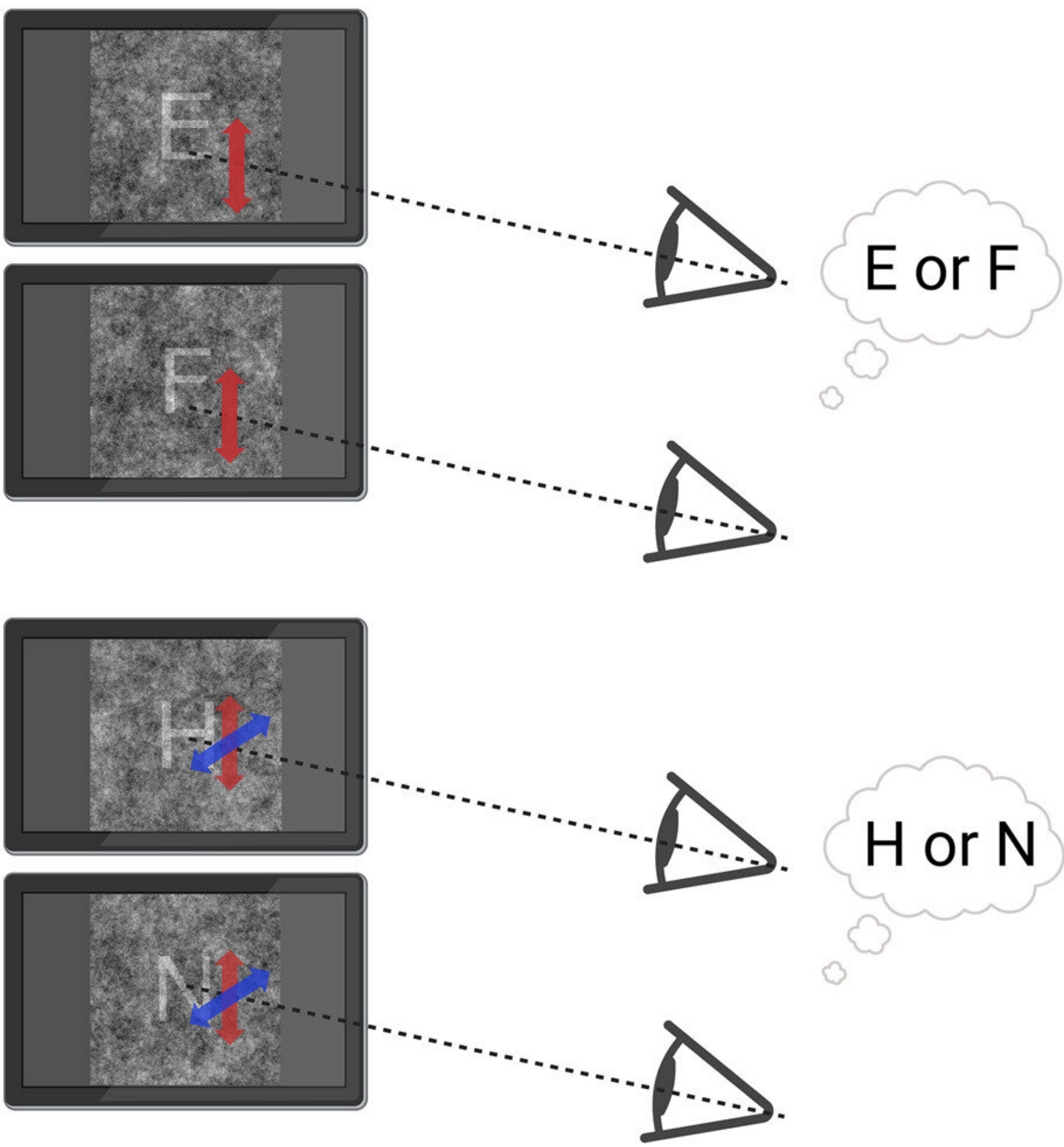
Tiny eye movements are under a surprising degree of cognitive control

April 3 2023



Graphical abstract. Credit: *Current Biology* (2023). DOI: 10.1016/j.cub.2023.03.026

A very subtle and seemingly random type of eye movement called ocular drift can be influenced by prior knowledge of the expected visual target, suggesting a surprising level of cognitive control over the eyes, according to a study led by Weill Cornell Medicine neuroscientists.

The discovery, described in *Current Biology*, adds to the scientific understanding of how vision—far from being a mere absorption of incoming signals from the retina—is controlled and directed by cognitive processes.

"These eye movements are so tiny that we're not even conscious of them, and yet our brains somehow can use the knowledge of the visual task to control them," says study lead author Dr. Yen-Chu Lin, who carried out the work as a Fred Plum Fellow in Systems Neurology and Neuroscience in the Feil Family Brain and Mind Research Institute at Weill Cornell Medicine.

Dr. Lin works in the laboratory of study senior author Dr. Jonathan Victor, the Fred Plum Professor of Neurology at Weill Cornell Medicine.

The study involved a close collaboration with the laboratory of Dr. Michele Rucci, professor of brain and cognitive sciences and neuroscience at the University of Rochester.

Neuroscientists have known for decades that information stored in memory can strongly shape the processing of sensory inputs, including the streams of visual data coming from the eyes. In other words, what we see is influenced by what we expect to see or the requirements of the task at hand.

Most studies of cognitive control over eye movement have covered more obvious movements, such as the "saccade" movements in which the eyes dart across large parts of the visual field. In the new study, Drs. Lin and Victor and their colleagues examined ocular drift, tiny jitters of the eye that occur even when gaze seems fixed.

Ocular drifts are subtle motions that shift a visual target on the retina by distances on the order of a fraction of a millimeter or so—across just a few dozen photoreceptors (cones). They are thought to improve detection of small, stationary details in a visual scene by scanning across them, effectively converting spatial details into trains of visual signals in time.

Prior studies had suggested that ocular drift and other small-scale "fixational eye movements" are under cognitive control only in a broad sense—for example, slowing when scanning across more finely detailed scenes. In the new study, the researchers found evidence for a more precise type of control.

Using sensitive equipment in Dr. Rucci's laboratory, the researchers recorded ocular drifts in six volunteers who were asked to identify which of a pair of letters (H vs. N, or E vs. F) was being shown to them on a background of random visual noise. Based on computational modeling, the scientists expected that optimal eye movements for discriminating between letters would cross the key elements distinguishing the letters at right angles.

Thus, they hypothesized that a more precise cognitive control, if it existed, would tend to direct ocular drift in both vertical and oblique (lower left to upper right) directions for the H vs. N discrimination, compared to more strictly vertical movements for the E vs. F discrimination.

They found that the subjects' eye movements did indeed tend to follow these patterns—even in the 20 percent of trials in which the subjects, though expecting to see a letter, were shown only noise. The latter result showed that the cognitive control of ocular drift could be driven solely by specific prior knowledge of the visual task, independently of any incoming visual information.

"These results underscore the interrelationship between the sensory and the motor parts of vision—one really can't view them separately," said Dr. Victor, who is also a professor of neuroscience in the Feil Family Brain and Mind Research Institute at Weill Cornell.

He noted that the direction of fine eye movements is thought to come from neurons in the brainstem, whereas the task knowledge presumably resides in the upper brain: the cortex—implying some kind of non-conscious connection between them.

"The subjects are aware of the tasks they have to do, yet they don't know that their eyes are executing these tiny movements, even when you tell them," Dr. Victor said.

Studies of this pathway, he added, could lead to better insights not only into the neuroscience of vision, but possibly also visual disorders—which traditionally have been seen as disorders of the retina or sensory processing within the brain.

"What our findings suggest is that visual disorders may sometimes have a motor component too, since optimal vision depends on the brain's ability to execute these very tiny movements," Dr. Victor said.

More information: Yen-Chu Lin et al, Cognitive influences on fixational eye movements, *Current Biology* (2023). DOI: 10.1016/j.cub.2023.03.026

Provided by Weill Cornell Medical College