Dust-covered flies reveal hidden logic of grooming behavior

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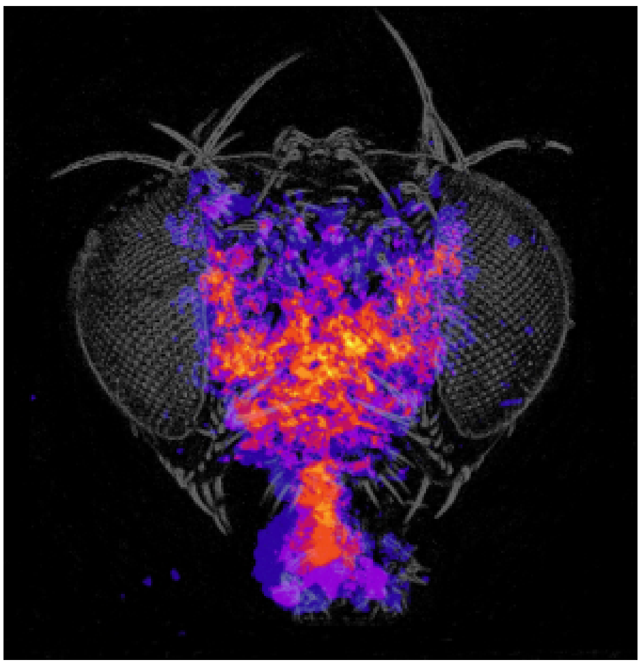

Flies remove dust from their bodies in an orderly way, starting from their eyes and proceeding to their heads, wings, and abdomens. This progression is likely influenced by mechanosensory feedback.

(Phys.org) —A dust-covered fly might spend more than 20 minutes removing the offending grit and grime from its body. With only its own legs to complete the chore, the fly needs a plan of attack. Thanks to a strategy hardwired into the insect's brain, most flies deal with the problem by performing a sequence of cleaning movements that begins with cleaning the head before progressing to lower-priority body parts.

A new study from scientists at the Howard Hughes Medical Institute's Janelia Research Campus suggests that the neural pathways that control the cleaning of each body part are organized into a hierarchy in which higher-priority cleaning movements suppress lower-priority ones, which are then executed later in the grooming sequence. The model, published on August 19, 2014 in the journal *eLife*, provides a new explanation for how the brain can drive sequential behaviors. "This kind of logical architecture might underlie lots of sequences," says Janelia group leader Julie Simpson, who led the research. Simpson says the findings of this behavioral study will help focus her team's search for the neural circuits that control grooming in fruit flies.

Simpson has been studying how fruit flies behave when they are dirty because she wants to understand how animals carry out sequences of movements that make up more complex behaviors. Grooming is an innate motor sequence; understanding its logic and circuits can potentially inform other kinds of sequences—such as the words a person puts together to form a sentence or the individual steps of an elaborate courtship dance. For some such behaviors, it is critical that each step is executed in a precise order. Less precise sequences still must be performed one step at a time. "You can't do everything at once," Simpson says, "so how do you manage competing demands on your limbs and brain so that you execute things in order of importance?"

By coating flies in dust and watching them deal with the mess, Andrew Seeds, a postdoctoral researcher in Simpson's lab, has found that flies groom themselves with a predictable sequence of cleaning movements. "Flies have to decide which body part to groom, and once they've cleaned one body part, there's a new decision of which of the remaining body parts to groom. This series of choices leads to the emergence of a sequence," he says.

Seeds found that a fruit fly that is completely covered in dust usually reacts by using its front legs to clear the dust from its eyes and antenna. Next, it uses its rear legs to clean its abdomen, wings, and finally its thorax. Periodically, the fly interrupts the sequence to brush accumulating dust from the legs that it is using to clean.

Although this is the favored sequence, Seeds noticed that individual flies sometimes stray from the pattern. "This sequence is not like language, where the exact order matters," Simpson says. "It's more flexible." That was a hint that grooming is not a simple cascade of events in which each movement directly triggers the next, a mechanism that is thought to drive some sequential behaviors, such as bird song. It seemed more likely, the scientists reasoned, that early steps in the grooming sequence were able to suppress later steps, at least most of the time.

To test that idea, Seeds designed an experiment in which he could activate multiple components of the grooming sequence, and see which movements a fly carried out. The normal trigger for grooming is the presence of dust on a particular body part, but the scientists also had a genetic tool that enabled them to manipulate individual movements of the grooming sequence.

For their experiments, the team used fruit flies developed in the lab of Janelia executive director Gerald Rubin in which sets of neurons can be switched on by exposing the flies to mild heat. Seeds identified strains of flies in which he could trigger a specific movement of the grooming behavior, even in a clean fly, by switching on a small set of neurons. The identity of those task-specific neurons remained unknown, but the ability to control them meant Seeds could activate individual cleaning movements.

Seeds found that when he switched on a cleaning movement in a dust-covered fly, the fly would begin its usual grooming pattern, but never progress beyond the switched-on movement. So when he activated abdominal cleaning in a dust-covered fly, the fly cleaned its head, then its abdomen—and then continued cleaning its abdomen, ignoring the dust on the rest of its body. "It progresses through the hierarchy to that point, and then it gets stuck," Simpson explains.

These findings fit with the team's early observations suggesting that activation of one cleaning movement could suppress later movements. "It's a beautiful demonstration that this proposed hierarchy that makes sense from our observations is actually the way the fly is running the show," Simpson says. "This mechanism for organizing a sequence is effective and flexible, and has not been previously demonstrated. It makes you wonder whether other sequential behaviors might also be established in this way."

Primoz Ravbar, Brett Mensh and Seeds developed computer models that suggest a few ways in which the neurons that control grooming might be organized to generate the scientists' proposed hierarchy. It's possible, Simpson says, that the fly's head is better than its other body parts at sensing the presence of dust, increasing the likelihood that it will be cleaned first. Alternatively, the neurons that control the fly's front legs, which carry out early cleaning movements, might be better at inhibiting competing movements than those that control the rear legs.

The next stage for Simpson's team will be to look for the neurons that control the movements that make up the fly's grooming sequence, as well as the neurons that mediate the interactions between those behaviors. "This deep understanding of the behavior changes the search image of what neural circuits we are looking for," Simpson says. "I think we are now looking for the right things with a formidable set of tools."

More information: The complete study is available online: elifesciences.org/content/3/e02951

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