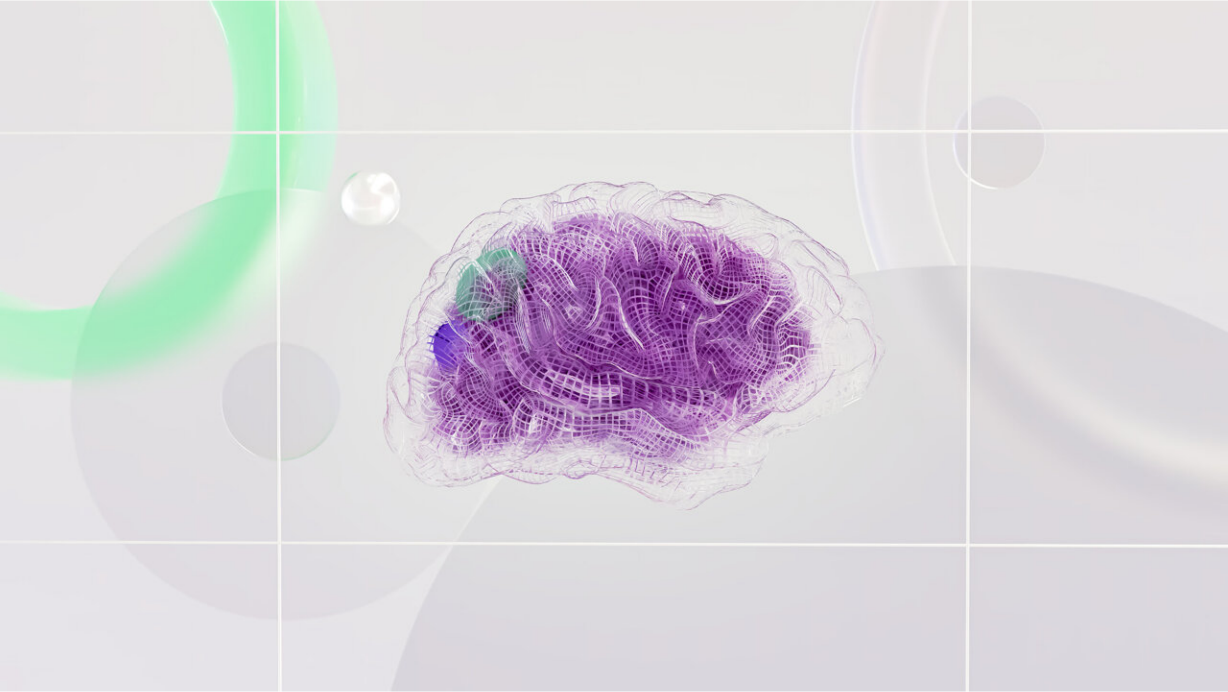
Taste and its two ways to the brain

February 18 2021, by William Weir



Credit: Google DeepMind from Pexels

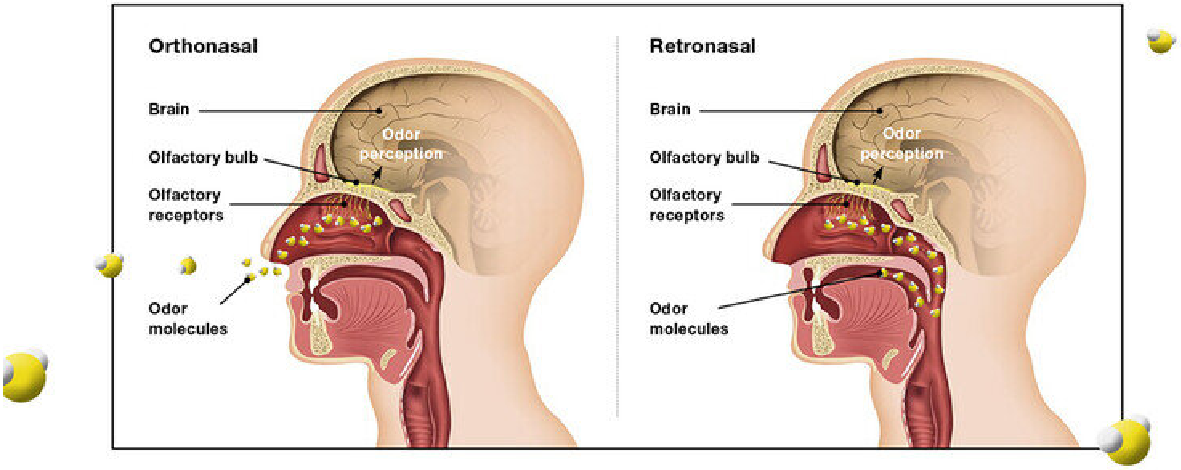
There are a few ways we perceive food, and not all are particularly well-understood. We know that much of it happens in the olfactory bulb, a small lump of tissue between the eyes and behind the nose, but how the stimuli arrive at this part of the brain is still being worked out.

How these stimuli are processed in the brain plays a major role in our daily life. Fully understanding how our perceptions of food are formed is critical, Fahmeed Hyder said, but getting a clear picture of what our brains do when we smell has been tricky.

"Knowing which exact pathways are affected and teaching our brain to appreciate and acknowledge both modes of perception in understanding the flavor is a part of our culture that we haven't fully exploited yet," he said. A better understanding of how smells get to our brain would not only tell us a lot about our eating habits, he said, it could even potentially help patients of certain diseases.

Hyder, professor of biomedical engineering and radiology & biomedical imaging, has taken a detailed look at the function of the olfactory bulb. It may not be one of the most talked-about regions of the brain, but it helps us make sense of the outside world by taking in molecules from food — known as food volatiles — and then sending these signals further into the brain. It serves a pivotal role as the gateway for chemical stimuli to the rest of the brain — specifically the piriform cortex, amygdala, and hippocampus. To see exactly how it does that, Hyder and his team mapped the activity in the entire olfactory bulb. It's the first time that this has ever been done for the two independent routes of odor delivery — that is, the orthonasal and retronasal routes. The results were published in *NeuroImage*.

The orthonasal route — one pathway odors take to the brain — is what we typically think of as smelling, when food volatiles or odor molecules enter the nasal cavity through inhalation. The other — the retronasal route — is more associated with eating, when food volatiles are released in the mouth while we chew and these odor molecules pass into the nasal cavity. Both of these routes, along with the flavors we pick up with the taste buds on our tongues, shape our perceptions of food. Professors Gordon Shepherd and Justus Verhagen, Yale collaborators in this study, have worked on comparing these routes of odor delivery before.



There are two pathways odors can take to the brain: Orthonasal (what we typically think of as smelling) and retronasal (what we associate with eating). Credit: Yale School of Engineering and Applied Science

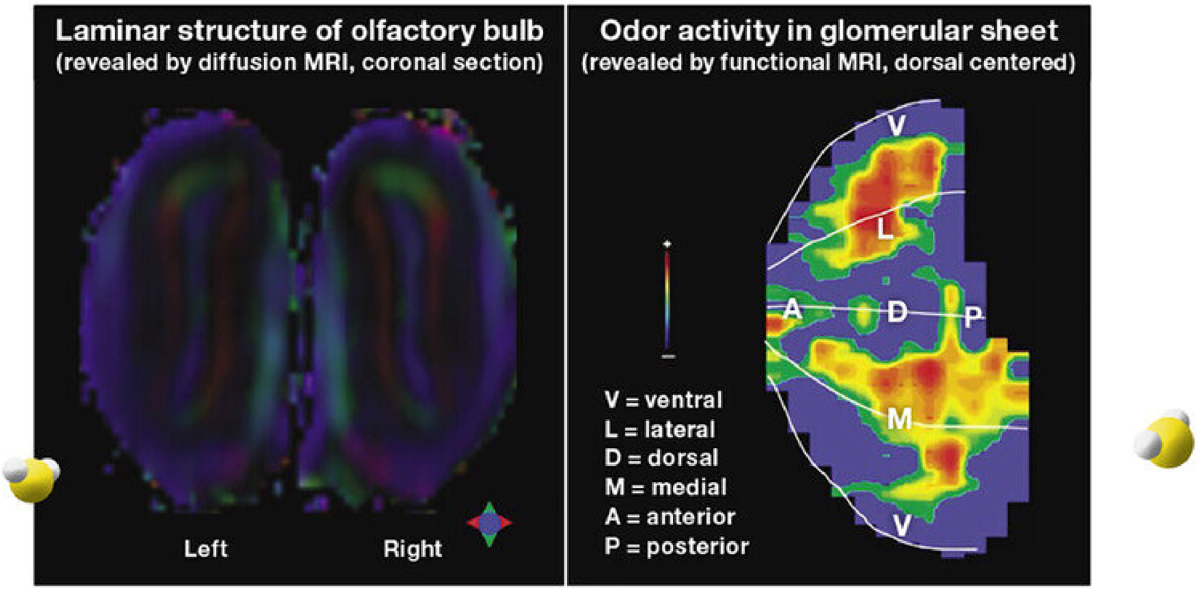
Among other discoveries in their recent work, Hyder and his team found that, regardless of the odor, responses to the stimuli traveling through the orthonasal route were much stronger than those that took the retronasal route. And while the brain responses in the two routes were similar in many ways, the orthonasal maps were dominant in some parts of the bulb, while the retronasal maps were dominant in others. Scientists hadn't observed these differences before, mainly because of the limitations of the standard imaging tools for this kind of research.

Hyder has studied the olfactory bulb for years and worked with Yale researchers Gordon Shepherd and Robert Shulman on some of the first studies on this region of the brain. For the *NeuroImage* study, he and his team wanted to learn more about the different routes that smells take to the bulb. It's important, Hyder said, partly because our perception of food is key to living healthily and recuperating from disease. Certain diseases can affect taste and smell — the discovery that temporary loss of these senses is a symptom in COVID-19 is a recent example.

"It's been shown that a lot of diseases — especially among those with onset later in life — affect smell much more than taste," he said. "That fact hasn't been appreciated much in the treatment of disease, mainly because smell hadn't been considered an important sensation in practiced medicine. But much like how we see and hear, taste and smell are all critical aspects to being human."

Getting a highly detailed look at how these senses are processed could be crucial in helping certain patients. For instance, one common side effect of chemotherapy is that it diminishes the patient's sense of taste. By knowing exactly how the brain responds to food, health care professionals could help train patients to enjoy the flavor of food through the other routes. Conversely, dementia often takes away a patient's sense of smell.

"In those cases, people can be retaught how to enjoy a flavor with more concentrated doses that go through the retronasal path," he said.



Laminar structure of olfactory bulb (revealed by diffusion MRI, coronal section)

Odor activity in glomerular sheet (revealed by functional MRI, dorsal centered)

Different magnetic resonance imaging methods reveal the unique structure and function of the olfactory bulb. Credit: Yale School of Engineering and Applied Science

"'Taste' vs. 'flavor': What's the difference?

"Taste" refers to the taste buds in the tongue to identify tastes like sweet, sour, bitter, salty and umami. "Flavor" is a sort of umbrella term that incorporates taste, but also the smell of the food and its texture as well. Culturally, Hyder said, taste has received the most attention between the two.

"If I ask what flavor is, most people will say 'taste' — the flavor of food and the pyramid of food that we've created in the Western world is very much based on taste, not the smell component," he said. "But a big part of flavor is actually the other part of the chemosensation — the smell components. Smell happens pretty much — not just in humans but also animals — as we chew our food. When we chew the food, molecules are released and become airborne."

One reason that the retronasal and the orthonasal routes aren't fully understood is due to the limitations of technology. Getting a full picture of the brain activity requires a technique that can map both routes simultaneously. Most studies of the olfactory bulb until now have relied on optical imaging, which can only map the bulb's dorsal and lateral regions, and only the superficial layers. Hyder is technical director of preclinical scanners at Yale's Magnetic Resonance Research Center. His team was able to map the entire olfactory bulb by charting these routes with functional magnetic resonance imaging (fMRI), which measures brain activity by detecting changes in oxygen inside red blood cells.

Hyder knows fMRI well. About 30 years ago, he helped pioneer its use in animal models for high-resolution neuroscience explorations. For this study, they created the maps by contrasting images of brain activity in rats — some with odors and some without odors. Between these sets of maps, they could determine how the amount of oxygen delivery was altered to support the activity of various synapses in the olfactory bulb.

Hyder said the study is also a starting point to find new ways to study metabolism — another subject of interest in his lab. Typically, his metabolism research has focused on the cerebrum, but the work in the *NeuroImage* study has paved a way to explore it in the olfactory bulb. It's a promising avenue of study because the olfactory bulb is a well-organized region with layers that can be easily separated, like an onion. Because the anatomy in the olfactory has many layers, and each distinct neuroanatomical makeup can be readily detected, the localization of specific metabolic events can shed light on what happens when and where. "Because of the nature of these separate layers in the olfactory bulb, it's much more straightforward to study," he said. "So, we're combining optical techniques to look at specific types of cells, and we're using fMRI techniques to look at specific metabolic signals. By combining them, we can understand the physiology and chemistry of the neural code."

More information: Basavaraju G. Sanganahalli et al. Orthonasal versus retronasal glomerular activity in rat olfactory bulb by fMRI, *NeuroImage* (2020). DOI: 10.1016/j.neuroimage.2020.116664

Provided by Yale University

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