Honeybees are math stars (Update)

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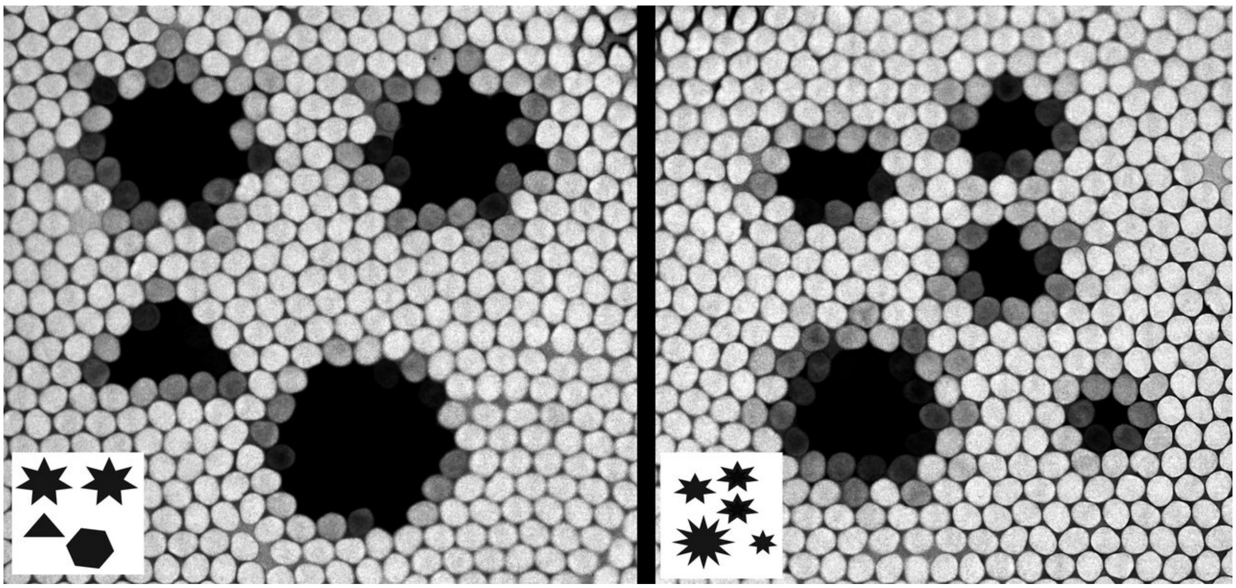

A 'bee eye' view of the 4 and 5 element cards that were used to test bee number discrimination. The insert shows how humans see the same cards. Credit: Adrian Dyer

Start thinking about numbers and they can become large very quickly. The diameter of the universe is about 8.8×10^{23} km and the largest number with a name—googolplex, $10^{10^{100}}$—outranks it enormously. Although that colossal concept was dreamt up by brilliant mathematicians, we're still pretty limited when it comes to assessing quantities at a glance. 'Humans have a threshold limit for instantly processing one to four elements accurately', says Adrian Dyer from RMIT University, Australia; and it seems that we are not alone. Scarlett

Howard from RMIT and the Université de Toulouse, France, explains that guppies, angelfish and even honeybees are capable of distinguishing between quantities of three and four, although the trusty insects come unstuck at finer differences; they fail to differentiate between four and five, which made her wonder. According to Howard, honeybees are quite accomplished mathematicians. 'Recently, honeybees were shown to learn the rules of "less than" and "greater than" and apply these rules to evaluate numbers from zero to six', she says. Maybe numeracy wasn't the bees' problem; was it how the question was posed? The duo publishes their discovery that bees can discriminate between four and five if the training procedure is correct in *Journal of Experimental Biology*.

Dyer explains that when animals are trained to distinguish between colours and objects, some training procedures simply reward the animals when they make the correct decision. In the case of the honeybees that could distinguish three from four, they received a sip of super-sweet sugar water when they made the correct selection but just a taste of plain water when they got it wrong. However, Dyer, Howard and colleagues Aurore Avarguès-Weber, Jair Garcia and Andrew Greentree knew there was an alternative strategy. This time, the bees would be given a bitter-tasting sip of quinine-flavoured water when they got the answer wrong. Would the unpleasant flavour help the honeybees to focus better and improve their maths?

'[The] honeybees were very cooperative, especially when I was providing sugar rewards', says Howard, who moved to France each April to take advantage the northern summer during the Australian winter, when bees are dormant. Training the bees to enter a Y-shaped maze, Howard presented the insects with a choice; a card featuring four shapes in one arm and a card featuring a different number of shapes (ranging from one to 10) in the other. During the first series of training sessions, Howard rewarded the bees with a sugary sip when they alighted correctly before the card with four shapes, in contrast to a sip of water when they selected the wrong card. However, when Howard trained a second set of bees she reproved them with a bitter-tasting sip of quinine when they chose incorrectly, rewarding the insects with sugar when they selected the card with four shapes. Once the bees had learned to pick out the card with four shapes, Howard tested whether they could distinguish the card with four shapes when offered a choice between it and cards with eight, seven, six or—the most challenging comparison—five shapes.

Not surprisingly, the bees that had only been rewarded during training struggled; they couldn't even differentiate between four and eight shapes. However, when Howard tested the honeybees that had been trained more rigorously—receiving a quinine reprimand—their performance was considerably better, consistently picking the card with four shapes when offered a choice between it and cards with seven or eight shapes. Even more impressively, the bees succeeded when offered the more subtle choice between four and five shapes.

So, it seems that honeybees are better mathematicians than had been credited. Unlocking their ability was simply a matter of asking the question in the right way and Howard is now keen to find out just how far counting bees can go.

More information: Howard, S. R., Avarguès-Weber, A., Garcia, J. E., Greentree, A. D. and Dyer, A. G. (2019). Surpassing the subitizing threshold: appetitive-aversive conditioning improves discrimination of numerosities in honeybees. *J. Exp. Biol.* 222, jeb205658. DOI: 10.1242/jeb.205658

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