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New findings in split-brain science: Even minimal fiber connections can unify consciousness

In findings that raise a variety of questions about how our brains work, and even about the nature of consciousness, UC Santa Barbara researchers and collaborators report that only a small section of intact corpus callosum — the bundle of nerves that connect the left and right hemispheres of the brain — can be enough to sustain full integration of the two halves of the brain. The discovery challenges decades of assumptions about split-brain function and offers a new framework for understanding neural resilience, with potential implications for epilepsy surgery, brain injury recovery and future models of consciousness.

“The corpus callosum consists of about 250 million axons, but you need only a small bundle of them to have full synchrony,” said Michael Miller, a professor in UCSB’s Department of Psychological & Brain Sciences. The corpus callosum relays signals and integrates information between the hemispheres that unifies perceptions, coordinates movements, and enables many complex behaviors that create a unified conscious experience.

The effects of a completely severed corpus callosum can be observed in split-brain patients — people who have undergone a callosotomy to reduce the effects of intractable epilepsy. The conventional assumption has been that these effects would be present in degrees that correspond to the level of disconnection of the corpus callosum, however, the researchers found that patients who had incomplete callosotomies were able to function as well as neurotypical, healthy subjects.

Their results are published in the Proceedings of the National Academy of Sciences (PNAS).

The corpus callosum, cognition and consciousness

If you quickly present an object to a split-brain patient’s left visual field, which travels to the right hemisphere only, the patient will know what the object is but they won’t be able to vocalize what it is. This is just one of the disconnection effects that were discovered in split-brain patients in the 1960s, through a series of groundbreaking experiments conducted by Caltech neuroscientist Roger Sperry and his then-graduate student, Michael Gazzaniga (now a UCSB distinguished professor emeritus of psychological and brain sciences, and a senior author in the PNAS study).

“What Mike discovered back in the 60s was that you can lateralize things to split-brain patients which led to the discovery of this disconnection syndrome,” said Miller, who studied under Gazzaniga. These experiments were built on the principle of contralateral control — the left hemisphere controls the right side of the body while the right hemisphere controls the left side. Meanwhile, specific cognitive functions are mapped to certain areas of the brain, and the corpus callosum is what synchronizes information and function across the two hemispheres.

“For example, if you ask a patient to close their eyes and you place a comb in their right hand, the left hemisphere can feel the object in the hand and tell you what it is,” Miller said. “However, if you take that same object and you put it in the left hand, the right hemisphere can sense it — it knows it’s a comb — but won’t say anything, because it’s mute.” Speech is controlled in the left hemisphere, but, unable to convey sensory information to that side for language processing because of the severed connection, the patient is unable to say they are holding a comb. The speaking left hemisphere is completely unaware of what the left hand is holding.

“But if you tell the patient to just use what’s in their left hand, they’ll take that comb and run it through their hair,” Miller said.

Over the last half-century, callosotomies have become quite rare, though they remain a surgery of last resort for severe epilepsy in a few parts of the world. Meanwhile, the rise of network neuroscience, enabled by fMRI scans, has made it possible to see which parts of the brain are active during tasks and how they synchronize with one another, leading to better models of how the brain works.

However, the brains of split-brain patients still have much to offer to our effort to understand the human brain. So, when Miller was contacted a few years ago by University of Cologne neurologist Lukas Volz to study a small group of callosotomy patients, he, lead author Tyler Santander and the rest of his team leapt at the chance.

“For the first time we could take these adult patients and put them in a scanner and really closely examine their network brain activity,” he said.

“What was really unique about this particular study was that we had one patient whose surgeon had intended to cut the whole corpus callosum, but he had to stop short of cutting it fully because one of the arteries in the area was becoming congested, and that was dangerous for the patient,” Miller explained. “So, the surgeon left about a centimeter of fibers in the posterior section.”

When they scanned this patient, they were expecting results along the lines of what they had seen with “full split-brain” patients, but with a little cross-hemispheric function.

“We thought he may have some ability to synchronize visual perception, but we thought there would be a lot of disconnection,” he said. “But we were really surprised there wasn’t any. Then we looked at his brain activity using several methods and, sure enough, his brain looked like a normal brain, fully synchronized.”

The researchers hypothesize that in the six years between his surgery and the current study, the patient’s brain essentially reorganized itself and the network connections that were thought to have been severed permanently were rerouted. The team uncovered evidence of some “unusual routing” of networks that moved from the front of the brain to the back, Miller said, possibly crossing over on that small ribbon of intact corpus callosum.

These results, according to the paper, “challenge classical models of callosal organization and function, which posit specific defects depending on which portions of the corpus callosum were severed.” The results also challenge the widely held notion that areas of the brain that are tightly synchronized must also be directly connected to each other.

“What this suggests is that that relationship is more adaptable than what we previously thought — those areas don’t necessarily need to be wired together in order to be functionally connected,” Miller explained. “The brain itself can find other ways and other routes perhaps through a number of different connections to synchronize together. And that’s a real advancement in our understanding of network neuroscience and how it works.”

These findings may also advance concepts of consciousness. The corpus callosum helps to create an experience of a unified consciousness by synchronizing sensory, motor and cognitive processes; one theory posits that consciousness arises from integrating information in the posterior sections of the brain.

“This could be direct evidence that you don’t need the whole corpus callosum; you just need that critical section in the back of the brain to be connected in order to have that unified consciousness experience,” he said.

Miller and his team have a lot more exploration in this realm to look forward to, more questions to ask and, hopefully, answers. For instance, would this ability to reorganize and reconnect the two hemispheres be possible if the corpus callosum was severed in the back but not the front? Is unified consciousness an all-or-nothing deal? Are there a certain, critical number of connected fibers necessary to create a unified consciousness experience?

“We are also interested in doing longitudinal studies of these patients to get what their brain activity looks like over time after surgery. We’ve actually started on some of those experiments now,” said Miller, who suspects that the reorganization happens in the first year after surgery. “And so we want to track and follow that.”

Research in this study was also conducted by Selin Beker, Jessica M. Simonson, Henri Etel Skinner and Barry Giesbrecht at UCSB; Theresa Paul and Valerie M. Wiemer at University of Cologne; Johanna Hopf, Anna Rada, Friedrich G. Woermann, Thilo Kalbhenn and Christian Bien at Bethel Epilepsy Center in Bielefeld, Germany; and Olaf Sporns at Indiana University.

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