First images of dolphin brain circuitry hint at how they sense sound

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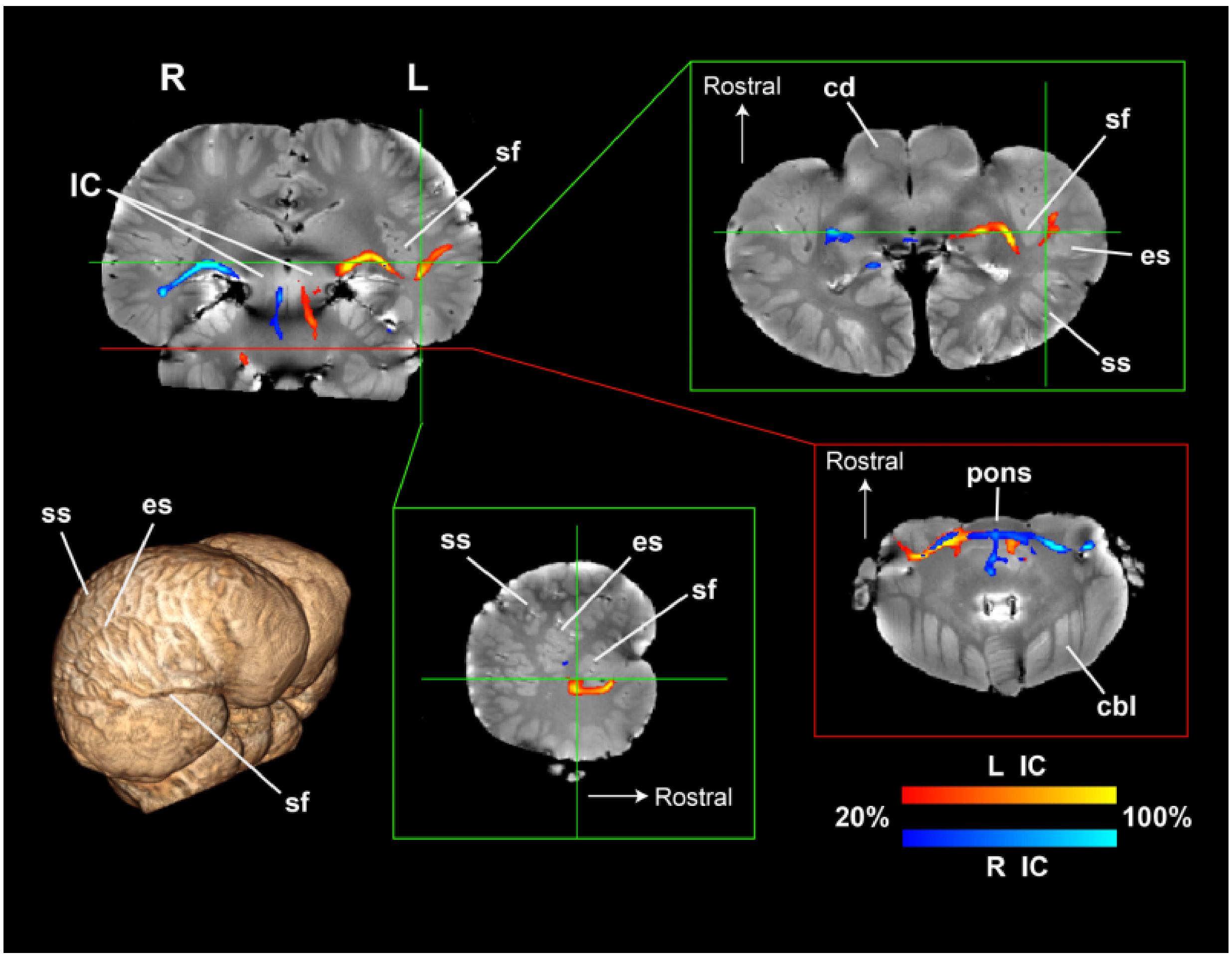

Probabilistic tractography in a dolphin brain was revealed used a novel technique of diffusion tensor imaging (DTI). Credit: Image via Gregory Berns, Emory University

Neuroscientists have for the first time mapped the sensory and motor systems in the brains of dolphins. *Proceedings of the Royal Society B* is publishing the results, showing that at least two areas of the dolphin brain are associated with the auditory system, unlike most mammals that primarily process sound in a single area.

"Dolphins are incredibly intelligent, social animals and yet very little is known about how their brains function, so they have remained relatively mysterious," says Gregory Berns, a neuroscientist at Emory University and lead author of the study. "We now have the first picture of the entire dolphin brain and all of the white matter connections inside of it."

The researchers applied a novel technique of diffusion tensor imaging (DTI) on the preserved brains of two dolphins who died after stranding on a beach in North Carolina more than a decade ago. The method for using DTI on a non-living brain was developed relatively recently and had previously only been used for research on deceased humans, primates and rats.

The study focused on the dolphin auditory system, since dolphins - along with several other animals, such as bats - use echolocation to sense their environments. "We found that there are probably multiple areas in the dolphin brain associated with auditory information, and the neural pathways look similar to those of a bat," Berns says. "This is surprising because dolphins and bats are far apart on the evolutionary tree. They diverged tens of millions of years ago but their brains may have evolved similar mechanisms for using sound not just to hear, but to also create mental images."

"For decades, we've thought of the dolphin brain as having one primary auditory region," says co-author Lori Marino, a neuroscientist specializing in the brains of dolphins, whales and other cetaceans. "This research shows that the dolphin brain is even more complex than we realized."

Formerly on the faculty at Emory, Marino is currently the executive director of the Kimmela Center for Animal Advocacy in Utah.

Emory houses a number of preserved cetacean brains collected by Marino, via colleagues at the University of North Carolina, Wilmington, from stranding events. Various environmental agencies respond when dolphins and whales are beached, in an effort to save the animals and return them to the sea. If the animals die, parts of them may be preserved for use in scientific research.

The current study used the brains of a common dolphin and a pantropical dolphin from the Emory collection.

Previous investigations using magnetic resonance imaging (MRI) have revealed the complex anatomy of cetacean brains. But MRI scans only capture images of the brain's basic structure.

DTI focuses on the brain's white matter, or the fiber pathways that connect neurons and different regions of the brain's gray matter. DTI can detect the movement of water molecules along these fiber tracks.

The researchers used a special DTI technique for post-mortem brains developed by study co-authors Sean Foxley, Saad Jbabdi and Karla Miller at the University of Oxford.

In a living, human brain, a DTI scan takes about 20 minutes. Scanning a post-mortem brain takes much longer, however, since they contain less water. The dolphin brains posed a particular challenge since they are large - about the size of footballs - and had been preserved for years. They retained only small amounts of the water normally found in healthy tissue.

"The signal was very weak, but it was there," Berns says. "Each of the specimens required nearly 12 hours of scanning."

The data from the DTI scans allowed the researchers to map out the white matter pathways, essentially the wiring diagram for the dolphin brain, in high detail. The results show that the dolphin auditory nerve enters the brain stem region and connects both to the temporal lobe (the auditory region of many terrestrial mammals) and to another part of the brain near the apex known as the primary visual region.

The researchers hypothesize that dolphins have more than one neural area associated with sound because they are using sound for different purposes.

Dolphins emit clicks, squawks, whistles and burst-pulse sounds to communicate, navigate and hunt. Echolocation allows them to perceive objects by bouncing sound off surfaces.

"Dolphins are the most sophisticated users of biological sonar in the animal kingdom," Marino says. "They can find fish hidden from sight in sand with ease."

Experiments have shown that dolphins can echolocate on a hidden, complex 3-D shape and then pick out that shape by sight. "They can rapidly move back and forth between their senses of sight and sound," Marino says.

One dolphin's echolocation signals and echoes may be picked up by another dolphin, she adds. "They have a complex communication system and a unique ability to emit different types of sounds, like a click and a whistle, simultaneously."

The researchers hope that their map of dolphin neural circuitry will help unlock secrets of the dolphin mind, including how they communicate and perceive their environment.

"Our study was the first to use this DTI technique on a dolphin brain, and on a specimen that was more than a decade old," Berns says. "Our success opens up the possibility of using this tool to study the archived brains of all sorts of amazing animals in museum collections around the world."

More information: Diffusion tensor imaging of dolphin brains reveals direct auditory pathway to temporal lobe, rspb.royalsocietypublishing.or … .1098/rspb.2015.1203

Provided by Emory University

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