UC SANTA BARBARA

THE Current

March 5, 2020

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Mapping Movement

Our day-to-day lives can be seen as a series of complex motor sequences: morning routines, work or school tasks, actions we take around mealtimes, the rituals and habits woven through our evenings and weekends. They seem almost automatic, with little conscious thought behind them.

In reality, however, they are the result of the myriad decisions and physical adjustments we make along the way, thanks to the continual signal processing in the brain that is guided by information we receive through our senses.

UC Santa Barbara researcher Julie Simpson is interested in the processes that go into these complex motor sequences, specifically how neural signals are translated into our physical behaviors.

“Every day, you get up in the morning and you decide what to do with your day,” said Simpson, an assistant professor in the Department of Molecular, Cellular and Developmental Biology. “There are many things you could do with your limbs, which are driven by motor neurons, which are controlled by commands from your brain.” Humans have a wide repertoire of behaviors and often we experience competing drives. How do we choose what to do first?

There are many obvious challenges to mapping out how human brain activity coordinates physical motions, not the least of which is the sheer complexity of the human brain’s networks. Fortunately, the fruit fly (*Drosophila melanogaster*) — a model organism for which we have the complete genome — possesses an analogous

but far simpler and much more tractable system. Using fruit flies, Simpson and her research team have uncovered neural mechanisms that contribute to complex motor sequences in fly behavior — specifically those that govern grooming, a universal fruit fly behavior that removes dust from the body with targeted leg movements.

Besides adding to our fundamental understanding of how our brains and bodies work, the findings, published in a paper in the journal Current Biology, could lend insight into pathologies in brain signaling, such as in Parkinson's Disease, or with obsessive-compulsive behaviors.

Through optogenetics — the use of light to activate specific neurons — and targeted, competing light, the researchers were able to turn small groups of these neurons off and on in the fruit fly subjects to see which behavior the fly chose to exhibit. In this case, the fly would have to decide which part to clean first when tricked into believing its entire body was covered in dust.

"If you give them everything dirty at once, what do they do?" Simpson said.

Fruit flies, it turns out, generally have a standard — but not set — grooming sequence. They use their legs to sweep their heads, then their abdomens, and then their wings, each time lifting and planting and swiping the legs between each sweeping session.

"It's always a higher probability of anterior behaviors, then posterior," Simpson said, "but the exact pattern and exact transition points differ, so it's not an utterly fixed action pattern. They're making probabilistic choices."

The choices the flies make, the lab found, are the result of spatial comparisons of levels of dust on each region. The "dust" is actually red light for optogenetic stimulation, like a mechanosensory virtual reality which allows for finer control over neuron activation.

"We found that spatial comparisons were more important; the flies didn't keep track of sensory input over time," said Neil Zhang, the study's lead author. "They compare between different body parts — between the head and the abdomen, for example." The head region, it seems, usually wins in competition, perhaps due to the large number of mechanosensory bristles located in the eyes and on the head, which makes that part of the body a cleaning priority.

“Flies in the dark will still clean their eyes first. Blind flies will still clean their eyes first,” Simpson said. But “bald-eyed” flies (those without the bristles) will have a weaker drive to go for the eyes first.

The sensory inputs the flies receive — not just mechanical but also visual, olfactory and via other senses — are sent to specialized regions in their brains and then to as yet largely unknown neural circuits that coordinate the decisions about what to do and what not to do.

“That kind of computation is made by their nervous system,” Zhang said. “The next step is to figure out which neurons, and which circuits are doing that comparison.” It’s a tall order, even for the relatively simple fruit fly, given the thousands of neurons it possesses. But with genetic tools, wiring diagrams from electron microscopy data, and functional imaging techniques, researchers in this field are off to a good start.

These behavioral experiments are a key clue. “Now we have a better idea of what circuits we should look for because of the behavioral evidence for the importance of the spatial comparisons,” Simpson said.

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