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A Flash of Insight into Visual Processing

Howard Hughes Medical Institute scientists at The Salk Institute have discovered a new class of optical illusion that they have studied in detail to show that humans use both the timing and spatial context of a visual stimulus to judge brightness.

The researchers said the discovery of the illusion, which they call the “temporal context effect,” suggests that the human brain has separate, parallel circuitry to process brightness. One circuit pathway adapts to a stimulus that is constant in intensity, while the other assigns a brightness to an object and does not adapt, they said. The researchers said their findings offer an experimental approach for teasing out new information about how the brain processes information about an object's brightness.

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The researchers, led by Howard Hughes Medical Institute investigator Terrence J. Sejnowski, published their findings in the April 15, 2004, issue of the journal *Nature*. Sejnowski and his colleagues at The Salk Institute for Biological Studies collaborated on the studies with researchers from the University of Texas and the University of California, San Diego.

According to Sejnowski, previous work in the field, some of which was done in his laboratory, had concentrated on the influence of the spatial context in people's judgment of the brightness of an object. Prior to the new studies it was known, for example, that a flash of brief duration looks dimmer than a physically identical flash of longer duration when the two flashes started at the same time.

“No one had ever compared a brief and a long flash that ended at the same time, so it wasn't clear which would be brighter,” Sejnowski said. “The question is how the brain integrates flash intensity and duration to produce a brightness, which is the perception of intensity.”

In their experiments, the researchers presented subjects with two flashes of light—one brief and one long. They asked the subjects to report on which

flash appeared brighter. When both short and long flashes began at the same time, the subjects in the study reported that the brief flash looked dimmer. But when the flashes ended at the same time, the brief flash looked brighter, according to the subjects.

“It’s a very dramatic percept, in the sense that you don’t have to average a lot of trials to see the effect,” said Sejnowski. “You see it on the first try, which means it’s a big effect and not a small one.

“And that immediately tells you that there’s something funny going on, because how could it be that just moving the timing of the short flash relative to the long one influences your judgment of the brightness? There must be something odd going on having to do with the representation of the long one.”

In additional experiments with various arrangements of flashes and variations in the long flash, the researchers confirmed that it was specifically the brightness of the brief flash that subjects were perceiving as changing with temporal context—rather than some change in perception of the long flash.

The researchers found that the effect was due to higher visual processing in the brain and not at the level of the retina or initial visual processing. They confirmed this by presenting the brief flash to one eye and the long flash to the other. Subjects still reported seeing the effect. This information suggested that the effect must occur in the primary visual cortex or later, beyond where binocular information from the two eyes converges in processing, said Sejnowski. Also, the researchers performed experiments indicating that the effect was not due to shifts in the subjects’ attention from one flash to another.

“These findings will help us to understand more about the cortical representation of brightness,” said Sejnowski. “It’s known that many neurons in the cortex respond vigorously at the onset of a stimulus and then adapt down to a lower rate of firing. One possible explanation is that somewhere in the circuitry there is a trace of the original absolute representation of intensity despite the fact that the firing rates of the neurons are adapting.

“People are still very sensitive to whether a stimulus is changing up or down. So, you have to come up with some explanation in which there are two different channels involved—one channel that gives you the percept of a stimulus that does not change in brightness and another channel that adapts to a constant stimulus. And somehow, the brief stimulus is compared with the adapting channel. Our experiments are able to probe those two channels.”

Sejnowski and his colleagues will next turn their human studies to exploring more complex patterns of stimuli to delve deeper into the phenomenon of the temporal context effect. He said that experimental neurophysiologists in other laboratories would begin electrophysiological studies to attempt to trace neuronal circuitry to distinguish the two processing pathways.

In general, said Sejnowski, these kinds of studies will bring a new understanding of the role of time-dependence on visual processing in the brain. "I think we know the least about how time is represented in the visual system," he said. "How does our impression of the world change when we're making comparisons in time as well as in space? Studying the perception of moving objects can't distinguish the two kinds of effects, since the objects are moving in both time and space. However, our experiments enable us to sort out the differences in processing in space and in time," he said.