Using E-Z Reader to examine the concurrent development of eye-movement control and reading skill

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ABSTRACT

Compared to skilled adult readers, children typically make more fixations that are longer in duration, shorter saccades, and more regressions, thus reading more slowly (Blythe & Joseph, 2011). Recent attempts to understand the reasons for these differences have discovered some similarities (e.g., children and adults target their saccades similarly; Joseph, Liversedge, Blythe, White, & Rayner, 2009) and some differences (e.g., children's fixation durations are more affected by lexical variables; Blythe, Liversedge, Joseph, White, & Rayner, 2009) that have yet to be explained. In this article, the E-Z Reader model of eye-movement control in reading (Reichle, 2011; Reichle, Pollatsek, Fisher, & Rayner, 1998) is used to simulate various eye-movement phenomena in adults vs. children in order to evaluate hypotheses about the concurrent development of reading skill and eye-movement behavior. These simulations suggest that the primary difference between children and adults is their rate of lexical processing, and that different rates of (post-lexical) language processing may also contribute to some phenomena (e.g., children's slower detection of semantic anomalies; Joseph et al., 2008). The theoretical implications of this hypothesis are discussed, including possible alternative accounts of these developmental changes, how reading skill and eye movements change across the entire lifespan (e.g., college-aged vs. older readers), and individual differences in reading ability.

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"Words, letters, and letter-groups flash into greater distinctiveness from moment to moment, and there is some thought of a mental traversing of the lines. If we watch closely, we are apt to find some sort of inner utterance of what is being read, and we have a notion of the meaning of it all… Thus reading appears to the casual introspection of the reader. We find, however, that underneath this apparent simplicity, there is an astounding complexity of processes. These have been built up slowly, and by an immense amount of practice, until they have organized and settled into the smoothly running machinery of our present-day reading."

–Huey (1908, p. 24)

Introduction

It has long been appreciated that the ability to read is one of the most complex cognitive skills that we routinely perform but did not specifically evolve to perform (Huey, 1908; Rayner & Pollatsek, 1989; Rayner, Pollatsek, Ashby, & Clifton, 2012). Inherent in this appreciation is an understanding that reading skill is acquired through extensive practice, like other complex skills. Understanding the nature of the complex developmental processes that contribute to reading skill is essential for fully understanding how children learn to read (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001, 2002). It is, therefore, somewhat surprising that eye movements, which have proven invaluable behaviors for understanding the cognitive processes of adult readers (for reviews, see Rayner, 1998, 2009), have until fairly recently been largely ignored in the study of reading acquisition (for a review, see Blythe & Joseph, 2011). This oversight is unfortunate because enough has already been learned about the differences between the eye movements of children vs. adults to suggest that these discrepancies provide an insight into how cognition interacts with the visual and oculomotor systems during reading, as well as how these interactions change as a beginning reader develops into a skilled reader.

The remainder of this article will attempt to start to redress this oversight within the theoretical context of a specific model of eye-movement control during reading—the *E-Z Reader* model (Pollatsek, Reichle, & Rayner, 2006; Rayner, Ashby, Pollatsek, & Reichle, 2004; Reichle, Rayner, & Pollatsek, 2003; Reichle, Warren, & McConnell, 2009; Reichle, Pollatsek, Fisher, & Rayner, 1998; for a review, see Reichle, 2011). Our objective is to use the model to test the feasibility of several existing hypotheses about how development affects the patterns of eye movements that are reported when children who are beginning readers (i.e., children who can read simple sentences but who have limited reading experience and proficiency) become skilled adult readers. In the remainder of this article, therefore, we first review what is known about the eye movements of children vs. adult readers, including a discussion of known differences and possible accounts of those differences. We then provide a brief overview of the E-Z Reader model and report a series of simulations that were designed to evaluate the feasibility of existing accounts of why eye movements change in the manner that they do as beginning readers become skilled readers. The value of these modeling exercises are threefold: First, they provide more formal hypotheses about why eye movements change as reading skill develops; second, they provide a method for evaluating the feasibility of these hypotheses; and finally, they provide new theoretical insights about the development of reading skill that can in turn be the impetus for future experiments, including ones that might lend further support for or falsify the assumptions of the E-Z Reader model.

Eye movements in children vs. adults

The following sections review what is currently known about the eye movements of children who are reading, how their eye movements (as a group) are similar to but, in important ways, different from those of adults, and two general accounts that have been provided to explain these similarities and differences. The discussion of these topics is organized into four sections corresponding (respectively) to the basic or more global characteristics of the eye movements, and how these eye movements might be affected by oculomotor and visual constraints, lexical processing, and higher-level (post-lexical) language processing.