

Everyday Life; Language; Top-Down and Bottom-Up Processing

Further Readings

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EYE MOVEMENTS DURING FIXATION

As you read this, your eyes are rapidly flicking from left to right in small hops, bringing each word sequentially into focus. When you stare at an object, your eyes will similarly dart here and there, resting momentarily at one place on the object, and then moving to another. But these large eye movements, called saccades (see color insert, Figure 25a), turn out to be just a small part of the daily workout your eye muscles are getting. Your eyes *never* stop moving, even when they are apparently settled, say, on a person's nose or a sailboat bobbing on the horizon. When the eyes fixate on something, as they do for 80% of your waking hours, they still jump and jiggle imperceptibly in ways that turn out to be essential for seeing. The tiny eye motions that you produce whenever you fixate your gaze are called fixational eye movements (see color insert, Figure 25b). If you could somehow halt these miniature motions while fixating your gaze, a static scene would simply fade from view. This entry discusses neural adaptation, visual fading, and microsaccades,

Neural Adaptation and Visual Fading

That the eyes move constantly has been known for centuries. In 1860, Hermann von Helmholtz pointed out that keeping one's eyes motionless

was a difficult proposition and suggested that “wandering of the gaze” prevented the retina from becoming tired.

Animal nervous systems may have evolved to detect changes in the environment because spotting differences promotes survival. Motion in the visual field may indicate that a predator is approaching or that prey is escaping. Such changes prompt visual neurons to respond with neural impulses. Unchanging objects do not generally pose a threat, so animal brains—and visual systems,—did not evolve to notice them. Frogs are an extreme case because they produce no spontaneous eye movements in the absence of head movements. For a resting frog, such lack of eye movements results in the visual fading of all stationary objects. Jerome Lettvin and colleagues stated that a frog “will starve to death surrounded by food if it is not moving” (1968; p. 234). Thus, a fly sitting still on the wall will be invisible to a resting frog, but once the fly is aloft, the frog will immediately detect it and capture it with its tongue.

Frogs cannot see unmoving objects because an unchanging stimulus leads to *neural adaptation*. That is, under constant stimulation, visual neurons adjust their gain so they gradually stop responding. Neural adaptation saves energy but also limits sensory perception. Human neurons also adapt to sameness. However, the human visual system does much better than a frog's at detecting unmoving objects because human eyes create their own motion, even during visual fixation. Fixational eye movements shift the visual scene across the retina, prodding visual neurons into action and counteracting neural adaptation. Thus, eye movements prevent stationary objects from fading away.

In 1804, Ignaz Paul Vital Troxler reported that precisely fixating your gaze on an object of interest causes stationary images in the surrounding region gradually to fade away. Thus, even a small reduction in the rate and size of your eye movements greatly impairs your vision, even outside of the laboratory and for observers with healthy eyes and brains (see color insert, Figure 25c).

Eliminating *all* eye movements, however, can only be achieved in a laboratory. In the early 1950s, some research teams achieved this stilling effect by mounting a tiny slide projector onto a contact lens and affixing the lens to a person's eye

with a suction device. In this set up, a person views the projected image through this lens, which moves with the eye. Using such a retinal stabilization technique, the image shifts every time the eye shifts. Thus, it remains still with respect to the eye, causing the visual neurons to adapt and the image to fade away. Nowadays, researchers create this same result by measuring eye movements with a camera pointed at the eye. The cameras transmit the eye-position data to a projection system that moves the image with the eye, thereby stabilizing the image on the retina.

Around the same time, researchers characterized three different types of fixational eye movements. *Microsaccades* are small, involuntary saccades that are produced when the subjects attempt to fixate their gaze on a visual target. They are the largest and fastest of the fixational eye movements, carrying an image across dozens to several hundreds of photoreceptors. *Drifts* are slow meandering motions that occur between the fast, linear microsaccades. *Tremor* is a tiny, fast oscillation superimposed on drifts. Tremor is the smallest type of fixational eye movement, its motion no bigger than the size of one photo-receptor.

Microsaccades in Visual Physiology, Perception, and Cognition

Since the late 1990s, fixational eye movement research has focused on microsaccades. Physiological experiments found that microsaccades increase the firing of neurons in the visual cortex and lateral geniculate nucleus by moving the images of stationary stimuli in and out of neuronal receptive fields. Perceptual experiments showed that the visual fading phenomenon described by Troxler is caused by the reduction of microsaccades that occurs during precise fixation.

Recent studies have shown that microsaccade rates are modulated by attentional shifts. Microsaccade directions may also be biased toward the spatial location of surreptitiously attended targets.

Fewer studies have addressed the neural and perceptual consequences of drifts and tremor. However, all fixational eye movements are likely to contribute significantly to visual perception. Their

relative contributions may depend on stimulation conditions. For example, receptive fields near the fovea may be so small that drifts and tremor can maintain vision in the absence of microsaccades. Receptive fields in the periphery may be so large that only microsaccades are large and fast enough, compared with drifts and tremor, to prevent visual fading, especially with low-contrast stimuli. But it is also possible that if drifts and tremor could be eliminated altogether, microsaccades alone could suffice to sustain central vision during fixation.

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See also Eye and Limb Tracking; Eye Movements: Physiological; Vision; Vision: Temporal Factors; Visual Illusions; Visual Processing: Primary Visual Cortex; Visual Processing: Retinal; Visual Processing: Subcortical Mechanisms for Gaze Control

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