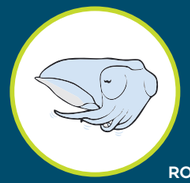
Sophie Cohen-Bodénès is a post-doctoral researcher in neuroscience at Washington University in Saint Louis. She received her PhD in cognitive neuroscience in France, at École Normale Supérieure, after completing a master in cognitive science. During her PhD studies, she studied cuttlefish behavior and discovered a previously undocumented communication signal in this animal: arm wave signs.

What the CUTTLEFISH Are Saying



I am an animal lover, genuinely interested in how animals feel and perceive the world. I have also always been curious about finding ways to connect with animals and understand what they want to convey. When I hear birds singing in a forest, I can't help wondering what they are saying. I am also very focused on animal welfare, especially in captivity. These interests led me to become a neuroscientist with a focus on how the information animals receive via their senses influences their behavior.

Cuttlefish are marine animals, cousins of octopus and squids, and are invertebrates. They do not have a spine like fish do, but their intelligence is comparable to that of mammals! To explain what makes them so special, I like to describe cuttlefish as abstract painters. A cuttlefish can dynamically transform the color of its skin and adjust its contrast to blend into rocky terrain, disappear into sand, and more.

Originally, the function of these patterns was for camouflage; then, over the course of evolution, these shapes and colors acquired a second function: expressing emotions and moods. The cuttlefish turns completely black when displeased or afraid, displays elegant zebra-like stripes to attract mates, or displays alternating waves of black-and-white contrast to hypnotize prey. When a cuttlefish seeks to repel or frighten, it sends the message to stay away by making two small black spots appear symmetrically on either side of its mantle. These visual signs thus constitute the alphabet of its own communication repertoire. To determine which array of forms to deploy, its complex visual system extracts environmental details like textures, contrasts, sizes, and contours. They have a very sophisticated camera eye, an example of convergent evolution between invertebrates and vertebrates.

This visual information is sent to its central nervous system, located in the optic lobe, forming a communication circuit with its motoneurons, which send signals to the pigment cells of the skin. These chromatophores—true paint-tubes of black, yellow, or white—can be activated or inhibited depending on the signals they receive from the motoneurons. An activation signal stretches the chromatophores, releasing colored pigments, whereas an inhibition signal contracts them. Hence, the cuttlefish displays a neural network visible to the naked eye. Its mantle forms a 2D flat surface that computational scientists can compare to a pixel screen. Cuttlefish pixel art comprises a palette of white squares, triangles, reticulation creating black spots on a bright orange background, spiny textures, and fifty other components that they can combine.

In neuroscience, people use cuttlefish as animal models to understand how their visual system works. At first, we also used cuttlefish to investigate vision, but after spending time with them, I got more generally interested in them; I wanted to study their behavior to improve their wellbeing, and to understand what they say to each other, and possibly to me. That's how my investigation started.

I was observing one of my beautiful males, and suddenly he displayed a very unusual movement of his arm that I had never seen before (the "up" sign). I had a strong intuition that this movement was not random and that the animal was trying to communicate something. But what? So, I started to document those signs each time I spotted one and try to understand in which context they would do it. I identified four different types of arm wave signs and performed experiments to attempt to demonstrate that they are used as communication displays.

We are still investigating what exactly the signs mean. They could be used as aversive displays or for courtship. Correlating the signs with the colors on the skin used for communication could provide more clues. For instance, cuttlefish will sometimes appear orange in color, black sport and sign with the wave sign crown at the same time. But other times they will do the wave sign up and display beautiful stripes on their skin.

Cuttlefish have an organ we do not have: the lateral line. Only fish and amphibians have one. It is like an ear on the skin. They can sense vibration in the water. We hypothesize that the arm wave signs could produce specific water waves perceived through the lateral line. Hence, the lateral line could be a perceptual modality cuttlefish use to communicate. They communicate multimodally with visual signals and postures, and spit ink to send chemical signals. We showed that they use arm wave signs to communicate, and we provided the first proof that they can also potentially produce vibration in the water to communicate.

My advice for students interested in careers in neuropathology is simple: anyone can be an animal behavioralist if they have genuine passion, empathy, and curiosity for animals. Jane Goodall, the absolute role model for ethologists, was brave enough to go alone to Africa and immerse herself in the wild with chimpanzees. She did not make her discovery right away. Thanks to her human qualities of empathy, patience, and respect for animals, she managed after months of perseverance to be accepted among the chimps and continued observing them. Observation is key, but animals need to feel that we respect them, approach them with softness and respect (for example, when we handle them), and do not treat them as experimental subjects.

Jane Goodall spread the message that everyone can make a difference. I believe that everyone has their own way of seeing the world and can participate in building knowledge about animal behavior. Hence my advice is for students to draw on their human qualities: keep being curious and open-minded, do not come with preconceived assumptions or reductionist ideas about what animals can or cannot do, and be driven by a passion to treat animals as equals.

Graphics depicting cuttlefish signs are courtesy of *Scientific American*.