concept of food."

Pyramidal cells also function like a receiver, taking input about food from the taste buds on our tongue and the smell of a biscuit, then broadcasting the information they collect to other parts of the brain. Just how they organized for these many tasks was unknown.

When all goes well with the prewired neural circuitry, we recognize a banana as the fruit and food that it is, know that we like it and usually eat it for breakfast. Nearby interneurons help the big neurons in those circuits talk with each other and help moderate their activity.

When it doesn't work well, we may have an eating disorder that prompts us to compulsively eat or conversely, to not eat.

In addition to better understanding how our brains process food, the scientists believe their work may one day provide insight into these difficult-to-treat eating disorders.

A few previous studies have indicated that the base of the amygdalae have a role in the food experience, but how our neurons line up to represent the experience was pretty much unknown, Tsien says.

For these studies, the scientists looked at the pyramidal cells' response in mice freely consuming biscuits, rice, milk and water, as well as the response of the interneurons connected to them.

"Interneurons are like a gatekeeper," he says, with a lot of power, noting their dysfunction also can result in problems like seizures.

They found the vast majority of pyramidal neurons increased their firing in response to just one food item, others to varying combinations like biscuits and rice or biscuits and milk. Only a tiny percentage of the neurons responded to all three of those foods and the ones that did also responded to water.

About one third of the neurons that increased their firing in response to food responded to milk, likely because of its important role in continued healthy development after birth, the scientists write. The duration of the pyramidal cells' increased firing generally correlated with how long it took mice to eat the food.

Also, when the mice ate several of the same food items consecutively, like consuming multiple rice pellets, the excitement of the pyramidal neuron that recognized that food began to diminish. That likely helps explain why mice—like many people—prefer a selection of foods as they eat, Tsien says.

Interneurons on the other hand did not get super excited over any specific food, the scientists note, but they were more excited about eating biscuits than drinking milk, a response they plan to pursue further by including more items of solid and liquid foods to see if the response to the two items continues to hold. Interneurons instead focused on the broader food experience.

The food-focused cell assemblage Tsien and his colleagues report is a fundamental organizational structure for the brain that reflect his Theory of Connectivity. The theory, first published in the journal Trends in Neurosciences in 2015, provides a basic algorithm that helps us understand how neurons line up in our brains to acquire and use knowledge about life experiences from food to friends. He and his colleagues subsequently identified 15 different cliques in the amygdalae involved in recognizing and categorizing the different foods consumed.

Tsien says these cliques form during development almost like they are waiting to experience that banana or biscuit. He notes that he doubts that those of us with a more vastly varied or even exotic diet, have significantly more pyramidal cells or cliques.

Tsien says cliques are prewired during development because they show up and start responding immediately to foods. The individual pyramidal cell structure persevered even when the NMDA receptor, a master switch for learning and memory, was disabled.

Pyramidal cells are some of the largest neurons in the body and are excitatory neurons, which means they usually call for some action. "Generally speaking, in any given neural circuit there are excitatory cells and there also are inhibitory cells to provide a balance," Tsien says.

The brain has about 86 billion neurons and each neuron can have tens of thousands of synapses, or connections, with other neurons, which helps explain the seemingly endless potential of the brain.

The amygdalae are found deep inside the brain on either side of the head in about the same vicinity as the ears, and are most widely associated with memory, processing emotions like survival and fear and even our libido. More recently, there is evidence they play a role in assigning value—good or bad—and in addictive behavior. There is some lab evidence the cells in the amygdalae also respond to things like salt and sucrose as well as temperature and texture.

More information: Jun Liu et al. Neural Coding of Appetitive Food Experiences in the Amygdala, *Neurobiology of Learning and Memory* (2018). DOI: 10.1016/j.nlm.2018.08.012

Provided by Medical College of Georgia at Augusta University