ANIMAL BEHAVIOR

Even a Robot Cricket Always Gets Her Mate

EDINBURGH—Female crickets have an impressive knack for tracking down a mate. By listening for the "call songs" of the male—the familiar chirping sound we associate with crickets—the female moves almost unerringly toward her goal, ignoring other sounds and all obstacles in her path. Animal psychologists don't follow quite as smooth a path, however. They run into an obstacle in the form of a question this behavior poses: Is the cricket making decisions about what she is doing, or is she just responding automatically to a stimulus?

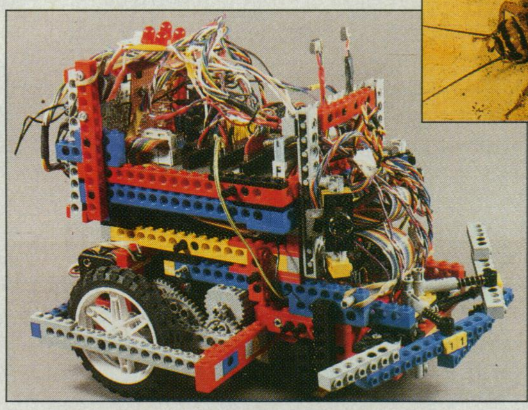
Psychologist Barbara Webb of the University of Edinburgh, U.K., believes the apparently complex behavior is due to reflexive responses—that a relatively simple physical/neural mechanism is responsible for leading a female cricket toward the calling song of the closest male of her species. Webb has a lot of experience testing such theories using computer models, but that involves second-guessing the physics and idealizing the environment. "The equations you need to do sound propagation in a complex environment are absolutely hideous," she says. Instead, she decided to try something different: a robot. "The same problems occur in understanding perception in a robot and understanding perception in an animal," says Webb. "They are encountering exactly the same difficulty of taking information from the environment, doing something with it, and then acting successfully at the other end."

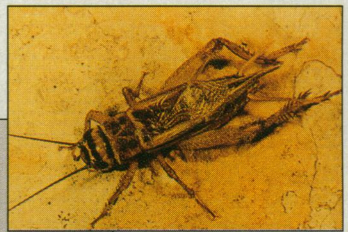
Webb's unorthodox method proved to be inspired. Not only did she succeed in reproducing the cricketlike behavior she had predicted, but she also identified intriguing behaviors that were not programmed into the system, emerging only during testing. "She has really put forward a new hypothesis about how crickets might work. ... Now biologists can go and start new experiments to test this," says Holk Cruse, head of the Department of Biological Cybernetics at the University of Bielefeld in Germany.

Seeking a mate involves two different tasks for a cricket: identifying the right call song, then moving toward it. Webb's theory is that a mechanism in the cricket allows her to recognize the song and simultaneously track its source. It is generally accepted among researchers that the position of a cricket's two ears helps it distinguish louder and softer signals coming from each side. Each ear is halfway down one of the cricket's front legs, and an acoustic channel links the ears through the legs and body. Sounds pass through the channel from one ear to the other so that the sound received at each ear can be compared and the loudest sound identified, giving the cricket directional guidance about the source of the sound. The cricket's rigid body provides an inflexible channel to carry sounds, and this fixed acoustic system means the cricket's hearing is sensitive to only one sound frequency—the song pitch of its own species.

But cricket song has many more variables than just pitch. The song is split up into "syllables"—short tones that repeat at regular intervals. Crickets emit these syllables in short bursts or "chirps." How this structure helps a female cricket track down a mate has remained something of a mystery, but it was thought that the repetition rates of both syllables and chirps were important.

Webb speculated that the repetition of syllables provides the material for a "summing" procedure in the cricket's brain. The intensity received by each ear is tallied during each syllable. After several syllables, the tally in one ear may reach a threshold, causing a set of neurons to begin firing, which causes the cricket to turn in the direction of the firing ear. The repetition rate of syllables is important because the summed tallies decay if they're not reinforced: Too slow a repetition rate means the neurons would never reach the threshold; too high and both sets of neurons would be firing and the cricket would not know which way to turn.





PHOTOS BY BARBARA WEBB

Imitating nature. Barbara Webb's robot cricket behaves much like its biological counterpart *(inset)*.

Webb implemented this theory in a wheeled robot made from plastic building blocks with microphones for ears. The comparison of loudness by the two "ears" was carried out by a dedicated circuit, while electronic neurons took the signals from the microphones, summed the chirp data, and stopped the left or right wheel to make the robot turn. The robot was equipped with infrared and touch-bumper sensors so it could avoid obstacles.

When the call song of the right sort of male cricket was played through a loudspeaker, the robot was very successful at reaching it. Its movements were efficient, and they had many of the zig-zag characteristics of real cricket motion. When the syllabic structure of the song was changed, the robot became less efficient at finding the source, again consistent with cricket behavior.

While this was the behavior Webb hoped to find, she had not expected the robot to display other cricketlike behaviors. For example, when two identical complete songs were played through different speakers, the robot simply "chose" one speaker, almost as if it were the only one playing. When the song was split, however, with syllables being played alternately from each speaker, the robot—again like a cricket—would move to a point between the speakers before eventually choosing one.

Cruse believes that because the robot's behavior so closely matches that of crickets, Webb's work makes sense and her approach will point researchers in new directions. "[This shows] you can get complicated behavior based on quite simple reaction-based systems," he says. But not everyone is so certain that this will tell us much about actual biological systems. Neurobiological behaviorist Ronald Hoy of Cornell University in Ithaca, New York, for instance, says he believes Webb has made too many assumptions to be able to extrapolate to real crickets, and that there is room for more neural processing, or decision-making, than she allows. "I'm not sure that this is going to change the way I look at processing, although I'm certainly going to look at it more closely," says Hoy.

Although Webb admits that the success of the robot model does not prove that the cricket uses the same perceptual mechanisms, it does at least show that it could. Despite "real-world" conditions—including noise, slipping motors, obstacles, and echoes—the robot cricket still gets her mate.

–Sunny Bains

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