Looking vs. Seeing

September 16 2008

The superior colliculus has long been thought of as a rapid orienting center of the brain that allows the eyes and head to turn swiftly either toward or away from the sights and sounds in our environment. Now a team of scientists at the Salk Institute for Biological Studies has shown that the superior colliculus does more than send out motor control commands to eye and neck muscles.

Two complementary studies, both led by Richard Krauzlis, Ph.D., an associate professor in the Systems Neurobiology Laboratory at the Salk Institute, have revealed that the superior colliculus performs supervisory functions in addition to the motor control it has long been known for. The results are published in the Aug. 6 and Sept. 17 issues of the *Journal of Neuroscience*.

"Beyond its classic role in motor control, the primate superior colliculus signals to other brain areas the location of behaviorally relevant visual objects by providing a 'neural pointer' to these objects," says Krauzlis.

The superior colliculus is currently under renewed scrutiny because recent findings have suggested that it does more than help orient the head and eyes toward something seen or heard. Results hinted that the superior colliculus might play a role in analyzing the current environment and deciding whether one specific aspect is worth paying closer attention to than another. Definitive proof, however, has been lacking.

The Salk scientists adopted a more "naturalistic" approach in their experiments to understand this role of the superior colliculus. Historically, physiological studies of eye movement control have relied on individual spots of light representing visual targets, but the real world is much more complex than a single dot on a computer screen. "For example, we can smoothly track a large airplane, with all its intricate visual details, by directing our gaze at its center," explains Ziad Hafed, Ph.D., Sloan-Swartz Fellow in the Systems Neurobiology Laboratory and lead author on both studies. "At night, we might only be able to see the strobe lights on the wing tips, but we are still able to track the object's invisible center."

Hafed designed a series of experiments where the subjects had to infer the invisible center of a visual target consisting of two peripheral features — much like the above airplane's strobe lights in the night sky — and track it for several seconds (www.cnl.salk.edu/~zhafed/tracking.mov) or fixate on a stationary dot while the peripheral features were moving back and forth (www.cnl.salk.edu/~zhafed/fixation.mov). (The green crosshair indicates the subject's eye position.)

For one study, the Salk researchers recorded the activity of single neurons in the superior colliculus while the subjects either fixated on the stationary dot or tracked the invisible center of the moving object. "The SC contains a topographic map of the visual space around us just as conventional maps mirror geographical areas," explains Hafed. "This allowed us to record either from peripheral neurons, representing one of the 'wing tips,' or central neurons, representing the foveal location of the invisible center that was tracked," he adds. (The fovea, which is responsible for sharp, central vision, is located in the center of the macular region of the retina, while peripheral vision occurs outside the center of our gaze.)

Surprisingly, the central neurons were the most active during this tracking behavior, despite the lack of a visual stimulus in the center of gaze. "These neurons highlighted the behavioral importance of the location of the invisible center, because it is this location that was the most important for the subjects to successfully track the object," says Krauzlis (www.cnl.salk.edu/~zhafed/rostral_neuron_track.mov). When the subjects ignored the invisible center, the same neurons were significantly less active (www.cnl.salk.edu/~zhafed/rostral_neuron_fix.mov).

As part of the second study, the Salk researchers, in collaboration with Laurent Goffart, Ph.D., a professor at the Institut de Neurosciences Cognitives de la Méditerranée in Marseille, France, temporarily inactivated a subset of superior colliculus neurons and analyzed the resulting changes in tracking performance. While the subjects still tracked well, their gaze consistently and predictably shifted away from the center, demonstrating clearly that the superior colliculus is essential for defining the object location (www.cnl.salk.edu/~zhafed/sample_inactivation.mov).

"By showing that the SC is not just a motor map, but also a map of behaviorally relevant object locations, our results provide a conceptual framework for understanding the role of the SC in non-motor functions such as visual attention and the functional links between motor control and sensory processing," says Hafed.
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Source: Salk Institute for Biological Studies