Microsaccades

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What are they? Saccades are the rapid, jerky eye movements that we use to scan the world around us. They are necessary because high-resolution vision is only possible with the high density of photoreceptors near the center of the retina. Microsaccades resemble regular saccades in most respects except that they are tiny and occur even when we are attempting to fixate the eyes on a particular location. For this reason, they are often referred to as 'fixational saccades'.

How small is 'micro'? During fixation humans typically make saccades smaller than 15 minutes of arc. To see how small this is, hold this magazine at arm's length and try to look first at the leftmost and then at the rightmost part of this W.

When do we make them? Essentially, our eyes never stay still; we normally scan our environment with about two to three large saccades every second, and even when we think we are fixating a single location, our eyes move. During fixation three kinds of eye movements occur. The first is a rapid, but very small tremor. The second is a slow movement of the eye that is often called drift. The third is the microsaccade, which happens about two or three times per second. Typically, we are not aware of any of these eye movements.

Some microsaccades bring the eye back after it has drifted away from the fixation location. But many microsaccades also take the eye away from the desired fixation location. In other words, microsaccades do not always correct for drift.

Subjects can make microsaccades to visual targets, and learn to make fewer microsaccades during fixation, so there is some level of voluntary, conscious control. Both the rate and amplitude of microsaccades is affected by the locus of attention, but also the presentation of an irrelevant visual stimulus, or even a sound. This suggests that they — just like large saccades — are part of the active sensing machinery that the brain uses to probe its visual environment.

Why do we make them? The debate about the usefulness of microsaccades has been heated at times, but many of the discrepancies disappear once one rephrases the question 'are microsaccades useful?' into 'what is the smallest saccade that is useful for a given purpose?'

There are two well-understood reasons to make eye movements. The first is to bring an object of interest onto the fovea such that the object can be inspected with the large number of cone photoreceptors that give us color vision and high spatial resolution.

Consistent with such a role, humans indeed make more microsaccades when they are performing a task that requires high visual acuity — like threading a needle. The benefit of making any saccade, however, is obviously reduced when the fovea is already near the point of interest. Moreover, humans are not able to bring the exact same spot onto the object of interest every time (our precision for doing this ranges from two to five minutes of arc). Hence, microsaccades smaller than this are unlikely to be useful as a way to bring the target onto a better spot on the retina.

The second reason to make eye movements is to prevent fading. Neurons respond vigorously to changing visual input, but rapidly lose their responses when the input is constant. To prevent this, the eyes move continuously and thereby turn a static visual scene into a rapidly changing visual input. Saccades can play a role in this. Microsaccades smaller than about 20 minutes of arc, however, are unlikely to have an important role in this given that there are so many other sources of motion — for instance slow drifts of the eye, but even motion of the whole head — that are of sufficient speed and size to prevent fading.

How do they affect neural activity? Every microsaccade moves the visual image over the photoreceptors in the retina. In many brain parts this evokes a small suppression of neural activity followed by a larger increase. This suggests that neural activity representing the visual scene may arrive in relatively synchronous volleys of high activity immediately after a microsaccade. This leads to the speculative idea that one role for microsaccades may be to serve a series of snapshots of the visual scene to the visual cortex for analysis.

Why don't we see them? Because microsaccades move the visual scene over the retina, they generate a lot of visual motion. Even though each microsaccade creates only a small displacement, they would be large enough for us to notice if they were caused by real motion in the visual scene. Therefore, one might wonder why we do not perceive that motion all the time. This phenomenon is called saccadic suppression, the topic of another recent quick guide (Krekelberg, 2010).

Where in the brain are they generated? The superior colliculus, in the midbrain, contains a map that is used to direct the eyes to particular locations in the visual field. Neurons near the top of the map (the rostral pole) represent the current fixation location; whenever the subject fixates, activity of these neurons is high. Before a saccade, activity starts to build up at a different location in the map, and this triggers the eye movement to the new location. Once the subject fixates the new location, the peak of activity is back at the rostral pole.

An elegant theory of microsaccade generation is that they occur when the activity at the rostral pole is disturbed. This can be the consequence of neuronal noise, which could move the peak of activity to a slightly different location in the map and thereby evoke a microsaccade; or of some visual or auditory input that changes activity elsewhere on the map; this activity may not be strong enough to induce a real saccade to that point, but it can induce a slight change in the activity near the rostral pole, which would then evoke a microsaccade.

Where can I find out more?

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