Neural connections mapped with unprecedented detail

July 4 2016

A team of neuroscientists at the Champalimaud Centre for the Unknown, in Lisbon, has been able to map single neural connections over long distances in the brain. "These are the first measurements of neural inputs between local circuits and faraway sites", says Leopoldo Petreanu, who led the research. In doing so, Petreanu and co-authors Nicolás Morgenstern and Jacques Bourg have also discovered that the wiring of the brain is more complex than previously thought. Their results have been published in the journal *Nature Neuroscience*.

"We want to understand the structure of the brain, but the wiring diagram we have of the brain is still very rough", says Petreanu. "Except at the local level, we don't know how individual axons [the fibers projected by neurons] connect."

Thanks to a novel technique involving neural stimulation with laser light developed at their lab, the scientists were able to track the activity of individual axons, in the mouse brain, between a brain structure called the thalamus and the part of the visual cortex which receives, by way of the thalamus, the visual stimuli from the retinas.

The visual cortex is structured in layers. One of them, called L4, is in fact the point of entry of most of the visual input into the cortex, and contains small groups of neurons that are highly and bidirectionally interconnected. It has been proposed that they may act as amplifiers of certain features of the visual signal—enhancing the edges of objects in the outside world, for instance. But how this is achieved, and how they interact with remote inputs from the brain to integrate visual information is not known.

Now, Petreanu and his team have found something that might give credit to this hypothesis: the fact that if two neurons in L4 are interconnected, an axon projecting from the thalamus to one of those neurons will "bifurcate" in order to also connect to the other. This means that these interconnected neurons receive the same input from the thalamus and are constantly signaling back and forth between them. Such a mechanism could generate an amplifying effect in these small neural circuits, according to Petreanu.

There's more: once the incoming visual inputs travel along axons from cells in the thalamus to cells in L4 (where some processing has already taken place), they are then transmitted unidirectionally, for higher level processing, to another layer, called L2/3. Thus, the common view today is that "visual processing is a serial process across layers", says Petreanu.But that's not what the scientist now saw. In fact, they discovered that when two neurons were connected across these layers, an axon projecting from the thalamus to the neuron in L4 also "bifurcated" and connected, independently, to the neuron in L2/3.

"That's our main finding", says Petreanu. The existence of these connections that "skip a layer" ensures that L2/3 not only receives processed visual inputs from L4, but also "raw data" from the thalamus ."This might allow L2/3 cells to become very specialized in the detection of visual features", he explains. "Neural simulations on computers have shown that if you want an artificial neural network to be good at recognizing faces, you better have a layered structure and connections that 'skip a layer' ". The same may be true of the brain.

"This changes the way we understand how the brain receives information", concludes Petreanu. And the same mechanism may be at work for other sensory inputs. The team now wants to determine if similar connection structures exist between different areas of the visual cortex.

More information: Multilaminar networks of cortical neurons integrate common inputs from sensory thalamus, *Nature Neuroscience*, DOI: 10.1038/nn.4339

Provided by JLM&A, SA