Moths with a Nose for Learning

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Researchers conditioned a moth to extend its proboscis in anticipation of a dollop of sucrose after being given a scent cue to study how the insect learned. Understanding how associations are built between stimuli and behavior can offer significant insights into how to build artificial systems to discriminate odors. Credit: I. Ito and R.C.Y. Ong, NIH

Much like Pavlov conditioned his dog to salivate in anticipation of food when a bell rang, insects can be trained to perform certain behaviors when enticed with different smells. Researchers at the National Institutes of Health (NIH), the Chinese University of Hong Kong and the National Institute of Standards and Technology (NIST) have discovered that when training insects, the interval between the signal, or odor, and the reward—delicious sugar water—is everything.

They also found that this process of building odor-sucrose associations would involve a mechanism that allows integration of neural activities (mental representations) that are not nearly coincident. Understanding how associations are built between stimuli and behavior gives insight into the nature of learning. Their findings were published online in *Nature Neuroscience*.

Associations or meanings are formed when a connection is perceived among mental representations. In Pavlov's experiments the dog was taught to understand that the ringing of the bell meant food. In this case, the researchers conditioned a particular species of moth, Manduca sexta, to extend its proboscis in anticipation of a dollop of sucrose after being given a scent cue.

The researchers attached electrodes to the insects' mushroom bodies, a structure in their brains known to be integral to learning and memory, in order to observe the mental representation of the scent through spikes in activity across groups of neurons called Kenyon cells. By observing this process, the group hoped to characterize how odors are represented by this neural population and how this representation gets associated with the reward.

The group found that most of the odor-elicited spiking in the Kenyon cells occurred during the beginning and end of an odor pulse, with little to no spiking in between. NIST/NIH researcher Baranidharan Raman says that this is can be understood by considering the analogy of going into a coffee shop. The onset signal occurs upon entering and smelling the coffee for the first time. That smell remains intense and noticeable for a few moments before it fades into the background. Again, when you the leave the coffee shop, you notice that change, the offset signal represents that change of state, and it does not elicit as much activity as is caused by the onset.

The group found that the interval between the odor stimulus onset and sucrose reward was crucial to whether or not the insect learned to link the representations. If the sucrose was presented during the onset of spiking, the insect did not learn as well. Moreover, if the researchers used a long odor stimulus and administered the sucrose just after the offset signal (long after the onset), the insect wouldn't learn to expect it.

Learning, or the capacity to associate the cue and its reinforcement, occurs when reward was presented a few seconds after the onset of neural activity. Since most Kenyon cells have finished producing action potentials (or spikes) by the time the reward is presented, the odor-sucrose association cannot be achieved through a well-known model of learning called spike-timing dependent plasticity where nearly coincident spiking on a millisecond timescale results in the association of two events.

Raman says that the study of biological olfactory systems can offer significant insights into how to build artificial systems to discriminate odors with sensor arrays.

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