Neural circuit in the cricket brain detects the rhythm of the right mating call

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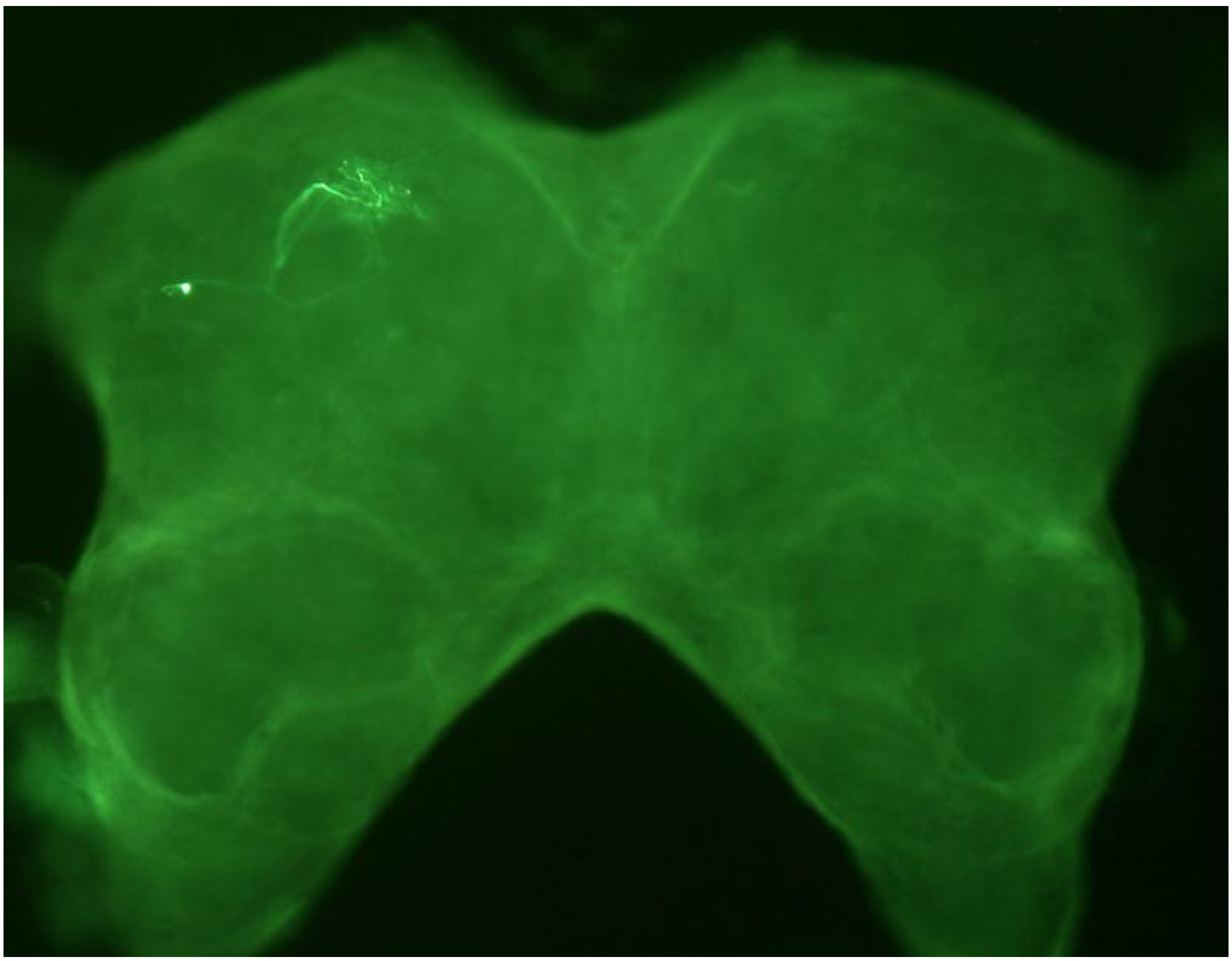

Auditory neuron in cricket brain. Credit: Berthold Hedwig/Stefan Schöneich

Scientists have identified an ingeniously elegant brain circuit consisting of just five nerve cells that allows female crickets to automatically identify the chirps of males from the same species through the rhythmic pulses hidden within the mating call.

The circuit uses a time delay mechanism to match the gaps between pulses in a species-specific chirp - gaps of just few milliseconds. The circuit delays a pulse by the exact between-pulse gap, so that, if it coincides with the next pulse coming in, the same species signal is confirmed.

It's one of the first times a brain circuit consisting of individual neurons that identifies an acoustic rhythm has been characterised. The results are reported today (11 September) in the journal *Science Advances*.

Using tiny electrodes, scientists from Cambridge University's Department of Zoology explored the brain of female crickets for individual auditory neurons responding to digitally-manipulated cricket chirps (even a relatively simple organism such as a cricket still has a brain containing up to a million neurons).

Once located, the nerve cells were stained with fluorescent dye. By monitoring how each neuron responded to the sound pulses of the cricket chirps, scientists were able to work out the sequence the neurons fired in, enabling them to unpick the time delay logic of the circuit.

Sound processing starts in hearing organs, but the temporal, rhythmic features of sound signals - vital to all acoustic communication from birdsong to spoken language - are processed in the central auditory system of the brain.

Scientists say that the simple, time-coded neural network discovered in the brain of crickets may be an example of fundamental neural circuitry that identifies sound rhythms and patterns, and could be the basis for "complex and elaborate neuronal systems" in vertebrates.

"Compared to our complex language, crickets only have a few songs which they have to recognise and process, so, by looking at their much simpler brain, we aim to understand how neurons process sound signals," said senior author Dr Berthold Hedwig.

Like in Morse code, contained within each cricket chirp are several pulses, interspersed by gaps of a few milliseconds. It's the varying length of the gaps between pulses that is each species' unique rhythm.

It is this 'Morse code' that gets read by the five-neuron circuit in the female brain.

Crickets' ears are located on their front legs. On hearing a sound like a chirp, nerve cells respond and carry the information to the thoracic segment, and on to the brain.

Once there, the auditory circuit splits and sends the information into two branches:

One branch (consisting of two neurons) acts as a delay line, holding up the processing of the signal by the same amount of time as the interval between pulses - a mechanism specific to a cricket species' chirp. The other branch sends the signal straight through to a 'coincidence detector' neuron.

When a second pulse comes in, it too is split, and part of the signal goes straight through to the coincidence detector. If the second pulse and the delayed signal from the first pulse 'coincide' within the detector neuron, then the circuit has a match for the pulse time-code within the chirp of their species, and a final output neuron fires up, when the female listens to the correct sound pattern.

"Once the circuit has a second pulse, it can define the rhythm. The first pulse is initial excitation; the second pulse is then superimposed with the delayed part of the first. The output neuron only produces a strong response if the pulses collide at the coincidence detector, meaning the timing is locked in, and the mating call is a species match," said Hedwig.

"With hindsight, I would say it's impossible to make the circuitry any simpler - it's the minimum number of elements that are required to do the processing. That's the beauty of nature, it comes up with the most simple and elegant ways of dealing with and processing information," he said.

To find the most effective sound pattern, the scientists digitally manipulated the natural pulse patterns and played the various patterns to female crickets mounted atop a trackball inside an acoustic chamber containing precisely located speakers.

If a particular rhythm of pulses triggered the female to set off in the direction of that speaker, the trackball recorded reaction times and direction.

Once they had honed the pulse patterns, the team played them to female crickets in modified mini-chambers with opened-up heads and brains exposed for the experiments.

Microelectrodes allowed them to record the key auditory neurons ("it takes a couple of hours to find the right neuron in a cricket brain"), tag and dye them, and piece together the neural circuitry that reads rhythmic pulses occurring at intervals of few milliseconds in male cricket chirps.

Added Hedwig: "Through this series of experiments we have identified a delay mechanism within a neuronal circuit for auditory processing - something that was first hypothesised over 25 years ago. This time delay circuitry could be quite fundamental as an example for other types of neuronal processing in other, perhaps much larger, brains as well."

More information: An auditory feature detection circuit for sound pattern recognition, *Science Advances*, advances.sciencemag.org/content/1/8/e1500325

Provided by University of Cambridge

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