Eye Tracking Research in Infants and Adults

Daniel C. Richardson (dcr@eyethink.org)
School of Psychology, Harry Pitt Building, University of Reading
Reading, Berkshire RG6 6AL UK

Scott P. Johnson (scott.johnson@ucla.edu)
Department of Psychology, Franz Hall, UCLA
Los Angeles, CA 90095 USA

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Introduction

Eye movements are arguably the most frequent of all human behaviors, and are the result of an intimate and constant interaction between cognitive and perceptual processes. They can provide insight into psychological processes such as language comprehension, memory, social cognition and decision making. The use of eye trackers by developmental psychologists, for example, has dramatically altered observational capacities, and made it possible to address questions which could not be examined previously and thus open up entirely new approaches and areas of inquiry.

Eye Tracking Research with Infants

Eye tracking studies with infants work best when the infant is engaged as fully as possible with the stimulus. Methods that involve frequent looks away from the stimulus, such as habituation paradigms, may not work well, though there are a few reports of successful eye tracking using such methods (Johnson, Slemmer, & Amso, 2004).

Implications of Eye Movements for Perceptual and Cognitive Development

In reaction time studies, infants' eye movements were recorded upon the onset of a new stimulus or the location where a stimulus was seen previously, to assess inhibition of return or spatial negative priming of the location. Longer reaction times to look at the new target location have been proposed to indicate effects of inhibition of the location, a location that was necessarily attended to covertly (Amso & Johnson, 2005). In oculomotor anticipation studies, infants are presented with stimuli in which an object repeatedly moves behind an occluder and re-emerges, to assess the extent to which the infant looks to the place of emergence. Consistent anticipations toward this location have been proposed to indicate a mental representation of the moving object despite occlusion, perhaps an early form of object permanence (Gredebäck & von Hofsten, 2004).

Eye movement patterns can also serve as an independent variable, as in studies that classify infants as "efficient" or "inefficient" in their scanning behaviors, and that analyze other experimental outcomes in light of this grouping variable. In one such study, infants were observed in a visual search task with displays consisting of a single target set amongst a large set of distracters (Amso & Johnson, 2006). Infants were also observed in a task designed to tap perception of the unity of a partly occluded object. Those infants who were more effective at target search also provided evidence of unity perception; those infants who were less proficient at target search tended not to perceive unity. These results imply a link between visual scanning behavior and early object perception skills.

Development of Oculomotor Behavior

Developmental psychologists have long been interested in developments in oculomotor behavior. Newborn infants scan the visual environment actively and their scanning patterns are principled and somewhat organized (Haith, 1980). However, there are limits in certain kinds of eye movement, such as smooth pursuit, that might reflect maturation of underlying neural mechanisms (Johnson, 1990). Little is known about infants' scanning behaviors in real world environments, and how developments in scanning patterns are related to other processes, though progress is being made in addressing these questions (e.g., Johnson, Davidow, Hall-Haro, & Frank, in press).

Eye Tracking Research with Adults

Spatial Attention And Scene Perception

Spatial attention and saccade planning are closely coupled during natural unconstrained eye movements, and are determined by two components (Henderson, 2003). Firstly, statistical properties of the image such as high spatial frequency and local contrast have been found to be closely correlated with fixation likelihood (Itti & Koch, 2000). Secondly, there are "top-down" influences from knowledge, memories, beliefs or goals that the viewer may bring to the image (Yarbus, 1965).

Reading

The general characteristics of eye movements during perception have been studied in great depth during the process of reading. In general, eye fixations during reading last approximately 200-250 milliseconds (Pollatsek, Rayner, & Collins, 1984) and saccades span on average about 7 to 9 letter spaces. Eye movements also vary as a function of the legibility of the text, syntactic difficulty and conceptual difficulty (for a review, see Rayner, 1998).

Language In A Visual And Social Context

Language use generally occurs within rich visual contexts, and the interplay between linguistic processes and visual perception is of increasing interest to psycholinguists and vision researchers (Henderson & Ferreira, 2004). For example, when facing a display containing a bag of candy, a candle, an envelope, and a spoon, and being instructed to "Pick up the candy," subjects occasionally look first at the candle (because of the overlap in the first few phonemes between "candy" and "candle") (Spivey, Tanenhaus, Eberhard, & Sedivy, 2002). This kind of real-time interaction between visual and linguistic processing is also seen during spoken language production (Griffin & Bock, 2000), and even natural unscripted conversation (Richardson, Dale & Kirkham, 2007).

Memory, Imagery, and Dreaming

Researchers have long been intrigued by the relationship between eye movements during a perceptual experience and the eye movements that occur when one remembers, imagines, or dreams about that experience. Early empirical investigations found that the frequency of eye movements increases during mental imagery, particularly that of a spatial nature (Clark, 1916); and an increase in rapid fluttering of the eyes while sleeping correlates with vividness of dreams (Antrobus & Antrobus, 1969). 'Scanpath theory' (Noton & Stark, 1971) holds that a picture is recognized partially by replaying the memory of this sequence of eye movements and visual stimulation and comparing it the present stimulus.

Conclusion

Eye movements are driven both by properties of the visual world and processes in a person's mind. Uniquely poised between perception and cognition, eye movements are an invaluable tool for psychologists. Compared to the single data point provided by a button-press reaction time, the eye movements of a subject can provide researchers with a rich, dynamic data source concerning the temporal dynamics and psychological processes that led up to the response. These properties are also of great value to designers and engineers, as they allow for detailed measurements of how a user is interacting with a device. Since the technology has become highly efficient, such information can now be fed back into devices in real time, and the movements of a user's eyes can be used to issue commands or tailor computational processes. Although such applications are currently in their infancy, this most frequent of all human behaviours could turn out to provide the most fluid and expressive interface between humans and computers.

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