Study tracks what moths think when they smell with their antennae

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Credit: Petr Kratochvil/public domain

Think of an animal tracking a scent, and you may picture a bloodhound with its nose to the ground. But a moth fluttering through the air is likely smelling for clues, too. Pollinating insects like the hawkmoth track scents to forage for food—not with a nose, but with their antennae.

In a new study, researchers have created a functional map of how the hawkmoth smells, tracing the process from the antennae to specific areas in the hawkmoth brain. Using a wind tunnel, calcium imaging, and 80 different odor compounds found in the hawkmoth's natural environment, researchers mapped how the hawkmoth distinguishes between odors to find a safe place to eat or to lay eggs, according to the study published February 27 in the journal *Cell Reports*.

"Pollination is an important service performed by insects, and many of the fruits we eat depend on it. Especially in times of increasing pollution and decreasing insect numbers, it might be beneficial to understand cues that guarantee this service," said first author Sonja Bisch-Knaden, of the Max Planck Institute for Chemical Ecology in Jena, Germany. Hawkmoths are known to feed on tobacco and other nightshade-like plants, which are partially dependent on the insects for pollination, as well as on various other flowers such as agave.

To figure out how the hawkmoth reacts to the odors it encounters in the air, Bisch-Knaden and colleagues first turned to the part of the brain responsible for processing scents.

Humans and other mammals have a brain structure called the olfactory bulb. Cells in our nose detect odors and send information about them to the olfactory bulb to be processed. In pollinating insects, the antennae detect odors and send scent information to be processed in a brain structure called the antennal lobe. Both the olfactory bulb of mammals and the antennal lobe of insects have a similar structure and are composed of a number of nerve subunits called glomeruli.

Bisch-Knaden and her colleagues started by exposing female hawkmoths to 80 different odors found in their natural habitat. With each odor, the research team used in vivo calcium imaging to track where the scent registered in the hawkmoth's antennal lobe. In total, the researchers identified 23 glomeruli activated by the odors.

Once the researchers had a functional map of where the 80 odors were processed in the hawkmoth brain, they could do a behavioral study to see what these odors meant to a hawkmoth. Did an odor signify a plant to eat or a safe place to lay eggs?

"To study odor-guided behavior, we need an airstream to bring the odor plume to the animal," said Bisch-Knaden. "In addition, wind motivates the moths to start fanning their wings for one to two minutes (they need that to warm up) and then to fly upwind."

Each wind tunnel test included a control paper soaked in solvent or a test paper with a drop of a diluted odor. The researchers noted when the moths hovered in front of a paper with an odor, whether the moths touched the paper with their proboscis (the tubular mouthpart), and how long they tried to taste the paper. The researchers also noted when the moths grabbed the paper with their tarsi (feet) and curled their abdomens, which is the position hawkmoths take when laying eggs.

With each wind tunnel experiment, the researchers could then cross-reference their functional map of the antennal lobe and how the moth reacted to the odor. They found that the hawkmoth has distinct clusters of glomeruli linked to feeding behavior and distinct clusters linked to egg-laying behavior.

"We would next like to test whether the position of the 'feeding glomeruli' and 'egg laying glomeruli' is conserved in different moth species," said Bisch-Knaden.

"Studying the brain activation patterns in honeybees would also be very interesting because bees, although they are day-active and heavily rely on visual cues to find flowers, also can use flower odors for navigation," she added.

More information: Sonja Bisch-Knaden et al, Spatial Representation of Feeding and Oviposition Odors in the Brain of a Hawkmoth, *Cell Reports* (2018). DOI: 10.1016/j.celrep.2018.01.082

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