RESEARCH NEWS

Can animals count?

Ten years ago Tetsuro Matsuzawa of the Primate Research Institute at Kyoto University in Japan put a 5-year-old female chimpanzee named Ai through a severe test and she came out with flying colours. Matsuzawa taught Ai to distinguish between 14 different objects, namely, padlock, glove, shoe, glass, bowl, brick, rope, paper, ball, box, spoon, brush, key and pencil. Ai was shown one of these objects on a computer screen and she had to press a key that she had been taught to associate with that object. Similarly, Ai was taught to identify 11 colours, namely, red, orange, yellow, green, blue, purple, pink, brown, white, grey and black. Finally, Ai was also taught to identify numbers from 1 to 6 by pressing the appropriate key when she was shown a certain number of objects on the computer screen. In the final exam she was shown any one of the five objects, pencil, paper, brick, spoon and toothbrush. The objects could be red, blue, yellow, green or black and there could be anywhere from 1 to 5 of these objects. This makes 125 possible combinations. Ai was given 830 tests in each of which she was required to identify correctly the object, its colour and the number of objects. Her accuracy score exceeded 98.5%, enough to gain her entrance to any IIT of her choice! And it is not as if Ai had not worked hard. In 95 separate sessions, she had spent a total of 68 hours and 21 minutes at the computer and had gone through 28,799 trials before taking the final exam. But the bottom line is that chimps can count[1]. It is a bold step from this to ask if honey bees can also count, but that is exactly what Chittka and Geiger at the Institute for Neurobiology at Berlin have done[2].

Chittka and Geiger worked with honey bees in a large meadow of about 2 km^2 which was practically devoid of any natural landmarks that could be used by the bees. This made it convenient for them to set up their own landmarks, which consisted of tetrahedral-shaped yellow tents, 3.46 m in height. As in almost all such training experiments, the bees were trained to accept sugar solution from a feeder kept at some distance from the hive. In the training period there were four tents in the flight path of the bees at distances of 75, 150, 225 and 300 m from the hive (Figure 1). The feeder was at 262.5 m from the hive and thus exactly midway between the third and the fourth tents. The bees, therefore, had to cross three tents on their way to the feeder.

In the first experiment, they put a second feeder midway between the second and the third tents at a distance of 187.5 m from the hive, retaining the original feeder midway between the third and the fourth tents at a distance of 262.5 m from the hive (Figure 1). Out of the 39 bees tested, only one went to the new feeder between the second and the third tents while all the remaining 37 went promptly to the feeder between the third and the fourth tents. This shows that the bees had actually learned to go to the original feeder at a distance of 262.5 m between the third and the fourth tents and that (with one exception) they were not merely going to the first feeder they encountered. What rules might the bees have employed to reach the feeder of training and ignore another feeder that came even earlier in their flight path, with such accuracy? Since there were no other natural landmarks, there are really only two possibilities. One is that the bees had some independent method of estimating that they had flown 262.5 m and the other is that they learned to cross three tents before searching for the feeder.

In the second experiment five tents were placed in the flight path of the bees at regular intervals of 60 m. One feeder was placed midway between the fourth and the fifth tents (Figure 1). This amounted to a distance of 270 m from the hive and thus very close to the location of the feeder during the training. The second feeder was placed between the third and the fourth tents and this amounted to a distance of 210 m from the hive. Feeder one, between the fourth and the fifth tents at 270 m, would be very nearly the correct choice by the criterion of distance from the hive but the wrong choice by the criterion of the number of tents to cross. Conversely, feeder two, between the third and the fourth tents at 210 m from the hive, would be the wrong choice by the criterion of distance from the hive but the correct choice by the criterion of the number of tents to be crossed. Of the 65 bees tested, 48 (74%) landed on feeder one – correct by distance but wrong by number. It is important, however, that the remaining 17 (26%) landed on feeder two – wrong by distance but correct by number. This proportion of bees landing on feeder two is significantly greater than the proportion of bees (1/38) that landed on feeder two in the first experiment, where feeder two was wrong even by the criterion of the number of tents crossed.

In the third experiment six tents were placed at regular intervals of 50 m from the hive (Figure 1). Now there were three feeders. Feeder one was between the fifth and the sixth tents and thus at a distance of 275 m from the hive, feeder two was placed between tents four and five and thus at a distance of 225 m from the hive and feeder three was placed between tents three and four and thus at a distance of 175 m from the hive. Feeder three would be the correct

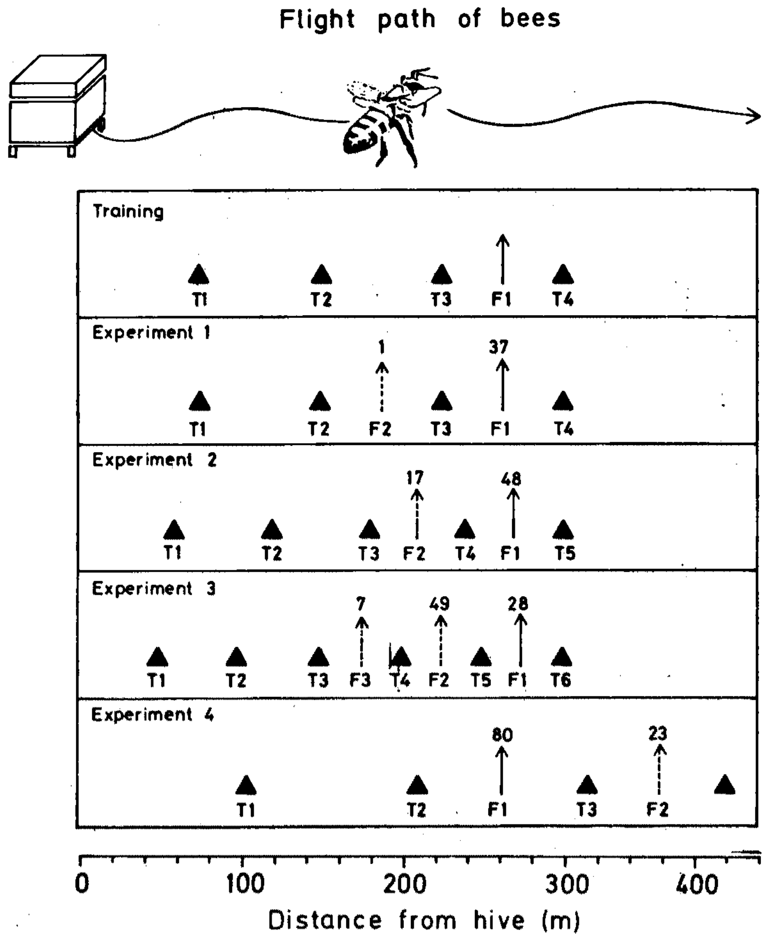

Figure 1. Experimental design showing the numbers of tents and feeders placed in the flight path of the bees at different distances from the hive. Tents are shown as filled triangles and labelled T1, T2, etc. Feeders are shown as upward-facing arrows and numbered F1, F2, etc. The numbers of bees landing on each feeder in different experiments are indicated by numbers above the arrows.

choice by the criterion of the number of tents crossed but quite wrong by the criterion of distance from the hive. On the other hand, feeder one is almost right by the criterion of distance from the hive but quite wrong by the criterion of the number of tents crossed (five instead of the required three). Feeder two is a bit of a compromise, wrong by both criteria but better than feeder one by the criterion of the number of tents crossed (four instead of the required three but better than five) and better than feeder three by the criterion of distance from the hive (225 m instead of the required 262.5 m but better than feeder three, which is at a distance of 175 m). Now, 28 out of the 84 bees tested (33%) landed on feeder one, 7 out of 84 (8%) landed on feeder three and as many as 49 out of the 84 bees tested (58%) landed on feeder two, which is a compromise between distance and the number of landmarks.

In the fourth experiment, only three tents were used but they were placed at distances of 105, 210, 315 and 420 m from the hive (Figure 1). Feeder one was placed between the second and the third tents and thus at the original distance of 262.5 m and feeder two was placed between tents three and four and thus at a distance of 367.5 m from the hive. Now, 80 out of the 103 bees tested (78%) landed on feeder one, which was at the correct distance but wrong by the criterion of the number of tents passed. It is striking, however, that as many as 23 out of 103 bees (22%) chose to fly more than 100 m further and land on feeder two, which was correct by the criterion of the number of tents crossed but quite wrong by the criterion of distance from the hive.

These results clearly suggest that the bees are confused when the number of landmarks to be crossed and the distance from the hive do not both match with what they have learned during the training and that the number of landmarks is at least one of the criteria that they use in finding the feeder. The authors make this conclusion even more convincing by considering and ruling out three alternate hypotheses for the behaviour of the bees that do not involve counting the number of landmarks. Can we then conclude from these findings that bees can count? Psychologists have defined three stages in the evolution of counting[3]. The first is called *subitizing*, which merely involves assessing the relative numerousness of simultaneously presented objects. The bees in these experiments did not see the landmarks simultaneously and they cannot, therefore, be said to be merely subitizing. The third stage is true counting, where the subject is able to transfer knowledge of the number of objects of one kind onto completely different objects. Clearly, this is what the chimp Ai was capable of doing. She would correctly press the key for the number three whether she was shown three pencils or three spoons on the computer screen. We do not yet know whether the bees can perform such true counting and so they can only be said to have mastered the second stage in the evolution of counting, which for lack of a better term is called 'protocounting'. The answer to the question in the title then is that chimps can count and bees can at least protocount!

1. Matsuzawa, T., *Nature*, 1985, **315**, 57–59.
2. Chittka, L. and Geiger, K., *Anim. Behav.*, 1995, **49**, 159–164.
3. Gallistel, C. R., *The Organisation of Learning*, MIT Press, Cambridge, MA, 1990.

Raghavendra Gadagkar is in the Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India, and in Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore 560 064, India.