

The Honeybee Dance-Language Controversy

Robot Bee Comes to the Rescue

Raghavendra Gadagkar

Language is usually credited with being the major factor in making humans so different from other higher animals. The fact that honey bees have a dance language that is unparalleled in the rest of the animal kingdom is therefore of great interest. Successful forager bees communicate information about the source of food discovered by them, to their sisters upon returning home. They do this by means of a round dance (which only says, there is food nearby) or a waggle dance which gives information about the distance, direction and quantity of food to be expected. Karl Von Frisch bagged the Nobel Prize in 1973, mainly for deciphering the dance language of honey bees. However there are some sceptics who believe that the dance that the foragers do perform may have no communication value and that bees locate sources of food based on the scent left behind by the discoverer on the way to and at the location of the food source. While bees can find food based on such odours, recent experiments, using a robot bee, convincingly demonstrate that bees can also find food, in the absence of smell, on the basis of information communicated through the dance language.

Language - The Prime Mover

Humans and chimpanzees share 99% of their genetic information. What then makes us so different from chimps? Our language is often credited with being the prime mover in making humans what they are. We have a unique ability to modulate our vocalizations because of the unusual structure of our vocal tract. For this we incidentally pay the price of the risk of choking to death while eating or drinking. Non-human apes can neither produce compa-



Raghavendra Gadagkar, who studies and teaches animal behaviour at the Centre for Ecological Sciences, Indian Institute of Science and Jawaharlal Nehru Centre for Advanced Scientific Research, has a particular fascination for social insects such as ants, bees and wasps. He hopes to provide a Darwinian explanation for the altruism, courage, industry, sacrifice and such other seemingly human attributes of these insects.



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rable variations in sound nor do they choke as they can simultaneously eat or drink and breathe. The unique structure of our vocal tract, taken together with our superior brains that permit us to detect virtually infinite variations in sound and associate them with objects or thoughts in an arbitrary and symbolic (see below) manner, lead to man's unparalleled ability to communicate and change the world. The only sobering fact is that we are not quite alone, at least in our ability to use a symbolic language. The only other example of a well-developed system of associating environmental stimuli in an arbitrary and symbolic manner with "universally understood meanings" is seen in the dance language of the honey bee. The claim is not that honey bees come anywhere near humans in their communication skills but that no other non-human animal, vertebrate or invertebrate, can match even the bee dance language.

Honey Bees

Honey bees live in extremely populous colonies and maintain an elaborate social organization. Every colony has a single queen, a few hundred drones (males) and tens of thousands of workers (all females). The queen is an egg laying machine and a chemical factory. She is responsible for all eggs laid in the colony and she manipulates the behaviour of the workers through various pheromones (chemical messengers) that she releases from time to time. The workers take on the responsibilities of nest construction and maintenance, brood care, and foraging for nectar and pollen from the environment. The drones do nothing for the colony itself and are chased away (often with limited success) during times of food scarcity. The success of honey bees to maintain such large colonies can be attributed to their ability to efficiently harvest large but ephemeral sources of pollen and nectar from flowers in their neighborhood. This in turn depends crucially on the unique ability of a successful forager bee to quickly recruit large numbers of naive workers from its colony to a newly found source of food. After decades of painstaking observations and many false starts, the Austrian zoologist Karl von Frisch (*Figure 1*) discovered and



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Figure 1 Karl Ritter von Frisch, recipient of the Nobel Prize in 1973 for his discovery of the honey bee dance language.

deciphered the honey bee dance language which enables such recruitment.

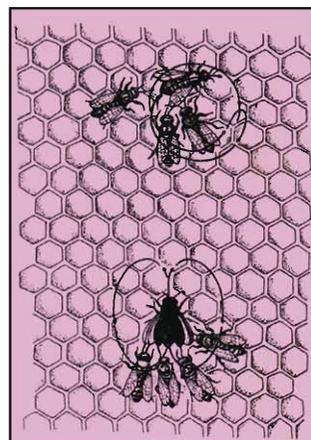
The Dance Language

A successful forager that returns to the colony attracts the attention of her sisters by means of a chemical she releases upon arrival. This usually ensures her an attentive audience to begin her dance. The forager, who alone possesses information on the location of food, performs either a *round dance* or a *waggle dance* (Figure 2). During a round dance the bee runs in small circles, often alternating between clockwise and counterclockwise directions. During the waggle dance, the forager waggles her body from side to side about 13 times per second while running in a straight line, and then returns to the starting point without wagging her body, in a clockwise or counterclockwise direction. She then repeats the waggle run, thus inscribing a figure of eight. The round dance is performed if the food is within 100m or so of the colony and the waggle dance is performed if the food is located beyond that. The round dance appears to provide no more information than that there is food close by. But the waggle dance has been shown to convey information on the distance between the colony and the food, the direction in which the food source is located as well as an indication of how much food is to be expected. The dancer also carries the smell of the pollen and/or nectar that she has recently encountered and that adds to the knowledge of the potential recruits, both during the round dances as well as during the waggle dances.

Is It a Language?

The direction of the waggle run contains information about the direction of the food. Most species of honey bees dance on the vertical surface of the nest which is built inside a dark cavity. Hence the bee uses gravity and not the sun as the reference point while dancing. For this the bees have to transform the angle between the sun (or, to be more precise, the sun's azimuth,

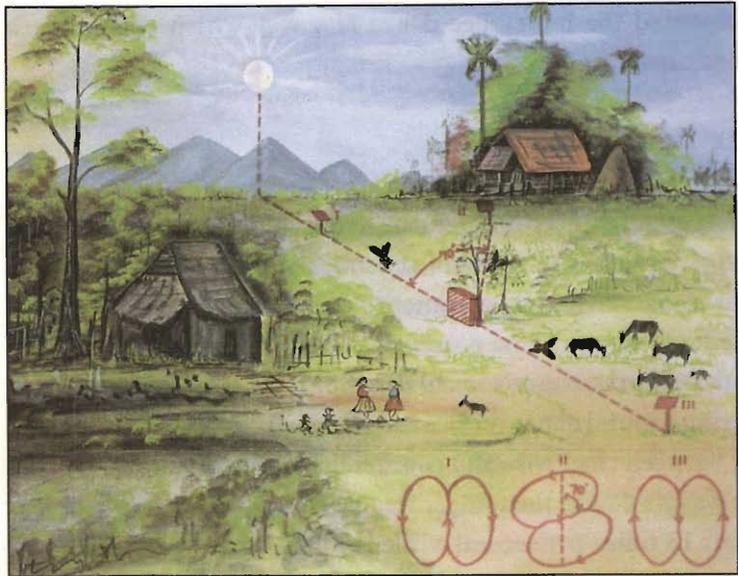
The bee uses gravity and not the sun as the reference point while dancing.



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Figure 2 Dancers and their followers. (Top): round dance and (Bottom): waggle dance.

Figure 3 *The waggle dance orientations illustrated for three different positions of the food source. When the food is in the direction of the sun as in I, the waggle run is directed upwards and when the food source is in the direction opposite to the sun, the waggle run is directed downwards. When the food is 80 degrees to the left of the sun, the waggle run is 80 degrees to the left of the vertical.*



meaning its projection on the horizon), the food, and their nest, into an angle with respect to the vertical. This is where the arbitrariness comes in. The symbolic representation that all bees seem to have “agreed” upon is to represent the direction of the sun with a waggle run pointing straight up, a direction against the sun with a waggle run pointing straight down, a location of food 60 degrees to the right of the sun with a waggle run direction 60 degrees to the right of the vertical, and so on (*Figure 3*). Every direction in the outside world can thus be accurately conveyed by the angle of the waggle run except only when the sun is exactly overhead at the equator (when the bees simply rest for a few minutes!). The number of figure eight circuits made per unit time and the duration of each waggle run indicate the distance between the nest and the food source. There are good reasons to call this communication system of the honey bee a language. Firstly, the bee language conveys information about something at great distance and not visible at the time of communication. The notations are arbitrary; “up” means in the direction of the sun because that is what the bees seem to have “agreed” upon, but it could as well have been that “down” means in the direction of the sun. More interestingly, the bee dance language also has dialects. There are slightly different calibrations of the figure of eight circuit dura-

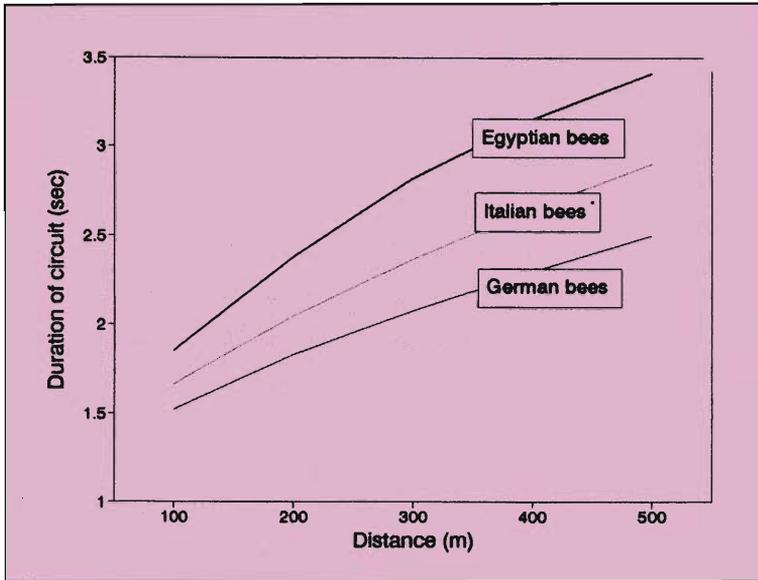


Figure 4 Different dialects of Egyptian, Italian and German bees. The distance corresponding to a circuit duration of 2.5 seconds for example, is about 200m for Egyptian bees, about 300m for Italian bees and about 500m for German bees.

tion with distance depending on the races of bees one is looking at' (Figure 4).

The Controversy

Karl von Frisch won the Nobel prize in 1973 for this discovery in spite of a challenge to his theory of the dance language thrown up by two scientists from California, Adrian Wenner and Patrick Wells. Their claim was that von Frisch's decoding of the dance language was a mere delusion and that bees really locate food discovered by their sisters by means of scent left by the original discoverer on the way to and at the location of the food. This counter argument cannot be dismissed out of hand because bees have a very well developed sense of smell. They are indeed capable of finding food discovered by their sisters by means of the scent of the discoverer on the way to and at the location of the food, under some circumstances. However, the question is not so much whether bees can ever locate a food source successfully by means of odour cues left by the discoverer. The question of interest is whether bees can ever successfully communicate using a symbolic, arbitrary dance language without the need for scent marks



The question of interest is whether bees can ever successfully communicate using a symbolic, arbitrary dance language without the need for scent marks of the discoverer along the way to and at the target location. This can only be tested by eliminating the scent marks of the discoverer and retaining only the information provided by the dancer.

of the discoverer along the way to and at the target location. This can only be tested by eliminating the scent marks of the discoverer and retaining only the information provided by the dancer. This was accomplished in an ingenious way by James L. Gould of Princeton University. He made the bees “lie” and proved the existence of a true language!

Bees Can Tell Lies

If a bee nest is removed from its normally dark cavity, the dancers need no longer use “up” to mean in the direction of the sun; they can as well aim their waggle runs in the direction of the food source using the sun directly as a reference point. The waggle runs can now be in the direction of the sun, away from the direction of the sun or 60 degrees to the right of the sun and so on, depending on where the food is located. A nasty trick used by Gould was to place a powerful source of artificial light close to the nest. When you do this the bees then ignore the sun and confuse this light for the sun. In other words, they orient their dances with reference to this artificial sun. If the light is placed in a position very different from that of the real sun, bees use the real sun while foraging, and the artificial sun while dancing and thus communicate completely wrong information. In addition to their two compound eyes, honey bees have three simple eyes called ocelli on the back of their heads. These ocelli are used to sense the intensity of light and help bees to decide when to start and when to stop foraging. The ingenuity of Gould’s experimental design was to paint the ocelli of the dancers so that they could not see the bright light. They therefore reverted to using gravity for conveying orientation and let us say indicated 60 degrees to the right of “up” because the food was located 60 degrees to the right of the real sun. However, the recruits (the dance followers) had normal unpainted ocelli and mistook the bright light to be the sun. Thus the recruits were expected to go to the misunderstood location, 60 degrees to the right of the bright light instead of going to the true location, 60 degrees to the right of the real sun. Gould of course was waiting at this “wrong” location (60 degrees to the right of the artificial

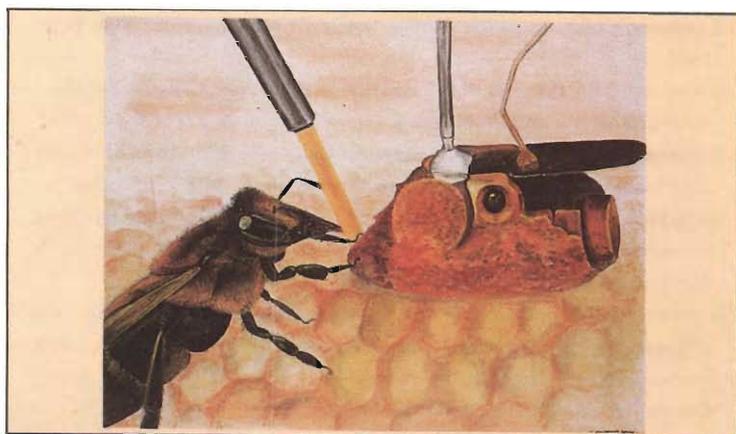


light, at the appropriate distance) where he was confident the recruits would go and sure enough he was rewarded by the arrival of the bees! Notice that the bees should have gone to the correct location, 60 degrees to the right of the real sun if they had relied on the scent of the dancers on the way to and at the location of the food. Although von Frisch retained the Nobel Prize, even this elegant experiment did not set the controversy to rest.

The Robot Bee — A Novel Solution

The main problem is that we cannot claim to know exactly what it is that the dancer is telling the recruits. What we need is to be able to talk to bees in their own language and restrict communication to only those elements of the language that we have deciphered. Sounds impossible, does it not? Well, not quite. A Michelsen and B B Andersen from Denmark and Wolfgang Kirchner and Martin Lindauer from Germany have constructed a mechanical “robot” bee that talks to the real bees through a computer, programmed by the scientists based on their idea of the bee dance language and, believe it or not, the bees understand! The robot bee was made of brass and was about the size of a real bee (*Figure 5*). It was coated with a thin layer of wax and made to sit in the nest among the real bees for about 12 hours and thus came to smell like the bees. It had wings made of razor blades which when vibrated produced acoustic signals similar to those

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Figure 5 Robot bee offering food to a real bee.

produced by real dancing bees. Two rods attached to the robot bee helped control its movements through a computer program. Most importantly a plastic tube near the model's head delivered, like the real bee, a drop of sugar solution from time to time. This was essential to prevent the real bees from attacking the model! Now by making the robot bee perform a waggle dance with a particular orientation of the waggle run, Michelsen and Co. thought that they could make the bees go wherever they wished them to go and sure enough they were right! This gives us confidence that our understanding of the bee dance language is sufficient to make the bees understand the true meaning of a message. This should lay the controversy to rest and vindicate the Nobel Laureate's theory but, knowing human nature, Wenner and Adrian are not going to be convinced. That won't be so bad really because it will motivate someone to do an even more ingenious experiment— science, after all, thrives on controversy and a penchant for disbelieving others' findings.

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Address for correspondence

R Gadagkar
Centre for Ecological
Sciences, Indian Institute
of Science,
Bangalore 560012, India.

