

# Eye Movements and Miscue Analysis: Reading from a Constructivist Perspective

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Our view of the reading process is one that involves readers transacting with text to construct meaning, a continual interplay that affects everything from global interpretations of the text to perceptions at the word level. Based on our view of reading, it may seem strange that we have included “eye movements” in our title; the contribution of eye movement research to constructivist reading theory may appear slim. In fact, that is part of the appeal that eye movement research holds for us: It allows us to examine reading with a tool different from those usually associated with constructivist approaches. In this article, we examine the process of reading as informed by the documentation of readers’ eye movements and combine eye tracking with miscue analysis, what we call EMMA, to provide a powerful window on constructive processes in reading. In a final section, we offer some suggestions for teaching strategies that derive from our analysis and research findings.

## EYE MOVEMENTS

### *Brief Physiology of Eye Movements*

Perhaps the first report of eye movement research in reading was Emile Javal’s 1879 observation (reported in Huey, 1908/1968) that readers’ eyes do not flow smoothly across a page of print but instead make a series of stops, or fixations. Further research would demonstrate that the purpose of a fixation is to bring print into the reader’s foveal, parafoveal, and peripheral fields of vision. The foveal region is the area we think of as being in focus and extends about 3 to 6 letter spaces (1 to 2 degrees of visual angle). The parafoveal region (about 24 to 30 letter spaces; 8 to 10 degrees of visual angle) is adjacent to the fovea, and the peripheral region includes everything in the visual field beyond the parafoveal region (Just & Carpenter, 1987). Visual input outside the fovea is experienced with a marked drop in acuity, and words presented to locations further from the fovea are more difficult, or impossible, to identify (Rayner & Sereno, 1994). When readers fixate a word, then, they have a very small area in focus, beyond which the print rapidly becomes

fuzzy. As Reichle, Pollatsek, Fisher, and Rayner (1998) pointed out, to fixate is to “look at” a word (p. 126); the implication is that readers must fixate a word in order to thoroughly process its component letters. There is, however, blurry information available from the parafovea and periphery that may be used by the brain under certain conditions and contexts.

Following each fixation, there is a saccade, or movement, that is extremely short and is so fast that it allows no useful information to be gained from it (Just & Carpenter, 1987). Reichle et al. (1998) used a “slide show” metaphor to explain the relationship between saccades and fixations in reading: “a ‘slide’ is on for a quarter of a second (representing the world as seen in one fixation), followed by a brief interval in which the slide is off, and then followed by a new slide representing the world as seen from a new fixation point” (p. 126). We perceive these “slides” the same way we perceive the individual frames on a movie reel, as a smooth, continuous, holistic visual stream.

### *Context and Words Fixated*

The foveal field of vision is the one that provides in-focus text information to the brain. However, this region is quite small, amounting to only about a word-length amount of letter information. Intuitively, then, one might expect that readers fixate every word because it is not physiologically possible to process its individual letters otherwise. This is not the case, however. In fact, a large percentage of words are not fixated while reading. Rayner (1997) reported that “at least 20% to 30% of the words in text are skipped altogether” (p. 319). Just and Carpenter (1987) found that their readers fixated 68% of the words. Hogaboam (1983) reported that “about 40% of the words were skipped” (p. 315), and Paulson (2002) reported that readers fixated 67% of the words.

Thus, approximately 20 to 40% of the words in a given text are skipped, but this percentage fluctuates based on the class of the word, whether content or function. Content words, which carry much of the semantic meaning of the sentence, are looked at more often than function words, which have a more syntactic, grammatical role. The difference can be great: Carpenter and Just (1983) found that participants fixated 83% of the content words and 38% of the function words in their study. Because many function words are small, and many content words are large, such differences might erroneously be attributed to the reader utilizing some non-comprehension-based strategy of simply skipping any word that is little. Carpenter and Just found, however, that readers were more likely to skip three-letter function words such as *and* and *the* than they were to skip three-letter content words like *act* and *two* because, along with word length and shape, “it is possible to recognize a great proportion of the three-letter function words on the basis of the prior syntactic context” (1983, p. 283-284). Also interested in the question of whether function words are skipped because of their length or their syntactic role, O’Regan (1979) asked participants to read pairs of sentences that began with the same initial clause but were then followed by either a function word or a same-size content word (thus, each sentence ended differently). He found that even though each type of word was located in similar places in

the experimental sentences, readers skipped three-letter function words substantially more frequently than they skipped three-letter verbs. O'Regan concluded:

local eye movement parameters (saccade size, regression probability, number of fixations, and perhaps fixation duration), are controlled sufficiently rapidly to be influenced from moment to moment by information concerning the lexical category of a word in peripheral vision . . . It is clear that some systematic influence of sentence structure exists. (1979, p. 59)

Thus, in general, readers look at anywhere from 60% to 80% of the words in a given text, making instantaneous choices about which words to fixate based on the semantic and syntactic context of the text.

It is interesting to note that the 20 to 40% of the words that were skipped, while physiologically not seen in focus, were actually processed and thus perceived by the reader. Indeed, Just and Carpenter (1987) explicitly asserted that “some of the words that are not fixated directly are still processed to some extent” (p. 39), a description that is reminiscent of the kind of processing that readers need to undertake to complete a cloze activity.

How is it possible, then, during authentic, connected reading, to skip a word with the eyes and still have “read” it? Perhaps the cloze analogy is not far off the mark. Although it can be a deliberate, time-consuming process, completing a cloze activity involves analyzing information ranging from the sentence level to that of the whole text in order to produce a reasonable estimate of what a missing word might be. In other words, prediction is key.

Prediction raises a red flag for some researchers and educators, especially if it is defined as the ability to guess each succeeding word in a text with complete accuracy. For example, what is the final word in the following sentence?

It was a bright, sunny \_\_\_\_\_.

If, for the sake of argument, we agree that the “correct” word at the end of the sentence is *morning*, then a definition of prediction that required complete accuracy would find a response of *afternoon* or *day* wrong. However, our definition of prediction is not an either/or, right-if-it’s-in-the-text-and-wrong-if-it’s-not definition. Rather, in our view, prediction is a recursive process that involves the narrowing down of reasonable possibilities based on a reader’s linguistic and conceptual knowledge of both the text and the world. While readers’ expectations and predictions can be specific, in a more general sense what we mean by prediction is the elimination of unlikely scenarios. With our example sentence above, words like *morning*, *day*, and *afternoon* are all predictable whereas words like *night*, *hailstorm*, *bookshelves* are less predictable. In other words, the predictable words above are constrained by context.

Eye movement research supports the idea that prediction and context affect fixation rates, fixation duration, and other aspects of eye movements. That is, eye movements reflect the meaning-making process during reading. Results reported by Fisher and Shebilske (1985) supported “the generality of the hypothesis that expectations based on

contextual constraints can interact with parafoveal information to determine the guidance of fixations” (p. 154). Similarly, McClelland and O’Regan (1981) demonstrated that the speed and ease with which readers can name a target word from a parafoveal preview is dependent upon the reader’s expectations: “a priori expectations and context greatly increase the benefit subjects gain from a preview of a word in parafoveal vision” (p. 634). They asserted that “our experiments have clarified one point: The ability to derive benefit from the preview we receive of upcoming words in parafoveal vision depends on a prepared mind” (p. 643). In addition, Rayner and Well (1996) showed that “highly constrained target words are skipped (i.e., not directly fixated) more frequently than unconstrained words [and] when target words are fixated, fixation time is shorter on constrained than unconstrained words” (p. 504). They concluded that “predictability of a word (or the amount of contextual constraint for that word)... will affect both fixation time and word skipping” (p. 507). Context plays an important role in the reading process, affecting how long, or even whether, a reader looks at a word.

However, Ehrlich and Rayner (1981) cautioned that experimental results that show the effects of context on eye movements should not be taken as supportive of a “hypothesis testing model” wherein “during each fixation the reader spends the major portion of the time generating a prediction of what will come next based upon what has already been read” (p. 654). Some reading researchers and educators may wonder if we are interpreting the eye movement literature differently than intended by the authors of the studies and arguing from their data for a “hypothesis testing model.” We are not. Instead, our view of the reading process is in line with Goodman (1994), who stated:

Reading involves a transaction between the published text and the reader. This transaction depends on visual input. Once the decision to read is made, light bouncing off print to the eye is processed optically and perceptually transformed so that the orthographic, syntactic, and semantic systems of language may be used. As perceptual and linguistic processing occur, they affect the quality of the optical information since the eyes are being directed by the brain in an informed way; thus, reading is a cyclical psycholinguistic process. Perceptual processing depends on optical input, syntactic processing operates on perceptual input, and semantic processing depends on syntactic input. In this sense the cycles are sequential, each dependent on preceding cycles; but it is a sequence that resembles a merry-go-round in which an optical cycle follows and precedes a semantic cycle. Furthermore, reading is goal oriented and the goal is always meaning. Each cycle is tentative and partial, melting into the next. Inference and prediction make it possible to leap toward meaning without fully completing the optical, perceptual, and syntactic cycles. Yet the reader, once comprehension is achieved, has the sense of having seen every graphic feature, identified every pattern and word, and assigned every syntactic pattern. (p. 1124)

Our point here is that we believe reader expectation, based on global and local syntactic and semantic contexts, is an important aspect of the reading process, and its critical role is supported by eye movement research. As Ehrlich and Rayner (1981) found, “The results of our experiments provide strong support for the hypothesis that context affects eye movements and

fixation durations on words during reading . . . Our results suggest that contextual information does allow a reduction in readers’ reliance on visual information” (pp. 652-653).

EYE MOVEMENT MISCUE ANALYSIS

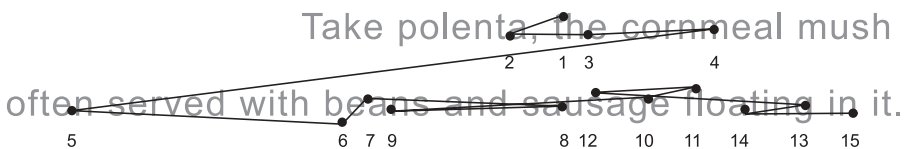
One problem with eye movement analysis is that, short of a quiz at the end of a passage, it is difficult to ascertain the level to which the reader was comprehending the text while reading. Eye movement researchers have struggled with this problem for years. Just and Carpenter (1984) pointed out that, to have truly effective eye movement data, it is useful to combine it with something else that lets a researcher know what else the reader is doing in addition to moving his or her eyes. For this reason, since at least the early 1920s (e.g., Buswell, 1922), researchers have recorded readers reading aloud while their eye movements were also being recorded. Not until recently, however, has a method of analyzing the oral reading been applied systematically to readers reading aloud in front of the eye tracker. In the last few years, several dissertations and studies have been published that have combined eye movement analysis with miscue analysis, an approach that has been termed EMMA, Eye Movement Miscue Analysis (e.g., Duckett, 2001, 2002; Freeman, 2001; Paulson, 2000, 2002).

EMMA: Constructive Nature of Reading

EMMA helps us understand the constructive nature of the reading process. To illustrate this idea, we examine the nonisomorphic relationship between eye fixations and words understood and produced by the reader. Figure 1 shows an excerpt of a short, factual article read in its entirety by a college-age reader while the reader’s eye movements and oral reading were simultaneously recorded using an Applied Science Laboratories Model 504 Eye Tracker. Oral reading data were collected in accordance with established miscue analysis procedures (Goodman, Watson, & Burke, 1987). What the reader said aloud was the following: “Take polenta, the cornmeal mush often served with beans and sausage floating in it,” a text that matches exactly the published text. What the reader looked at while reading the text is indicated by the numbers below the words in Figure 1, illustrating the reader’s fixations and the order in which these occurred. Thus, the words the reader saw, in the order he saw them, were the following: the polenta the

Figure 1

Order of fixations on line of text.



cornmeal often beans beans sausage beans sausage floating sausage floating floating in. Clearly, this reader looked at the text in an order that would seem to produce semantic and syntactic gibberish. However, he produced (and ostensibly perceived) an oral text that was verbatim to the published text. This phenomenon is well documented (e.g., Kolars, 1976) and leads us to reject the explanation of reading as a serial, word-by-word, “look-understand” process, in favor of an explanation that involves a systematic search for information, not simply a visual “grab” of all the letters in the visual field. Eye movement research shows that readers regress (go backwards) 10-15% of the time (Rayner, 1997). This is not a regular, automatic motor activity on the part of the reader but rather an attempt to get more information, disconfirm a prediction, fix a misconception, and so on. Eye movement researcher Hogaboam (1983) concluded:

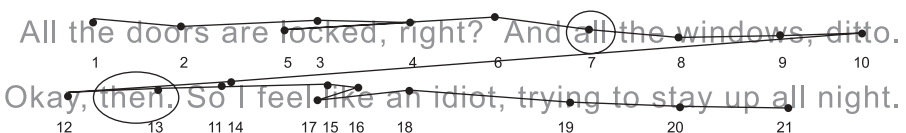
Models assuming this [sequential, word-by-word] characterization of eye movements might be disregarding over three-fourths of the normal eye movement data . . . The point to be taken from this is that it is inaccurate to characterize skilled reading as a process of moving ones [sic] eyes forward from one word to the next with occasional regressions. (pp. 314-315)

*EMMA: Fixations and Miscues*

One recently published EMMA study looked at the location of readers’ eye movements in relation to their oral reading substitutions and omissions (Paulson, 2002). As mentioned earlier, readers fixate 60-80% of the words in a text. Because readers also make omissions and substitutions when reading aloud, one might expect that the words they orally omit are also ones they visually skip. The following example, see Figure 2, typifies the pattern of eye movement data that was repeatedly observed in the study. A teenage reader reading aloud the excerpt of a short story fixated 60% of the words. While visually skipping 40% of the words, the reader made two oral word omissions (the words that are circled in the figure). There would seem to be several candidates for determining which two words were omitted; after all, there are several that were not looked at by the reader. Common sense would dictate that the words that were not fixated, like *All*, *are*, *to*, and *night*, are among those most likely to have been orally omitted. Instead, as Figure 2 indicates, the orally omitted words, *all* and *then*, were both fixated; this reader looked right at two words that he orally did not read. This observation runs counter to the

*Figure 2*

Eye movements and miscues on short story excerpt.



common sense idea that oral reading miscues must have visual causes. Thus, the idea that a reader “didn’t say it because he didn’t see it” may need to be rethought. Also note that there were several words that the reader did not look at but still read aloud, such as *All* (first word), *are*, *feel*, *idiot*, *up*, and *night*, for example. Several recent dissertations have reported similar phenomena (Duckett, 2001; Freeman, 2001; Paulson, 2000) and a recent study found that statistically “readers were as likely to fixate a word they orally substituted or omitted as they were to fixate a word they produced verbatim to the text” (Paulson, 2002, p. 62).

Throughout our discussion, we have implied that what the reader brings to the act of reading is as important as the text. By asserting that the reader is important, however, we are not detracting from the importance of the text during the reading process. If the text were the only variable in position and duration of eye movements, we might expect all readers to have the same eye movements when reading a particular text. Or, if the reader were the only variable, we would see a single reader’s identical eye movement pattern across several different texts. Neither is the case, of course; eye movement patterns vary widely between readers and between texts. This important aspect of the reading process has been understood for nearly a century; for example, Huey (1908/1968) and Buswell (1922) discuss the fact that eye movements reflect both reader and text variables.

## IMPLICATIONS FOR TEACHING

A great deal has been written about how people learn about written language. In order for readers to construct knowledge about written language, they need access to a rich and diverse literary environment with ample opportunities to transact with a wide variety of genres and formats (Cambourne, 1988; Goodman, 1990; Jaggar & Smith-Burke, 1985). Every new text provides experiences for readers to apply strategies and language that they already control to new settings (Goodman & Wilde, 1992; Wells, 1986). EMMA research (e.g., Paulson, 2002) has shown that for each reading, the reader produces different patterns of eye movements and of miscues that relate to the organization of that particular text and how that reader approached the text on this specific occasion. The purpose of the reading, the organization and conceptualization of the subject matter, and the grammar and vocabulary differ in significant ways for each new text with which a reader transacts. Learning to read and reading to learn take place simultaneously as the reader learns to transact with a text through the experience of reading. The reading of fiction, history, science, or math each calls on different uses of strategies. Reading trade books, basal readers, or programmed materials provide different kinds of reading opportunities. The ways to make use of the graphophonics on a page from a math textbook, for example, can be different from an end-of-level reading test. Even in English, the print in some texts is not always in the same kind of left-to-right orientation as in others. This can be particularly true in some reading assessments, with negative consequences (Paulson & Henry, 2002). The greater the variety of texts readers experience, the more flexible they become as readers. In contrast to rich reading

opportunities, reading from the same kind of texts or having limited reading experiences over many years in school limits the opportunities for readers to develop flexibility in reading.

Authentic text is crucial to this effort, and providing students with varied reading opportunities means seeding classroom environments with a range of written materials, signs, captions, reference materials, songs, poems, fantasy, and nonfiction, related to a range of content areas. The written language we find on computers is providing a wealth of new experiences for even the most literate among us to develop new kinds of reading strategies. Reading across the curriculum becomes essential as teachers help students to discover that learning to read occurs throughout the school, the home, and the community, not only during the time of day labeled reading instruction. Each subject matter calls for instructional strategies concerned with how to read the genre in that particular content field.

Insights generated by EMMA research have strengthened our belief that interrupting a reader during oral reading is counterproductive. Teachers often interrupt readers after an oral miscue, but the reader's brain and eyes are already elsewhere: reading ahead, self-correcting, thinking about what they have read, planning what to do next. Our research suggests that if a teacher interrupts to correct a word that a reader has just uttered or to recommend a strategy, he or she potentially robs the reader of an opportunity to learn how to solve his or her own problem. Instead, the teacher unintentionally may be sending a message to the reader that suggests, "I can help you understand the text better than what you are trying to work out by yourself." Such messages may encourage instructional dependency and can convince readers of their own helplessness (Board, 1982).

Insights about the role of miscues and eye movements in reading can help teachers show students how all readers struggle with new texts as they are working out what the author is trying to say. Using evidence from a student's miscue analysis and eye movements, teachers can demonstrate how readers use language knowledge such as phonics, grammar and word meanings in concert with their reading strategies to make sense of a text (Paulson, Flurkey, Goodman, & Goodman, 2002). Through discussions between teacher and student, readers become aware that they are predicting and self-correcting appropriately as they struggle to comprehend. They learn that their miscues change qualitatively across a text by examining the ways in which they treat the same words or phrases differently across the text. As a result, students discover the ways in which they transact with the text and learn from the text as they read.

We call such conversations in which readers think about the reading and learn to use language to talk about reading Retrospective Miscue Analysis (Goodman & Marek, 1996). Readers learn that making miscues, predicting, continuing to read, questioning the author, rereading, and rethinking are all aspects of good reading, even though the surface reading includes miscues, starts, and stops. During such conversations, teachers demonstrate strategies as expert readers that are similar to the strategies students use, and they plan strategy lessons to help readers consider ways to improve the kinds of strategies they may already be aware of but hesitate to use. Teachers support readers as they inquire into their own reading processes and become introspective about their reading. Readers, especially

those who experience difficulty in reading, benefit from learning the ways in which all readers struggle with texts and that such evidence actually reveals readers' abilities and is not symptomatic of disability. Our research shows how productive such conversations and inquiry into their own reading can be and how they support readers in revaluing themselves and developing more successful reading strategies (Goodman & Marek, 1996). Retrospective Miscue Analysis has also been extended to use a reader's own eye movements in addition to his or her miscues as part of the reading discussion (Paulson & Freeman, 2003).

While a great deal of knowledge about the reading process was developed in the 20th century, many controversies remain. EMMA research suggests a new understanding of the reading process and implications for teaching that supports reading development. It may help to shift the debates and discussions in new directions as we move into the 21st century.

## CONCLUSIONS

EMMA brings together two research traditions: eye movement research that shows how perception is used in reading to provide the brain with sensory input, and research using miscue analysis that reveals the knowledge and strategies readers use as they comprehend. By a close examination of the relationship between these two methods, we can gain valuable insights into the process of making sense of written language. EMMA studies have examined the reading of picture books by first graders (Duckett, 2001), the reading of English and Spanish stories by bilingual readers (Freeman, 2001), and the reading of adult readers with diverse abilities of English, Japanese, Chinese, and Russian (Mirseitova & Paulson, 2000; Paulson, Freeman, Duckett, Hung, Yamashita, & Goodman, 2002). Based on these and the other studies we have described in this article, we offer the following conclusions: (a) The reader does what is necessary and efficient to make sense of the text; comprehension is central to the reading process; (b) Readers do not look at every letter or word in a text but rather use syntactic and semantic context and prediction as natural elements of the reading process; (c) Readers do not process meaningful text letter by letter, word by word, or character by character; (d) Readers are as likely visually to examine a word they miscue as they are to look at a word they do not miscue and, conversely, most words that are not fixated are read without miscues; and (e) Readers engage their syntactic, semantic, and graphophonic knowledge flexibly while using a variety of reading strategies to make sense of texts. In sum, EMMA research provides insight into the perceptual cycle of reading and supports a view of reading as a constructive process.

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