The thalamus, middleman of the brain, becomes a sensory conductor

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Two new studies show that the thalamus--the small central brain structure often characterized as a mere pit-stop for sensory information on its way to the cortex--is heavily involved in sensory processing, and is an important conductor of the brain's complex orchestra.

Published in *Nature Neuroscience* and the Proceedings of the National Academy of Sciences, the two studies from the laboratory of Murray Sherman both demonstrate the important role of the thalamus in shaping what humans see, hear and feel.

"The thalamus really hasn't been a part of people's thinking of how cortex functions," said Sherman, professor and chairman of neurobiology at the University of Chicago Medical Center. "It's viewed as a way to get information to cortex in the first place and then its role is done. But the hope is these kinds of demonstrations will start putting the thalamus on the map."

When light hits the retina of the eye, that information makes a stopover in the thalamus before being sent to the visual cortex of the brain to be processed. Similarly, auditory and somatosensory (touch) information is routed through the thalamus before traveling to cortex for more complex processing.

One set of experiments, conducted by Brian Theyel and Daniel Llano in Sherman's laboratory and published online Sunday December 6 in Nature Neuroscience, used a novel imaging technique to demonstrate how the thalamus remains a part of the conversation even after that initial "relay."

The flavoprotein autofluorescence imaging technique, developed with University of Chicago assistant professor of neurobiology Naoum Issa, allowed the researchers to observe neuronal activity in a specially-prepared mouse brain slice that preserved connections between thalamus and somatosensory cortex.

Once sensory information reaches the cortex, it is thought to remain segregated there as it moves from primary cortex to secondary cortex and higher-order areas. But when Theyel severed the direct connection between primary and secondary cortical regions, stimulating primary somatosensory cortex still activated secondary cortex as well as the thalamus (see video), suggesting a robust pathway from cortex to thalamus and back. Only when the thalamus itself is interrupted does the activation of secondary cortex fail.

The observation that at least a portion of sensory information passes back through the thalamus on its travels between cortical areas refutes the notion of the thalamus as a passive, one-time relay station, Theyel and Sherman said.

"The ultimate reality is that without thalamus, the cortex is useless, it's not receiving any information in the first place," said Theyel, a postdoctoral researcher. "And if this other information-bearing pathway is really critical, it's involved in higher-order cortical functioning as well."

The somatosensory pathway finding demonstrates for the first time that this corticothalamocortical loop, which is also present in the auditory and visual systems, significantly activates cortex. Keeping the thalamus "in the loop" may help the brain coordinate sensory information with motor systems to direct attention or coordinate multiple cortical areas to accomplish different tasks, Sherman said.

"The thalamus is a remarkable bottleneck," Sherman said. "But that may be because as a bottleneck, it provides a convenient way to control the flow of information. It is a very strategically organized structure."

In the PNAS paper, published online Monday, December 7, postdoctoral researcher Charles Lee mapped two auditory pathways entering different parts of the thalamus to see whether they carried the same or different information.

Lee recorded from neurons in different areas of the thalamus while stimulating different areas of the inferior colliculus, another brain region of the auditory pathway. When the central nucleus of the inferior colliculus was stimulated it excited an area in the thalamus known to project to primary auditory cortex, suggesting that this is the direct route for auditory information through the brain.

By contrast, stimulating the surrounding "shell" region of the inferior colliculus provokes a different response, sending a mixed combination of excitatory and inhibitory input to a different region of the thalamus in contact with higher-order cortex.

"These are two parallel streams serving different functions," Lee said. "The thalamus is also the central hub for transferring information between cortical areas. Rather than carrying information, this second pathway winds up modulating information being sent between cortical areas."

Both papers newly characterize the complexity of the thalamus and its role in shaping sensory information both before and after that information reaches higher cortical regions - not a crossroads, but a conductor.

"These experiments not only give you a new way of looking at how cortex functions, but also answers a question about what most of thalamus is doing," Sherman said. "People who study how the cortex functions now have to take the thalamus into account. This can't be ignored."

Source: University of Chicago Medical Center

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