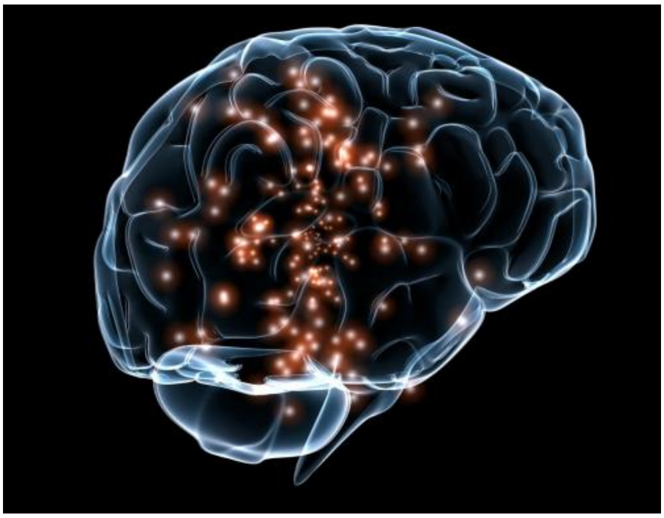
New insights into how the human brain processes scent

6 June 2017, by Sarah Plumridge



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Theta oscillations, a type of rhythmic electrical activity that waxes and wanes four to eight times per second, may play a fundamental role in processing scent in the human brain, according to a new study recently published in *Neuron*.

The use of intracranial EEG recordings in patients with medically resistant epilepsy allowed Jay Gottfried, MD, PhD, professor of Neurology, and his team to characterize, for the first time, the time-frequency dynamics of odor processing in the human piriform cortex, a region in the brain important for smell.

"The study we did here was to understand what happens at the microstructural level of the human brain when you smell an odor," Gottfried said. "The advantage of the approach is we can record the physiological rhythms of the brain using these electrodes in this unique and rare patient population."

They found that odors could be decoded as early as 110 milliseconds from a person's first sniff.

"A lot of people think that the sense of smell is a very slow sense, so this study highlights the speed of the sense of smell and relates it to its biological underpinnings," Gottfried said.

Heidi Jiang, a graduate student and the first author of the study, obtained electrophysiological recordings while patients took part in a cued odor detection task.

Jiang and Gottfried found that odor stimulation enhanced theta waves in the piriform cortex, in each of seven patients. Under conditions where patients smelled odorless air, the scientists observed no change in theta waves. Across four different odors, the physiological features of the theta waves could be used to distinguish between each odor.

"Based on this rhythmic activity, we can decode which smell the patient has encountered," Gottfried said. "These oscillations contain critical information about whether the smell is strawberry, peanut butter, chocolate or garlic, and this information is already available to the brain within a very rapid timeframe."

Additionally, with electrodes in the piriform cortex and hippocampus, they found the presence of odor caused both regions to fall into a synchronized rhythm, suggesting that theta oscillations facilitate the coordination and exchange of information between those two areas.

"What is neat about this finding is that the hippocampus is a central hub through which memories can be reactivated and retrieved—like what ice cream you ate, when you ate it, and where you ate it. It's possible that the hippocampus is able to telegraph some of that information to the piriform cortex to facilitate olfactory processing," Gottfried said.

As noted above, the subjects in the study were patients with medically resistant epilepsy who had existing electrode implants placed for purely clinical considerations, but gave the scientists an opportunity to gather detailed electrophysiological data.

"A lot of our work has used fMRI techniques to relate brain activity patterns in the human brain to different odor perceptual states such as memory, but the fMRI work provides a very limited understanding of the mechanisms and timing that support the sense of smell. So it has been a special opportunity to work with these rare epilepsy patients at Northwestern," Gottfried said.

Previous research has shown that theta oscillations are a dominant rhythm in rodent brains, in line with the rapid breathing rate of rats and mice. Gottfried found that while the human brain oscillates at this same theta timescale, humans breathe at a much slower rate.

"It poses a question in my mind that, for humans, theta isn't simply something that falls in line with the breathing cycle, but rather might be a more fundamental rhythm for odor processing in the brain," Gottfried said.

A Type of Timekeeping Mechanism

In terms of functional significance, Gottfried believes these oscillations might serve as an internal clock in the brain.

"The brain doesn't really have access to an external time reference, and across numerous studies there is more and more evidence to suggest it is the oscillations in the brain that are time-keeping mechanisms," Gottfried said. "The brain may use these oscillations to segment information into malleable packets of information."

Gottfried said in future studies, he wants to understand more about the importance of theta oscillations in contributing to odor perception and test the hypothesis that theta rhythms might serve as a clock for regulating brain dynamics.

More information: Heidi Jiang et al. Theta Oscillations Rapidly Convey Odor-Specific Content in Human Piriform Cortex, *Neuron* (2017). DOI: 10.1016/j.neuron.2017.03.021

Provided by Northwestern University