The consciousness of bees

Experiments indicate that bees have surprisingly rich inner worlds

Perspective by Lars Chittka

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The French philosopher René Descartes, whose views on animals were highly influential, argued that these creatures acted purely by reflex — they had no intellectual capabilities. But there has been a Copernican revolution since then: We now know that sophisticated minds are all around us in the animal queendom — not just in close relatives of humans such as chimps and apes, but also in "aliens from inner space" such as the octopus.

And now we are learning just how smart insects can be. As I show in my new book, "The Mind of a Bee," the latest research indicates that even tiny-brained bees are profoundly intelligent creatures that can memorize not only flowers but also human faces, solve problems by thinking rather than by trial and error, and learn to use tools by observing skilled bees. They even appear to experience basic emotions, or at least something like optimism and pessimism. The possibility of sentience in these animals raises important ethical questions for their ecological conservation, as well as their treatment in the crop pollination industry and in research laboratories.

Social insects are traditionally thought to be wholly governed by instinct: They can build complex nests and efficiently divide up their labor through innate behaviors, but are considered stupid as individuals, with complexity emerging only at the group level. But there is significant evidence that bees have an inner world of thought — that they are not responding to stimuli only with hard-wired responses.

To explore bees' learning abilities, scientists reward them with little drops of sugar water when they have solved a task — the same reward that bees obtain in nature when they discover a nectar-rich flower. For example, to probe bees' face recognition skills, foragers were first rewarded with sugar water on a platform in front of a black-and-white photo of a human face. Once they learned to fly to this platform, they were confronted with a test in which they had to locate the correct photo out of a number of images of other people. No rewards were now present, and the correct photo was located in a different position during the test. Nonetheless, they found the correct face over 80 percent of the time — lending credence to the common beekeepers' assertion that bees can recognize the person who looks after them.

To test whether bees can count, we trained them to fly from their hive past four identical landmarks, shaped like 11-foot-high pyramids. During the training, they found a sugar reward after the third landmark. In the tests, we increased the number of landmarks between the hive and the training location of the feeder. When we did, bees landed at a shorter distance from the hive than during the training, apparently thinking they had flown far enough when they encountered the third landmark. Reducing the number of landmarks had the opposite effect — bees then overshot the training distance and flew farther to seek the third landmark.

Bees are flexible in accessing memories. A master storyteller of the mysteries of memory, Marcel Proust describes in "Remembrance of Things Past" how the narrator, after tasting a tea-soaked madeleine, suddenly recalls long-lost childhood memories in vivid detail. Similarly, a scent experienced by a bee inside its hive can bring back the memory of a flower patch with the same scent. To demonstrate this, scientists first trained bees to memorize two different feeding locations about 55 yards from the hive and 33 yards apart, one smelling of rose and the other of lemon. When researchers blew one scent or another into the hive, it activated the bees' memory of the correct feeding station, to which they flew directly. Thus, their memories can be activated separately from the setting in which they are learned.

On occasion, bees activate such memories in the darkness of the hive at night, and even communicate with other bees about them. Bees have a "dance language" by which they can inform others in the hive of the precise location of a rewarding flower patch. The symbolic language involves repeating the motor patterns ("dances") of a knowledgeable bee on the vertical honeycomb. The movements make reference to gravity and the direction of the sun; since it's dark in the hive, bees that want to learn from the dancer need to touch its abdomen with their antennae. Sometimes, such dances are displayed at night, when no foraging takes place: The dancer appears to think about locations visited on the previous day, without an obvious need to do so at the time, indicating that memories can be browsed in an "offline" situation.

My team has shown that bees can, in a sense, picture things in their minds. Bees that first learn that balls, but not cubes, are linked to a sugar reward by seeing these shapes through plexiglass — in a "look but don't touch" situation — can subsequently identify the same shapes by touch alone. We tested this in darkness, viewing the bees' behavior with infrared equipment (such conditions are not unusual for bees, since their nests are naturally dark). Bees trained to tell cubes from spheres in darkness could also later identify the correct shapes when seeing but not touching them, indicating a form of mental image that can be accessed with more than one sense.

Bees can also solve problems in a manner that indicates they understand the desired goal. In one experiment, bees learned to roll a ball to a certain area to obtain a sugar reward — a simple form of tool use, in which an object needs to manipulated in a specific way. Untrained bees then improved the technique. A trick was played on the "demonstrator" bee, so that only the farthest of three balls could be moved to the target area (the two other balls were glued to the horizontal surface). A naive bee was then allowed to observe the skilled bee's performance — always moving the farthest ball — three times. But when the observer was subsequently allowed into the arena alone, now finding none of the balls glued down, it spontaneously (without trial and error) picked the closest ball to move to the goal, solving the task in a manner inspired by the demonstrator but clearly not merely imitating its performance. Observer bees could have conjured up this solution only through a kind of mental exploration. This indicates a form of intentionality that was previously recognized only in large-brained animals, such as chimps.

And we now have evidence of emotion-like states, using the same criteria that researchers employ to evaluate whether domestic animals such as goats or horses are being kept in conditions that result in a positive or negative outlook on life. We trained bees to learn that blue was rewarding and green was not (another group of bees was trained with the opposite conditions) and subsequently presented them with an intermediate color, turquoise — an ambiguous stimulus. Crucially, the bees' judgment of this ambiguous color depended on what happened *before* the experiment. Unexpected rewards before the test appeared to induce an optimistic state of mind in bumblebees, making them more curious about new stimuli and more resilient to aversive stimuli. This optimistic state relied on the neurotransmitter dopamine, as it does in humans.

A negative emotional state can be induced by predator attacks. Some species of spiders sit on flowers and try to catch pollinating insects. We re-created this in the lab, constructing a plastic spider with a mechanism by which a bumblebee was momentarily held between two sponges and then released. The bees' behavior changed fundamentally: They seemed more nervous for days after such attacks. Beyond a simple learned aversion to flowers with artificial spiders, they extensively scanned every flower before landing, and even if there were flowers without a robotic spider, they sometimes fled — as if they were "seeing ghosts." The bees behaved as if they were suffering from post-traumatic stress disorder.

A critical reader might observe that each of these abilities could be programmed into a nonconscious robot. She would be correct, but such a robot would often fail at tasks that a programmer did not build into it. For example, a robot built 20 years ago to replicate all the skills of a honeybee as understood at the time would not have been able to exhibit the abilities of bees that were more recently discovered: to roll balls to a goal, recognize shapes across senses or display emotion-like states. Nature has no room to generate beings that just pretend to be sentient. Thus, while there is no accepted formal proof for consciousness in any animal or machine, common sense dictates that growing evidence of consciousness does indeed indicate what it seems to show.

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The observation that bees are most likely sentient beings has important ethical implications. It's well known that many species of bees are threatened by pesticides and wide-scale habitat loss, and that this spells trouble because we need these insects to pollinate our crops. But is the utility of bees the only reason they should be protected? I don't think so. The insight that bees have a rich inner world and unique perception, and, like humans, are able to think, enjoy and suffer, commands respect for the diversity of minds in nature. With this respect comes an obligation to protect the environments that shaped these minds. Common migratory beekeeping practices in industrialized agriculture, for example, involve the frequent transport of hives across continents on trailers, which not only spreads disease but is most likely detrimental to bees' psychological well-being, weakening their health further. Finally, countless insects are sacrificed annually in research laboratories and the insect food industry, the methods of which are entirely unregulated. It is plausible that our findings about bees' capacity to suffer also extend to other insects, and this should be considered in any legislation regulating their treatment.