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# Eye Movements

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Eye movements are a necessary component of human visual function because of the variation in acuity across the retina, and humans direct gaze so that locations of interest fall on the high acuity foveal region.

Consequently, a person's direction of gaze typically reveals what they are attending to. Knowing the location and timing of gaze therefore allows measurement of visual and cognitive processes on a finer time scale than verbal report. Because eye movements are tightly linked to shifts in attention, they have been a rich source of information about visual and cognitive mechanisms. Improvements in eye tracking technology have recently allowed a much broader range of experimental contexts to be examined, making it an important tool in cognitive science.

## History

The study of eye movements has been tightly linked to the development of devices that can accurately record eye position. The eye is a very powerful optical system, which means that a very small rotation of the eye—say a shift of gaze direction from one word to the next when reading—corresponds to a displacement of the iris of about 0.3 mm. Given that it is hard to keep the head perfectly still, the measurement problem becomes apparent. Initially, eye tracking devices, developed beginning in the early 1900s, were therefore either uncomfortable (such as magnetic search coils embedded in a contact lens) or inaccurate (such as the electrooculogram; see [Wade & Tatler, 2005](#) for a more detailed history). This constraint also meant that early eye tracking studies went to great lengths to stabilize the head, which limited the kinds of experiments that could be performed because even a simple reaching movement involves postural adjustments.

Over the last 30 years, the development of head-mounted eye trackers has allowed increasingly accurate measurement of gaze location (the location in space where the fovea is directed) in a wide variety of circumstances. An image of a subject wearing a magnetic search coil eye tracker and a more recent image of a child wearing a Pupil Labs Neon tracker is shown in [Figure 1](#). This technical improvement has meant that a broader range of questions can now be addressed, such as gaze and attentional control in the context of natural behavior such as walking and cooking and how infants or special populations use gaze [see [Attention](#)].



**Figure 1**

A subject wearing a magnetic search coil eye tracker in the 1980s (left) and a Pupil Labs Neon eye tracker in 2025 (right).

## Core concepts

In perception and cognition, the most frequently studied eye movements are high velocity *saccadic* eye movements that shift the eye to a new location of interest. This is the primary information-gathering eye movement type, and the period when the eye is stationary is called a *fixation*. The typical duration of a fixation is 200 to 300 ms, but shorter and longer fixations are common. During these brief gaze shifts, the image is blurred because of the high velocity of the movement, and the visual system suppresses perception of this information (called *saccadic suppression*). Consequently, fixations define the periods when visual information is being collected.

An important development in the study of eye movements was the discovery that the activity of neurons in the saccadic eye movement circuitry was influenced by the dopaminergic reward systems ([Kawagoe et al., 1998](#); [Platt & Glimcher, 1999](#)). This means that eye movements, like other actions, should be thought of as the

outcome of decisions that involve costs and benefits, which are encoded by the dopaminergic machinery [see [Neuroeconomics](#)]. This feature of the oculomotor system allows cognitive control of gaze location, as behavior is typically driven by behavioral goals.

Although much of the early work on saccadic eye movements implicitly assumed that the driver of an eye movement was a visual stimulus, it is clear that cognitive goals are critically important and drive both location and timing of gaze. Thus, when making tea, gaze is tightly linked to the actions performed, fixating on the tap to fill the kettle, the teapot spout to pour the tea, and so on. Indeed, in activities like this, there are almost no fixations that are not relevant to the task ([Land et al., 1999](#)). It is this feature that makes eye movements a rich source of information about cognitive mechanisms. For example, the timing and location of eye movements can reveal prediction or whether information is present in visual working memory ([Hayhoe, 2017](#)). However, if the current cognitive operation is not demanding, it may not matter very much where gaze falls, so it is important to understand the limits on the information about cognitive processes that gaze can reveal.

## Questions, controversies, and new developments

Although it is generally accepted that gaze location can be driven either by salient properties of the visual stimulus (bottom-up) or by cognitive goals (top-down) ([Kümmerer & Bethge, 2023](#)), there is no real consensus on their relative importance or the circumstances when one or the other factor is in control. Much of the work that focuses on bottom-up salience (such as high contrast) investigates stimuli presented on computer monitors, which differ in many ways from the real world. For example, such stimuli represent natural scenes in a smaller magnification, are projected onto the two-dimensional plane of the monitor, and differ in light intensity distributions. In addition, the cognitive goals in experiments on image saliency are often either undefined or narrowly defined. The issue of how such experiments might generalize to the real, three-dimensional world remains an important unresolved issue.

The increased ease of eye tracking in mobile subjects, together with increased awareness of the context dependence of neural activity in a variety of species ([Krakauer et al., 2017](#); [Miller et al., 2022](#); [Parker et al., 2020](#); [Urai et al., 2022](#)), has led to renewed interest in measuring eye movements in the context of more natural behavior. This measurement is technically more challenging when neural recordings are involved, but behavioral work has allowed collection of combined eye, body, and three-dimensional image data reconstructed using computer vision algorithms. An example can be seen in the following video: [https://youtu.be/TzrA\\_iEtj1s](https://youtu.be/TzrA_iEtj1s). The general question of how attention is controlled in natural environments remains relatively unexplored, however.

## Broader connections

Improved eye tracking has also made it possible to measure eye movements in young children and infants [see [Infant Perception](#)]. This allows collection of the statistics of early visual experience that shape perceptual development. The viewpoint of the adult is quite different from that of the young child ([Bambach et al., 2018](#)),

and this means that the statistics of early visual experience need to be measured in situ. For example, a recent study recorded the visual input of young infants and adults at home using head-mounted cameras ([Petroff et al., 2025](#)). Analysis of the statistical regularities in the visual input revealed that infants experience a preponderance of horizontal and vertical orientations, and this might underlie the greater sensitivity to these orientations observed in adults.

In addition to work in vision, eye tracking has proved useful in the field of language understanding in the case of the so-called *visual world paradigm*, in which fixations to the display are closely time locked to the utterance and have provided insights into all aspects of language processing ([Tanenhaus et al., 1995](#) and many subsequently). Other important applications are in the field of mental disorders such as autism, in which recent work tracking the eyes during toy play suggests a more nuanced understanding of attentional control in this population (e.g., [Yurkovic-Harding et al., 2022](#)) [see [Autism](#)].

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