Preface

Stark and Sandberg (1961) reported the construction of a simple instrument to follow the movements of the eyes over 50 years ago. The instrument was designed to detect the difference in the light reflected from the sclera and the iris (Stark, Vossius, & Young, 1962). Over the past 50 decades, this simple instrument has evolved into machines and computers that can pinpoint the location of a subject’s gaze to the letter in 18-point font on a 21” inch monitor. The development in the technology, the data-gathering methods, and the understanding of the cognitive processes underlying eye movements have led to advances in human factors, reading psychology, neuropsychology, cognition, lie detection, and many other scientific endeavors. It is only in the past decade that the use of eye tracking technology has made its way into research in education. The editors of this volume have found our way into this arena from three different paths: Cognitive/Educational Psychology, Cognitive Development, and School Psychology. We have each seen the utility of this technology in research, but have also seen the potential of this technology to inform practice.

Advances in eye tracking technologies have led to several different apparatuses to measure eye movement. Early instruments of ocular motor recording required a great deal of control over subjects’ head movements. For example, the double-Purkinje-image (DPI) eye tracking system designed by Crane and Steele (1985) is based on capturing reflected infrared light that is projected on the eye. This system requires that the participants’ head remains still while ocular movement is recorded. This system is remarkably precise and still used in many research labs. More researchers are looking for ways to capture eye movements in more natural settings, or at least less restrictive environments, and thus laptop, head mounted, and eye wear systems have been developed to support this type of research. Our goal in the current text is not to provide a review of the applications of eye tracking systems and methodologies. Duchowski (2007) provides an excellent review of the eye tracking systems and methods available to that date and we recommend that text for those who would like a review of the systems available as although 10 years old, Duchowski’s review is thorough and provide as great overview of how eye tracking works.

Duchowski (2002) also presented a review of the neuroscientific, psychological, and human factors applications of eye tracking. However, with other such early reviews (e.g., Gedabach, Johnson, & von Hofston; Jacob & Kam, 2003; Wedel & Pieers (2009) the applications for education and educational research are not presented.
EYE TRACKING RESEARCH METHODOLOGIES

Recording eye movements allows researchers to collect an objective measure of visual attention (Hayhoe & Ballard, 2005). The basic unit of eye tracking measurement is the saccade, a rapid shift in visual attention between two points in the visual field (Duchowski, 2002; Zirnsak, & Moore, 2014). In general, saccades are directed towards areas that are interesting or important for completing a task. For example, when making a peanut butter and jelly sandwich, most eye movements were direct towards task-relevant items in the visual scene like the bread, knife, and ingredient jars (Land & Hayhoe, 2001). As described in the text, researchers make use of various types of visual responses to infer underlying cognitive processes related to the task at hand.

The simplest measure of visual attention is to count the number of times fixations are directed towards a specific area, known as fixation counts, which are often used to measure interest. This measure is particularly useful in experiments with infants and young children. For example, a recent study found that infants with more experience in racially-diverse contexts were less likely to develop an “own-race bias” compared to children raised in racially-homogeneous contexts (Gaither, Pauker, & Johnson, 2012). The researchers used fixation counts on pictures of adults from different races to measure interest in “own” or “other” races.

Another commonly used measure is the amount of time spent in the same area of visual attention, of fixation duration. This measure of sustained attention has been used as a proxy for interest, sometimes as the result of unexpected events (Rosander, & von Hofsten, 2004). A recent investigation used duration to measure infant attention to social information (i.e., the eyes of adult speakers) to investigate early indicators of Autism Spectrum Disorder (ASD; Jones & Klin, 2013). The results showed that children who were later diagnosed with ASD showed significant declines in the amount of time spent looking at eyes between 2 and 6 months of age, suggesting an early behavioral marker of ASD.

Linking the pattern of saccades allows researchers to follow the path of information pickup through a task, sometimes known as “process tracing” (Hayhoe & Ballard, 2005; Zentall & Morris, 2012). For example, in making a cup of tea, eye movements anticipate motor actions for each step of the process (Land, 2006). In a recent study, University students who successfully solved multiple-choice science exam questions were more likely to focus on relevant items while students who were unsuccessful were more likely to focus on irrelevant items while comparing options (Tsai, Hou, Lai, Liu, & Yang, 2012).

Pupil dilation is another measure that is often used and is associated with interest (Duchowski, 2002) and amount of mental activity (e.g., cognitive load; Wierda, van Rijn, Taatgen, & Martens, 2012). In infancy research, pupil dilation is being used more frequently because it seems resistant to order effects, unlike measures of fixation duration (Jackson, & Sirois, 2009). Because increases in dilation are associated with higher levels of mental effort, dilation is often used to measure cognitive load. For example, during the AB task, which requires attention across a series of distractors, dilation increased significantly as the time between stimuli and number of distractors increased (Wierda, van Rijn, Taatgen, & Martens, 2012).
Preface

EYE TRACKING AS A FUTURE TOOL FOR EDUCATIONAL RESEARCH AND PRACTICE

Eye tracking offers a great range of research opportunities within the field of education. First, the application and expansion of eye tracking within education permits researchers to decode notable characteristics of learners. Specifically, eye tracking allows researchers to identify how learners go about reading and understanding text, syntax, and other computational and/or problem-solving processes. Researchers, then, can better describe and evaluate difficulties that students experience, as well as levels of expertise based on aggregated data that compares novice and expert patterns. By comparing normative eye gaze patterns, researchers can help identify differences in the strategies of learners with various levels of expertise, knowledge, and skills. Armed with such information, researchers could identify meaningful information about the concrete learning processes that are difficult to detect and measures sing behavior response paradigms. With such information, researchers and developers could advance more precise strategies and tools to assess and assist learners of all idiosyncrasies. With the expanding use of eye tracking technology within applied settings, such a task is not too distant.

Second, data provided by basic eye tracking research can be used to advance the development of learning materials and teaching tools within education. For example, sophisticated uses of eye tracking devices and software could provide highly contextualized feedback to learners through the use of an automated tutor. Such automation would indicate that a student is having difficulties with the material (using automatic assessment of fixation and/or gaze—visual cueing); and, then, provide a hint or other form of remediation in order for the student to make progress. That is, if a student looks too long at a word or their gaze scans over the entire screen within focusing on any particular part, a prompt would appear to refocus the student on the content. Such tools become vital for assisting learners in an era when educational resources have been diminished.

Third, and perhaps most unique to educational research, eye tracking reveals valuable information among and within an increasingly diverse group of learners. Because eye tracking technologies enable the collection of data without an overt behavioral response, the possibility of evaluating performances in individuals who are difficult to assess using traditional measurement tools is enhanced. Barriers to traditional assessment, and to some extent intervention, include motor, language, behavioral challenges, learning difficulties, and neuropsychological impairments, among others. An individual who has learning difficulties, for instance, may have the cognitive ability to understand and solve tasks on traditional assessments, but may be unable to demonstrate that capability due to difficulty producing a reliable motor response in an allotted time and/or fatigue in responding over the course of an evaluation session. Similarly, individuals who demonstrate difficulty understanding oral instructions may perform poorly on traditional assessments, not because they are unable to engage in the cognitive demands necessary for the required task, but rather because they did not understand the task itself. Eye tracking research offers the potential to extend the scope of evaluations to populations of individuals at-risk for or diagnosed with a variety of educational disabilities.
ORGANIZATION OF THE BOOK

In this book, we have presented eye tracking as a method to enrich educational research. Specifically, we provide a context within this book to build upon the small, but growing, body of research on eye tracking in the context of education with hopes to enhance both future research and practice. This book is organized into a series of sections and 14 chapters.

In Chapter 1, Pedro Rodrigues of the Instituto Superior Manuel Teixeira and Pedro J. Rosa, of the Universidade Lusófona de Humanidades e Tecnologias and the Instituto Superior Manuel, Teixeira present a review of eye-tracking theory and methods that bridge the psychological literature and learning literature in the field of education.

Anne Cook and Wei Wei from the University of Utah present measures of eye movement in reading and the inferences that can be drawn about cognitive processes in Chapter 2. The authors provide insight into methodological considerations based on their research and that of others.

Chapter 3, authored by Shannon R. Zentall of the University of Akron, describes the relationship between physiological measures (i.e., eye tracking) and emotional responses in motivation contexts.

Section 2, “Eye Tracking and Language Comprehension,” presents two chapters that provide information about developmental and methodological issues related to eye tracking research in language comprehension. In Chapter 4, Jocelyn R. Folk and Michael A. Eskenazi of Kent State University discuss how eye movements in reading change across the lifespan, individual differences in eye movement behavior in lower-skill and higher-skill adult readers, and eye movement patterns in special populations. This chapter highlights what is known about changes in eye movement behaviors from developing readers to older adult readers.

Chapter 5, written by Elizabeth Kaplan, Tatyana Levari, and Jesse Snedeker of Harvard University, helps close the gap between psycholinguistic research and educational topics. The authors discuss how various eye-tracking paradigms have informed current theories of language comprehension across the processing stream, and how early linguistic experiences influence later educational outcomes all with a lens on the ways in which eye-tracking techniques can shed light on the language processing of children with developmental disorders.

Section 3, “Multimedia Learning,” comprises two chapters that present multimedia learning and literacy issues from an eye movement perspective. A discussion of how eye tracking informs the understanding of children’s interaction with literacy tools in computer mediated contexts is presented by Domenica De Pasquale and colleagues from Wilfrid Laurier University in Chapter 6. Chapter 7, written by Malinda Desjarlais from Mount Royal University, Canada continues the discussion of eye tracking measures in the context of multimedia learning and the interpretation of various eye movements in relationship to attention in learning contexts. This section closes with a summary of eye tracking research in multimedia learning written by Katharina Scheiter and Alexander Eitel of Leibniz-Institut für Wissensmedien.

Section 4 introduces eye tracking in mathematics learning. Shabila Shayan of Utrecht University and Dor Abrahamson of University of California – Berkeley, with Arthur Bakker Carolien A. C. G. and Marieke van der Schaaf, Utrecht University present an empirical study of attentional anchors in a math learning activity (Chapter 9) and Jennifer L. Cooper, Wesleyan University, Joseph E Michaelis, Martha W. Alibali, and Mitchell J. Nathan, University of Wisconsin – Madison, present a study of middle school students in which findings of an expertise reversal effect are discussed in the contexts of eye tracking, cognitive theory of multimedia learning and cognitive load theory (Chapter 10).
Preface

Two chapters that discuss visual spatial learning and cognition are presented in Section 5. Chapter 11 written by Linlin Luo, Kenneth A Kiewra, Markeya S Peteranetz, and Abraham E Flanigan from the University of Nebraska-Lincoln, discusses how eye tracking methods can be used to understand how students benefit from graphic organizers. In Chapter 12 Alina Nazareth of Temple University, with Rosalie Odean, and Shannon M Pruden, both from Florida International University, discuss the advantages of eye tracking technologies in spatial thinking research.

The book concludes with Section 6, “Special Populations.” Llorenç Andreu, Universitat Oberta de Catalunya, and Mònica Sanz-Torrent, Universitat de Barcelona, describe how eye tracking technologies are an effective tool for examining language processing in children with language disorders, in Chapter 13. We conclude with Chandi Parikh’s discussion of eye tracking technology as a method for identifying biomarkers in high-risk infants with siblings diagnosed with autism spectrum disorders.

REFERENCES


