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The SAGE Encyclopedia of Intellectual and Developmental Disorders

Eye Tracking

In the 1990s, the National Institutes of Health ushered in the "Decade of the Brain" to enhance public awareness of the benefits of brain research. This initiative included a number of programs aimed at introducing the public to cutting-edge research on the brain and encouraging dialogue about the implications of such research. The highest profile techniques included brain imaging methodologies that allowed for a visualization of the brain from within the organ, including structural and functional magnetic resonance imaging, near-infrared spectroscopy, and electroencephalography. Around the same time, although perhaps with less fanfare, commercially available eye tracking devices became available and made their way into the research literature as a complementary technique for understanding visual attention and, ultimately, brain mechanisms mediating visual attention. This entry examines eye tracking systems and their use and impact within the research of intellectual and developmental disorders.

Eye Tracking Systems

Modern eye tracking systems either are head-mounted (e.g., attached to a cap) or rest on a table in front of the research participant (either integrated with a display monitor or a stand-alone table-top version).

Most quantify gaze by measuring the distance between the moving pupil and a stationary reflection on the cornea created by a harmless infrared light emitted from the eye tracker. Eye tracking data are collected at rapid rates of at least 60 hertz (Hz), although faster acquisition rates (> 250 Hz) allow researchers to address a wider range of research questions, including smooth pursuit, fast eye saccades, and pupil dilation. Typically, eye tracking is used in research to measure visual attention while viewing static or dynamic images presented on a computer monitor, but it can also be used to address attentional shifting, both spontaneously and in the context of instructions to inhibit attention shifts. Variations of so-called cuing paradigms, pioneered by psychologist Michael Posner, involve the presentation of a cue on one side of the visual field followed by a target that appears either at the location of the cue or on the opposite side of the cue. The latency and accuracy of attentional shifts to the target location quantifies visual orienting, whereas the capacity to inhibit shifts, or to shift to the opposite location of a cue (e.g., an antisaccade paradigm), indexes executive control of visual attention.

Questions That Eye Tracking Research Addresses

By providing an objective measure of gaze behavior, eye tracking has become a critical tool for investigating endophenotypes, or hereditary characteristics, related to the etiology of psychiatric and neurodevelopmental disorders. Eye tracking is also emerging as a potential treatment outcome measure in the context of clinical trials for such disorders. Eye tracking abnormal perceptual strategies in clinical populations can be used to evaluate disorder-specific pathophysiology, promote early identification of neurodevelopmental disorders, and inform treatment development. In the context of intellectual and developmental disorders research, eye tracking has become particularly useful given that it may be used with very young infants, it is noninvasive, acquisition is quick (i.e., some paradigms are as brief as 5 to 10 minutes in duration), children may sit in their caregivers' laps during data acquisition, and moderate amounts of motion may be tolerated.

Eye Tracking Studies in Autism Spectrum Disorder

A large proportion of clinical eye tracking research has been dedicated to studying autism spectrum disorder (ASD). A core symptom of ASD is impairments in social communication, and thus most eye tracking research in ASD has focused on gaze during social information processing, most typically while viewing still or dynamic images of faces or people. These paradigms allow researchers to investigate spontaneous attention to all or parts of social stimuli in infants as young as 6 months. Whereas typically developing infants show preferential attention to social information and tend to focus on the socially revealing features of the face, such as

the eyes rather than the mouth, children with ASD show deficits in social orienting and demonstrate impaired face recognition and impaired facial expression identification. Eye tracking thus offers an effective method for directly quantifying these differences in social visual attention and linking them to broader aspects of impaired social cognition and social functioning. Indeed, the first eye tracking studies in ASD found decreased social attention to the eye regions of faces using both static and dynamic stimuli, with reduced social attention predicting greater social impairment.

Eye tracking has also shown that very young children with ASD demonstrate decreased orienting to social stimuli, and atypical social orienting has been shown to predict decreased social competence in adolescents with ASD. For example, researchers Katarzyna Chawarska and colleagues investigated attention disengagement from faces in toddlers with ASD using a cued attention task. They found that toddlers with ASD disengaged from faces (but not non-faces) more quickly than typically developing or developmentally delayed toddlers, suggesting that faces do not retain attention to the same degree for toddlers with ASD. Similarly, researchers Frederick Shic and colleagues reported that, while viewing videos of adult–child play interactions, 20-month-old toddlers with ASD showed reduced visual attention to the heads and activities of others and focused more on background objects such as toys. Furthermore, this pattern of reduced social monitoring predicted cognitive deficits and greater ASD severity. Taken together, these findings have contributed to the emergence of theoretical frameworks seeking to explain the emergence of social impairments in ASD. Specifically, these frameworks posit that reduced social attention early in life in children with ASD limits the normative level of social experience needed for the typical development of social cognition and social communication skills.

Prospective Baby Sibling Eye Tracking Research in Autism Spectrum Disorder

Eye tracking has also proven to be a powerful research tool for studying infants who may go on to develop ASD. The most common approach to this type of research is an at-risk baby sibling design (so-called baby sibs research) wherein infants with older siblings with an ASD diagnosis are recruited when they are very young (e.g., 6 months old) and then are followed prospectively until the age when a reliable diagnosis of ASD may be made (typically 2 to 3 years old). At that point, the infant data are analyzed by comparing the at-risk infants who go on to develop ASD with those who do not develop ASD. Often, a third group is included, comprising children who do not go on to develop a formal ASD diagnosis but nevertheless have prominent delays and/or ASD symptoms. This baby sibs design is powerful because the recurrence risk of developing ASD (i.e., the risk of developing ASD if a sibling has ASD) ranges from nearly 20% to as high at 50% for later-born male children in multiplex families, which is far higher than the population prevalence of approximately 1.5%. Thus, baby sibs research allows for the collection of data from infants with an increased likelihood of being diagnosed with ASD.

One prospective longitudinal baby sibs study evaluated eye fixation in toddlers later diagnosed with ASD. Data from 110 infants were collected at 10 time points between 2 months and 2 years of age, with ASD diagnoses made at 3 years. The infants viewed videos of an adult female encouraging the child to engage in a game such as pat-a-cake. At 2 months of age, babies who went on to be diagnosed with ASD showed reduced attention to the eyes of the woman in the video. However, by 6 months of age, their attention to the eyes showed a steep decline. Substantively, this finding marks one of the earliest identified indicators of ASD risk and also suggests that eye looking may be intact during the first few months of life but is impaired by 6 months of age. This pattern may reflect the narrowing of a developmental window during which typical social development may be canalized and when intervention may be particularly beneficial. Methodologically, this study highlights the utility of eye tracking in research with young infants given the brevity and noninvasive nature of the assessment.

Eye Tracking in Other Neurodevelopmental Disorders

Although the majority of eye tracking research has been conducted in the context of ASD, eye tracking has also proved valuable in studies of various other intellectual and developmental disorders. Because eye tracking can be used without the need for verbal or complex motor demands on the part of the research participant and because most modern systems are largely tolerant of participant movement, this technology can be used with individuals who are younger, nonverbal, or have lower cognitive functioning. This flexibility has resulted in a variety of research and clinical uses of eye tracking with individuals with intellectual and developmental disorders, ranging from studies of social attention, functional communication, and cognitive processing.

For example, eye tracking has been used to explore social orienting in individuals with fragile X syndrome (FXS) during naturalistic face-to-face conversation. Researchers Scott Hall and colleagues found that individuals with FXS spent less time looking at their partner's face during a conversation than did matched controls. Additionally, gaze to the face of their partners was shorter in duration than that of controls. Within the FXS group, these effects were moderated by gender and communication ability such that females and individuals with greater communicative ability were likely to look at the face of their partner longer.

Eye tracking has also been used to develop more efficient and user-friendly augmentative and alternative communication (AAC) systems and displays, allowing individuals to use their eye gaze to manipulate and select visual stimuli for communicative purposes (e.g., Tobii Dynavox software). Individuals who use these communication devices vary greatly in their level of functioning. Eye tracking provides insight into an individual's capacity to understand and use a given AAC interface and can serve as a primary resource by which to communicate.

Additionally, eye tracking has proven fruitful in research addressing cognitive processing impairments in numerical calculations and reading and interpreting letters, words, and sentences. For example, eye tracking has been used to examine how gaze shifts during reading may be related to dyslexia or other reading disorders, and studies of specific learning disability have demonstrated that individuals with dyslexia typically make relatively shorter rapid eye movements between fixation points, or saccades, and have relatively increased regressive saccades. Additionally, researchers Korbinian Moeller and colleagues used eye tracking to demonstrate that individuals with developmental dyscalculia, characterized by difficulty with arithmetic calculations, had deficits not only in numerical calculations but also in basic number processing.

Future Directions

Most eye tracking research, and indeed most behavioral, cognitive, and translational neuroscience ASD research, has entailed passive engagement with standardized stimuli given the high level of control they afford. This ensures a certain degree of internal validity in that recording conditions are nearly identical for every research participant, as are the precise timing and visual angle of experimental stimuli. However, this internal validity comes at the cost of limited external validity: Social interactions in the real world are vastly more complex and unpredictable than in laboratory-based studies. This cost is particularly relevant for individuals with ASD because the social challenges they experience are most evident in naturalistic social interactions. Indeed, recent evidence indicates that social attention abnormalities in ASD are more sensitively detected when the ecological validity of the social stimuli increases, suggesting that insights derived from the study of social function from the passive viewing of static stimuli may have limited external validity.

For these reasons, a number of research groups have started to develop innovative methods to study ASD in interactive social contexts. For example, there has been excellent progress in the development of interactive gaze-contingent stimuli and dynamic stimuli to simulate social interactions. These types of interactive stimuli are part of an emerging area of "interactive social neuroscience" in that they involve either concurrently recording responses from two interacting people or they utilize dynamic stimuli that react to feedback from the research participant. These types of designs will help researchers to more fully understand dynamic gaze in

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the context of joint or shared attention, social enjoyment, social synchrony, and social decision making. Further, wearable, portable head-mounted eye trackers have recently been developed that allow for eye tracking data collection in real-world contexts, including at home and at school. What the participant sees, as well as gaze and pupilometry data, is stored for offline epoching, area of interest definitions, and analyses. This approach has the potential to address unanswered questions about how individuals with ASD gaze at the social world in ways that have been previously unaddressed.

Finally, despite the rich data eye tracking provides, it is but one method within an ever expanding toolbox of social neuroscience tools. New technologies are allowing for the integration of eye tracking with neuroimaging data collection to allow for simultaneous recording of gaze and brain activity. Similarly, eye trackers with high data acquisition rates allow for simultaneous eye tracking and electroencephalography data collection that enable millisecond precision in linking patterns of gaze behavior with analysis of event-related potential data. Ultimately, no single translational cognitive neuroscience tool will be capable of completely addressing mechanistic and etiologically relevant questions about neurodevelopmental disorders. Rather, only through merging different methods can a more complete understanding of neurodevelopmental disorders be achieved, which is ultimately the first step toward the rational development of etiologically relevant interventions.

See also Augmentative and Alternative Communication; Autism Spectrum Disorder; Siblings of Individuals With Developmental Disorders; Social Skills Deficits

Rachel K. Greene, Noah J. Sasson & Gabriel S. Dichter
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Further Readings

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