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Selective Vision: The Brain's Spin Machine Starts Early

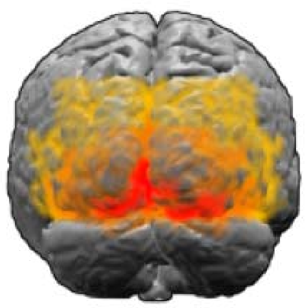
Welcome to

Mind Matters

Sciam.com's "seminar blog" on the sciences of mind and brain. Each week, top researchers in neuroscience, psycholo gy, and psychiatry explain and discuss the research driving their fields. Readers can join them. We hope you will.

This week we look at

Selective Vision



The primary visual cortex (shown here in red) was long thought to passively record unfiltered information from the eyes. New findings suggests it's not quite so simple.

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Introduction

by David Dobbs, Editor, *Mind Matters*

It's hardly news that our hopes and expectations shape our interpretation of what we see around us -- that we see, as the old saying goes, what we want to see, or at least what we expect to see. As a psychological dynamic, this spin on perception goes a t least as far back as Shakespeare, who urged, "Let every eye negotiate for itself." Freud stressed the notion that our minds shape our p erceptions to accommodate our fantasies and fears.

Now a new finding suggests that the brain's coloring of the eye's bounty begins at one of the earliest stages of v isual processing -- the instant that the retinal signals first flash onto the back of the brain. As Susana Martinez-Conde describes below, this ne w study, "Reward Timing in the Primary Visual Cortex" (from *Science*, 17 March 2006), suggests that the brain begins the vital business of interpretation at a stage of visual processing long thought to be more bucket than filter. The implications run the gamut from perception to addiction .

Anticipating Reward: More Than Meets the Eye

by Susana Martinez-Conde

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My grade school in Spain had a color-coded system for test scores: "A" was red; "B" was blue; "C" was green and "F " was brown. So the color distribution in your academic chart indicated at a glance how well you were doing in your various classes. One result of this system was that red and brown became, respectively, my favorite and least favorite colors as a child.

This story is one of many examples of how a fundamentally neutral visual stimulus (the color red) may become associated to a reward value (a high score). From this lesson it is easy to predict that neurons in the brain's reward processing system may be activated by the physical properties of certain sensory stimuli that are associated with rewards -- that my brain's reward centers, in other words, would react to red.

Far less intuitive, however, is a dynamic just discovered in the remarkable paper reviewed here: that visual neurons in the brain's primary visual cortex -- long thought to conduct purely sensory, value-free visual information -- can also modulate their response as a function of expected reward. In a clever study that sharply revises the view of the fundamentals of how we see, Marshall Shuler and Mark Bear show that visual neurons once considered to be mere feature detectors are affected by complex cognitive influences such as reward expectancy. Even at the most fundamental level, it seems, our expectations influence how and even what we see.

A brain hierarchy of visual areas?

Our experience of vision is constructed, step-by-step, by neurons in different areas of the brain. Visual brain areas are traditionally thought of as a hierarchy of processing stages, dealing with increasingly complex aspects of our perception. Thus neurons in the primary visual cortex are chiefly concerned with very simple stimuli attributes, such as contour and contrast. Neurons in "higher" visual areas, meanwhile, respond to more complex stimuli, such as hands and faces. And neurons in "association areas" of the cortex integrate visual information with information from other sensory modalities and with cognitive processes such as attention, motivation or expectations.

Shuler and Bear challenge this traditional view by showing that neural activity in the brain's primary visual cortex predicts with high accuracy the expected timing of rewards associated with simple visual stimuli. Shuler and Bear implanted rats with microelectrodes that recorded the activity of neurons in the primary visual cortex, then fitted the animals with head-mounted goggles that could deliver flashes of light to either eye. They programmed the goggles to deliver a flash of light to either the left or right eye as the rats approached a water tube. When the flash was presented, the animals had to lick the water tube to obtain their reward: a drop of water. If the left eye was stimulated, water could be obtained more quickly: the rats needed to lick the water tube half as many times as when the right eye was stimulated. Thus the experimenters paired left-eye stimulation with a short reward waiting time and right-eye stimulation with a long reward waiting time. As an experimental control, half the trials were unrewarded. This control allowed the researchers to know whether the neural activity recorded after a flash might be related to the expectancy of the reward (which would occur whether the reward was actually delivered or not) or to the reward delivery itself.

In inexperienced animals, all neuronal responses recorded were related to encoding the visual stimulus's physical properties, such as the onset of the flash, its duration or which eye it flashed in. That is, at first the neurons responded to the stimulus but did not respond to the reward or its timing. This result matched the classical conception of the primary visual cortex as a region that serves solely as a detector of visual features.

A Smarter Sort of Primary Processing

However, once the rodents became familiar with the task, Shuler and Bear discovered that the animals' primary visual cortical neurons responded to both the physical stimulus and the reward. Neuronal responses generated by flashes to the two eyes developed distinctive and consistent new differences. Those generated by flashes to the left eye predicted short reward waiting times, whereas responses to right-eye stimulation predicted long reward waiting times. Irrespective of which eye was stimulated, the reward-correlated response timing was startlingly accurate, as if the neurons in the primary visual cortex had somehow become important to processing the expectancy of the visually predicted reward.

Moreover, because this neural activity also occurred in unrewarded trials once the animals were conditioned, Shuler and Bear showed that the reward-correlated activity was truly linked to the animal's expectancy of the reward's timing rather than to obtaining the reward per se. This result suggests that the primary visual cortex may be able to learn cognitive processes previously relegated to higher association areas such as the prefrontal cortex. Those neurons in the primary visual cortex are pretty smart after all.

In a subsequent experiment, Shuler and Bear asked whether the results obtained were constrained to the specific situation in which the animals were rewarded for performing the task, or whether they might generalize to other situations in which the reward was not accessible. This question is of great interest. If the reward-response effect persisted when a reward was no longer available to the animal, it would indicate that primary visual cortex circuits can give rise to long-lasting high-level cognitive associations.

To explore this possibility, Shuler and Bear compared neuronal activity in "within-task" versus "outside-task" recording sessions, in which the water tube was obstructed and no water reward was available. When the tube was obstructed, the rats in general did not bother to approach it. Yet the previously trained primary visual cortical neurons continued to show reward-timing activity in response to the visual stimulation. This finding suggested that the alterations in neuronal responses produced by pairing a visual stimulus with a reward persist and generalize to a variety of contexts.

Hopes Spring Eternal -- and Early

The implications of these discoveries are multi-faceted. First, these findings challenge the traditional belief that the primary visual cortex is strictly a visual area concerned with low-level analyses of stimuli features. Second, they demonstrate that neurons in the primary visual cortex of adult animals retain an unexpected degree of plasticity, with long-term effects.

But as a vision scientist, I find especially intriguing a third aspect of this work. Reward expectation is a major driving force in our behavior: we tend to repeat actions that promise reward and avoid actions that promise no reward. Shuler and Bear have now shown that reward expectation also plays a major role not just in shaping behavior, but also in shaping the perceptual responses of neurons at the very early stages of visual processing. It is tempting to speculate that our basic visual perception may be influenced by cognitive factors, such as reward or attentional load, at its most fundamental level. It would be very exciting to see follow-up studies addressing how the expectancy of reward may distort or bias perception or even create reward-based visual illusions.

This finding could prove highly important for our understanding of everyday decision making as well as our understanding of impairments affecting the brain's reward pathway, such as drug dependencies and other types of addictive behaviors.

Susan Martinez-Conde is the director of the Barrow Neurological Institute's Laboratory of Visual Neuroscience, where she studies, the neural code and dynamics of visual perception.

Posted by David Dobbs · 2 comments