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Eye-Movement Study Shows Glimpse of How Brain Plans Movement

Researchers are getting closer to understanding how the brain is able to hold a moving image on the retina, yielding smooth, relatively stable images of the moving object. Howard Hughes Medical Institute (HHMI) researchers have discovered that a region of the brain that was formerly believed to control eye movement is actually involved in the high-level planning of movement.

Their findings offer new insight into how the area in the brain's motor cortex adjusts eye movement to track objects, say the researchers. And their experimental approach—which involves measuring and altering via electrical stimulation the tiny eye movements by which rhesus monkeys track a spot of light—provides a precise, quantitative approach to studying the basic mechanism by which the brain plans muscle movement.

HHMI investigator [Stephen G. Lisberger](#) and colleague Masaki Tanaka, both at the University of California, San Francisco, reported the results of eye-movement studies in an article published in the January 11, 2001, issue of the journal *Nature*.

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- Stephen G. Lisberger

Their experiments were designed to find out whether the frontal pursuit area (FPA) of the motor cortex is involved in "gain control" of the tiny eye

movements that animals use to adjust how their gaze to track moving objects.

"Gain control—that is, changing how large the response is to a given stimulus—is fundamentally important to all motor control," said Lisberger. "It's part of the brain's feedback system that people use every day. For example, when you take a shower, you stick your hand in the stream of water to determine the temperature and adjust the controls back and forth until it's just right. Without a gain-control system, you'd make the same adjustments back and forth, oscillating from hot to cold. You'd never achieve 'just right.'"

Even walking would be impossible without gain control, said Lisberger, because muscles normally react to stretching by contracting. The brain compensates for this natural tendency by adjusting gain control of muscle contraction to allow the legs to take steps without activating a reflexive contraction.

"In smooth pursuit eye movement, the visual system's objective is to get the eye moving at the speed of a target," said Lisberger. "And the eye does this by sensing how fast a target is moving across the retina and trying to correct its tracking speed so eventually the eye is moving at the same speed as the target."

In their experiments to study how gain control fits into this smooth-pursuit system, Lisberger and Tanaka trained rhesus monkeys to fix their gaze on a spot of light, whether stationary or moving, in return for a juice reward. One characteristic of gain control in this arrangement, said Lisberger, is that briefly perturbing a stationary spot during eye fixation causes tiny eye movements, whereas the same perturbation of a moving spot when the eye is actively pursuing the spot causes larger eye movements.

Lisberger and Tanaka sought to pinpoint the regions of the brain responsible for gain control by using hair-thin electrodes to stimulate different regions of the monkeys' brains, in an attempt to alter this normal gain control as the animals' gaze fixed on the target.

They knew that the FPA was involved in gain control when they discovered that stimulating the FPA when the monkeys' gaze was fixed on a stationary spot produced the larger eye movements that are characteristic of the eye adjusting to a moving target that is being perturbed.

"Neurobiologists have traditionally thought of the frontal cortex as being involved in planning and decision-making, but the frontal pursuit area—which is part of the more primitive primary motor cortex—is also the place that represents the movement that will be made," said Lisberger. "This finding changes the way we think about the frontal pursuit area, taking it out of the realm of controlling movement and putting it into the realm of motor planning." More broadly, said Lisberger, the experimental approach he and Tanaka used opens the way to new studies to understand the basic strategy by

which the brain plans movement.

"With this approach, the frontal pursuit area can become an exemplar area for studying motor planning," said Lisberger. "We now have a way of controlling the plan that the system is making, by using electrical stimulation to adjust gain. And eye movement is a precisely quantifiable, reproducible measurement." Using such a quantifiable phenomenon method will allow precise understanding of neural processes that are now only generally defined, he emphasized.

"It is one thing to use general descriptive terms like 'planning,' 'perception,' or 'attention,'" said Lisberger. "But the real scientific challenge is to define those terms rigorously and quantitatively. Eye-movement studies provide a way to achieve that definition."

According to Lisberger, the ultimate goal of his research is to understand how the brain completes a single action, all the way from sensing the external events of the world to programming precise muscular contractions.