REFERENCES

Becker, W. & Juergens, R. (1979). An analysis of the saccadic system by means of double-step stimuli. *Vision Research, 19,* 967–983.

Brühl, D. & Inhoff, A. W. (1995). Integrating information across fixations during reading: The use of orthographic bodies and of exterior letters. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 55–67.

Epelboim, J., Booth, J. R. & Steinman, R. M. (1994). Reading unspaced text: Implications for theories of reading eye movements. *Vision Research, 34,* 1735–1766.

Fisher, D. F. (1976). Spatial factors in reading and search: The case for space. In Monty, R. A. & Senders, J. W. (Eds), *Eye movements and psychological processes* (pp. 417–427). Hillsdale, N.J.: Erlbaum.

Inhoff, A. W., Pollatsek, A., Posner, M. I. & Rayner, K. (1989). Covert attention and eye movements during reading. *Quarterly Journal of Experimental Psychology, 41A,* 63–89.

Kolers, P. A. (1968). The recognition of geometrically transformed text. *Perception & Psychophysics, 3,* 57–64.

Kowler, E. & Anton, S. (1987). Reading twisted text: Implications for the role of saccades. *Vision Research, 27,* 45–60.

McConkie, G. W. & Zola, D. (1979). Is visual information integrated across successive fixations in reading? *Perception & Psychophysics, 25,* 221–224.

McConkie, G. W., Kerr, P. W., Reddix, M. D. & Zola, D. (1988). Eye movement control during reading: I. The location of initial eye fixations on words. *Vision Research, 28,* 1107–1118.

Morris, R. K., Rayner, K. & Pollatsek, A. (1990). Eye guidance in reading: The role of parafoveal letter and space information. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 268–281.

Morrison, R. E. (1984). Manipulation of stimulus onset delay in reading: Evidence for parallel programming of saccades. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 667–682.

O'Regan, J. K. (1981). The convenient viewing position hypothesis. In Fisher, D. F., Monty, R. A. & Senders, J. W. (Eds), *Eye movements: Cognition and visual perception* (pp. 289–298). Hillsdale, N.J.: Erlbaum.

Pollatsek, A. & Rayner, K. (1982). Eye movement control in reading: The role of word boundaries. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 817–833.

Rayner, K. (1978). Foveal and parafoveal cues in reading. In Requin, J. (Ed.), *Attention and performance VII* (pp. 149–162). Hillsdale, N.J.: Erlbaum.

Rayner, K. (1979). Eye guidance in reading: Fixation locations within words. *Perception, 8,* 21–30.

Rayner, K. & McConkie, G. W. (1976). What guides a readers eye movements? *Vision Research, 16,* 829–837.

Rayner, K., McConkie, G. W. & Zola, D. (1980). Integrating information across eye movements. *Cognitive Psychology, 12,* 206–226.

Rayner, K., Well, A. D., Pollatsek, A. & Bertera, J. H. (1982). The availability of useful information to the right of fixation in reading. *Perception & Psychophysics, 31,* 537–550.

Spragins, A. B., Lefton, L. A. & Fisher, D. F. (1976). Eye movements while reading and searching spatially transformed text: A developmental examination. *Memory & Cognition, 4,* 36–42.

Vitu, F., O'Regan, J. K. & Mittau, M. (1990). Optimal landing position in reading isolated words and continuous text. *Perception & Psychophysics, 47,* 583–600.

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Much Ado About Nothing: the Place of Space in Text

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We reply to the critique of Epelboim, Booth and Steinman (1994, *Vision Research*, *34*, 1735–1766) by Rayner and Pollatsek (1996, *Vision Research*, *36*, 461–465). We show that they are wrong in all respects. Word recognition, rather than spaces, guides reading eye movements.

Reading Eye movements Word recognition Saccadic programming

Rayner and Pollatsek (1996), henceforth R&P, continue to believe, despite our results, that spaces between words constitute the primary cue used to guide saccadic eye movements during reading, and that in the absence of spaces, readers resort to a very different and much less effective oculomotor strategy. They also find our paper neither "novel" nor "diagnostic" and claim that our results are "largely based on one subject". We will show that R&P are wrong on all three counts. Our reply begins with a brief summary of the findings and conclusions of our paper (Epelboim, Booth & Steinman, 1994). It then

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‡One can, with effort, construct a sentence where the absence of spaces between words makes reading excedingly difficult, viz. THEREDONATEAKETTLEOFTENCHIPS (Jusczyk, 1986). Such combinations of words, however, occur only very rarely in ordinary text, and when they do, meaning provided by context can make such material easier to read than the above example which was constructed to demonstrate the segmentation problems that a listener solves while perceiving speech.

addresses the essence of this controversy. Namely, we believe that we provided compelling evidence that spaces do not guide saccades during reading, whereas R&P believe that we did not. We then deal with other, and less important, issues raised by R&P.

Our paper

Our study was initially motivated by the fact that ancient and medieval languages, as well some modern languages, are written without spaces between words, whereas most contemporary reading research emphasizes the importance of spaces between words for guiding reading saccades. We examined the role of spaces in reading by recording eye movements with an exceptionally accurate and precise eye movement monitor, while subjects read spaced and unspaced texts, both aloud and silently. Removing spaces did not prevent unpracticed subjects from reading unspaced texts relatively rapidly and with meaning. Two of our unpracticed subjects were able to read unspaced text without slowing down at all. Even our poorest reader of unspaced text read unspaced text relatively fast, considering she had never tried to read such text prior to this experiment. Other traditional *global* measures of reading competence (viz. percentage of regressions and probability of skipping a word) did not differ in four of the five subjects, whose eye movements were recorded. Furthermore, the number of progressive saccades/line and fixation durations were also either the same or only very slightly different with the two kinds of text in three of these five subjects. Even more important, *local* reading eye movement patterns (viz. the most likely landing letter and the probability of fixating a letter as a function of word length) were similar in both kinds of text, indicating that the same oculomotor strategy was used with and without spaces. These results make, in our view, a very strong case against the importance of spaces for saccadic programming. Our paper concluded by proposing, as Kowler and Anton (1987) and Kolers (1968) had previously, that *word recognition* plays the key role in saccadic programming. As we said in our paper, "spaces may serve a perceptual role by facilitating word recognition, but they do not, in themselves, play an important role in the programming of reading eye movements" (p. 1764).‡

Our conclusion was based primarily on the following observations: (i) decreases in reading rates produced by removing spaces were modest, and even non-existent in some subjects, all of whom had had no prior experience with reading unspaced texts; (ii) both local and global reading eye movement patterns were similar when spaced and unspaced texts were read, suggesting that the same oculormotor strategy was used in both types of texts; (iii) subjects had great difficulty reading when individual letters in unspaced texts were blurred, or when spaces were placed in inappropriate locations within words. We take our findings to imply that the targets for reading saccades are words themselves (recognized or anticipated on the basis of meaning conveyed by context) rather than peripheral groups of unprocessed letters delimited by spaces (the scheme proposed by R&P).

THE CENTRAL ISSUES IN OUR CONTROVERSY

Is reading unspaced text easy?

In the absence of a comprehensive quantitative theory of reading eye movements, resolution of issues, such as this, rests entirely on expectations about performance [see Suppes (1990) and Viviani (1990) for discussion of the importance of developing such a model and our paper for an application of Suppes' stochastic model]. We started our experiments expecting that the subjects would have difficulty reading unspaced texts because they had had no prior experience with reading unspaced texts, and because all of them said that they could not read unspaced text when they looked at it for the first time. Despite this subjective impression, they could read unspaced text rather well. Two subjects did not slow down at all. If spaces were the primary cue for saccadic programming, one might expect a catastrophic drop in speed. Such catastrophes have been reported. When Kowler and Anton (1987) reversed the order of letters in words, as well as the order of words in sentences, and rotated the letters by 180 deg, subjects read at one-tenth of their normal speed. Even a much more minor manipulation of their texts, simply reversing the order of letters in words and keeping word order the same, slowed reading down by over 80% *after* subjects had been given relatively extensive practice reading this specific kind of text. By comparison our nine subjects had no practice with unspaced text, whatsoever, and as a group, they only slowed down by about 30%.

How do R&P manage to maintain their enthusiasm for the role of spaces in light of these modest decrements in reading speed? They arbitrarily exclude two of our subjects (CE and ZP) from their summary of some of our data (their Table 1) and then go on to suggest that subject RS, whom they call "deviant", should also be dropped in order to bring our results somewhat closer to those of another experiment (Spragins, Lefton & Fisher, 1976). We would prefer to exclude a different subject, BG, because he did not follow our instruction to read with meaningful expression. He read spaced text so quickly that his speech was difficult to understand (p. 1746). Without BG, who could be dropped *legitimately*, the mean reading speed decrement of the remaining eight subjects becomes only 25%. Is this little enough for us to claim that reading unspaced text, without any prior practice whatsoever, is easy? We think it is. R&P may not, and in the absence of a quantitative theory of reading speed, we must leave this issue open and turn to an examination of the performance of individual subjects, rather than base the rest of our discussion on the performance of averaged groups. In this, we follow a long tradition in visual psychophysics and basic oculomotor research, where the results of individual subjects are usually reported and examined in detail.

Once we do this, R&P have the burden of explaining how *any* subject can read spaced and unspaced text equally well and equally fast. We have two such subjects (RS and CE). Here, we can only repeat the hypothesis we provided in our paper (p. 1747). CE is a Dutch scientist, fluent in both Dutch and English. He read unspaced Dutch text as fast as he read spaced Dutch text, and slowed down by only 18% when he read unspaced English text. Perhaps, his 40 or so years experience reading Dutch allowed him to read unspaced text, English as well as Dutch, so easily. Consider the following Dutch sentence (provided by CE from among the materials he found lying on his desk):

De stichting Levenswetenschappen, samengesteld uit een aantal werkgemeenschappen, heeft een correspondentieadres. [The foundation of Life Sciences, composed of a number of working committees, has an address for correspondence.]

A reader who relies heavily on spaces in text to program reading eye movements would find such material exceedingly difficult, and Dutch is not unique in being stingy with spaces. Although it is possible to argue that spaces are used to guide eye movements of readers of English and other generously-spaced languages, and some other, unknown, feature is used as a guide in sparsely-spaced or unspaced languages (e.g. Thai), a theory of reading eye movements that does not rely on spaces would be better because it could explain the programming of reading eye movements on the basis of some property common to all written languages. Word recognition could serve this purpose.

*Spaces do **not** guide reading saccades*

In their critique, R&P attempt an explanation of why the reading eye movement characteristics of our subjects changed only very slightly when they read unspaced texts. They propose that our readers "soldiered on" by making saccades whose length was approximately equal to the length of an average word. We considered this possibility explicitly in our paper and rejected it (see our discussion of the "constant step strategy", on pp. 1748–1751 and examine Table 1). We rejected this strategy for three reasons: (i) the sizes of reading saccades were not constant, they were highly, and similarly, variable in both types of text; (ii) there were similar, albeit small, effects of word-length on local eye movement characteristics in both kinds of text: this means that, to the extent that local characteristics of the text are important for saccadic programming, they were equally important in both kinds of text; (iii) when the letters could not be seen clearly, the absence of spaces made it virtually impossible to read. If readers "soldiered on", using the constant step strategy for unspaced reading, they could just as easily have "soldiered on" through blurred unspaced text. However, if, as we claim, saccades are programmed on the basis of recognized words, making words harder to recognize will impair unspaced-text-reading more than spaced-text-reading because, as we pointed out in our paper (p. 1764), spaces *do* serve to facilitate word recognition even if they do not guide reading saccades.

We performed a new experiment recently that provides additional support for the importance of word recognition, rather than spaces in saccadic programming (Booth, Epelboim & Steinman, 1995). Subjects read normal and incoherent text, i.e. text made up of real words ordered so as to convey no meaning. Both types of text were read aloud and both were presented spaced and unspaced. We already knew from prior work that words in context are read faster than the same words in a random order (Biemiller, 1977–1978). So, removing meaning from text should slow unspaced-text-reading more than spaced-text-reading, just as blurring letters did, because word recognition will be impaired. We found that meaning mattered. The decrease in speed when spaces were removed, was greater with incoherent than with normal text. This new finding adds additional support for our claim that the main role of spaces in text is to assist word recognition, *not* to guide saccadic programming.

OTHER ISSUES

The "novelty" and "diagnostic" value of our study

R&P mentioned three studies (Spragins *et al*., 1976; Pollatsek & Rayner, 1982; Morris, Rayner & Pollatsek, 1990) that were, in their opinion, either the same as our study or more "diagnostic". Although there is some superficial similarity between our study and these three, a close examination shows that our study was actually very different.

Our study was novel in that we used a unique and exceptionally accurate and precise eye movement monitor to examine both global and local characteristics of our subjects' eye movements as they read, both silently and aloud, paragraphs of normal text both with and without spaces. We published the calibration records for each of our subjects, an essential, but usually overlooked source of information for any eye movement work that sets out to examine local features of the reading eye movement pattern. We reported data for each of our subjects and included error bars in our graphs and SDs in our tables. All prior work discussed by R&P: (i) used relatively crude eye movement monitors, or (ii) reported only data averaged across subjects with no indications of intra-and inter-subject variability, or (iii) used unusual texts or reading conditions, viz. texts contaminated by filling the spaces between words with irrelevant symbols or by perturbing texts by changing or moving parts of it as it was read. Details follow.

The Spragins et al. (1976) study. Contrary to R&P's claim, we did not overlook the Spragins *et al*. (1976) study. We were aware of it, and similar studies. These studies were reviewed by Fisher (1976), and this review was cited in our paper. Fisher's review made it clear that this prior work was quite different from ours. It told us little about the main topic of our paper, i.e. the role of spaces in *programming reading eye movements*, because in Spragins *et al.* (1976), and in all other prior studies of unspaced-text-reading cited by Fisher, either eye movements were *not recorded* or the eye movement recording apparatus was too crude to know where the line sight fell within the text as it was read.

In preparing this reply, we reread Fisher's (1976) review and its source papers. We found that they, as we believed initially, were largely irrelevant and anticipated little, if anything, of what we found. We did, however, notice another interesting detail in the developmental data of Spragins *et al.* (1976) that supports *our* conclusion. Specifically, Spragins *et al.* (1976) found that third-graders, as compared to adults and older children, are relatively good at reading unspaced text. Their reading rates went down by only 26%, whereas reading rates of adults in the same study, went down by about twice as much (49%). Spragins *et al.* (1976) interpreted this result to mean that adults and older children use peripheral information about the physical appearance of the text when they read, whereas younger children, who are less skilled at reading, do not. We offer an alternative explanation. It has been found repeatedly that young children use context during reading to a greater extent than adults and older children (Stanovich, 1980; Schwantes, 1991). Our new results (Booth *et al.*, 1995, described just above) showed that for adults, context helps unspaced-text-reading. Spragins *et al.*'s (1976) third-graders may have been better at reading unspaced text than adults because they were not yet as skilled at word recognition and had, therefore, to depend more on context. This made it easier for the younger children to read unspaced text. Yet another example of the importance of word recognition, rather than spaces, in reading.

The studies by Pollatsek and Rayner (1982 and Morris et al. (1990). These studies, emphasized by R&P, were also cited in our original publication, but not discussed in any depth because, as indicated then (p. 1738), there are obvious problems with the interpretation of experiments in which displays are perturbed as texts are read. For example, O'Regan (1990, pp. 402–406), a very accomplished reading eye movement expert, who, like ourselves, has background in basic visual processes, has called attention to the many problems inherent in interpreting the results of such perturbation experiments. The putative control conditions in these experiments are not really controls. For example, in Pollatsek and Rayner (1982), in R&P's critique of our paper, and elsewhere, reference is made to the condition in which a perturbation is made during a saccade, rather than during a reading fixation, as a "control" condition on the grounds that subjects tend not to report noticing the perturbations when they are introduced during saccades. This is not a suitable control for effects of perturbation because both reading and the eye movement pattern could be affected without alerting the subject. The fact that subjects do not report perturbations in this so-called "control" condition means little because they are attending to the material being read and may not notice or may forget noticing irrelevant events, e.g. changes or additions to the text that occur simultaneously [see Sperling (1990) for a discussion of models of attention as they would apply under similar conditions]. Much more study of the influence of perturbations is necessary before results from such experiments can be uncritically interpreted as "diagnostic" of the nature of the kind of information used to program eye movements during normal reading. We suspect that at least some types and amounts of perturbations will prove to have either visual, attentional or other cognitive influences that preclude using the results of these experiments to infer processes underlying *normal* reading.

The results of Pollatsek and Rayner (1982) and Morris *et al.* (1990) are also difficult to interpret because when spaces between words are filled, irrelevant information, which is likely to interfere with word recognition, is added to the text. A "diagnostic" experiment on the role of spaces in reading must either avoid or control for this confounding. We avoided using space-fillers because without them the experiment is simpler and its interpretation more straightforward. If, however, one wishes to use the filler technique, the following control conditions must be performed for each type of filler being used (letters, numbers, gratings etc.). Text examples are given within quotes.

Normal text: "spaces are not important".
Text with filled spaces:
"xspacesxarexnotximportantx".
Spaced text with fillers before each word:
"xspaces xare xnot ximportant".
Spaced text with fillers after each word:
"spacesx arex notx importantx".
Spaced text with fillers before and after each word:
"xspacesx xarex xnotx ximportantx".

To our knowledge, up until now only (1) and (2) have been compared. Items (3)–(5) must also be examined to control adequately for the presence of irrelevant information in the text, so as to be able to infer that it is the absence of spaces in the text, rather than the presence of the extra material, that slows reading down. Furthermore, in Pollatsek and Rayner (1982) and in R&P's critique, assumptions are made as to which types of filler are disruptive to lexical access and which are disruptive simply because they fill spaces and, therefore, interfere with saccadic programming. No empirical basis is provided for these assumptions, and although it may be obvious, and even rational, to assume that introducing extraneous letters into a text would have a detrimental effect on word recognition, it is not obvious at all that introducing numbers or gratings would not interfere with word recognition. In fact, it is likely that words written like this: 6*word*1 or even like this: #*word*# will take more time to recognize than words like this: *word*. To our knowledge, there are no experiments that test the effects of introducing irrelevant symbols on word recognition. Until such studies are performed, experiments like those of Pollatsek and Rayner (1982) and Morris *et al.* (1990) say little about the role of spaces in reading and would be better described as "uncertain" than as "diagnostic".

But even if we ignore these potential flaws in the Pollatsek and Rayner (1982) and Morris *et al.* (1990) experiments, their pattern of results actually support our view of the importance of word recognition, rather than spaces, for saccadic programming. Both the Discussion in Pollatsek and Rayner (1982) and the R&P critique of our paper state that one effect of filling (or removing) the space next to the currently fixated word is to interfere with lexical access. We not only agree with this reasoning, but think that disrupting lexical access (or word recognition) is the *only* effect of *removing* spaces, which is precisely why we preferred this technique to the filler or perturbation technique R&P prefer. Once we agree that having the first space to the right of the currently fixated word can assist with word recognition, the critical test for the importance of spaces as guides for saccades is to see what happens when the space to the right of the fixated word (henceforth "the first space") is preserved, but the next space, the space at the end of the next word (henceforth "the second space") is filled or removed. In this situation, the reader should have no problem reading and recognizing the currently fixated word, but, if eye movements are programmed on the basis of the length of the next word, and if word length is determined primarily by spaces, the saccade to the next word should be measurably different from the saccades observed when normal texts are read. Pollatsek and Rayner (1982) as well as Morris *et al.* (1990) found that when the first space is preserved and the rest of the spaces to the right of fixation are filled, the effects on saccade length and latency were very small indeed. These effects varied among experiments and conditions, but the *largest* effects of filling all but the first space were less than a one character decrease in saccade length (close to the noise level of their recording system) and *at most* a 15 msec increase in saccade latency (7%). Such minuscule effects do not support the *importance* of spaces for saccadic programming. Furthermore, these effects are based entirely on data averaged over groups and no indication of the prevalence of such effects in the data of individual subjects was provided. Perhaps these effects offer a hint that spaces might make some minor contribution. We suspect, however, that they would have been wiped out completely if spaced text with irrelevant characters had been used as "control" instead of the normal text that was actually used to make the comparison.

Miscellaneous issues

R&P had difficulty in interpreting several features of our paper. For example, they missed the reason we included a discussion and analysis of the "preferred landing position" (PLP) [the PLP is sometimes assumed to be the "optimal viewing position" (OVP)]. We included this analysis because the existence of a PLP is often used as evidence to support the claim that spaces are important guides for programming reading eye movements. Some of our subjects did favor a particular location within words as the endpoint for the saccades they made into each word, i.e. they demonstrated a PLP. However, those who did show this tendency, showed it in both spaced and unspaced texts. The fact that those subjects who showed this tendency, showed it in texts that had no spaces makes it clear that this phenomenon cannot be used to support the importance of spaces in programming reading eye movements as has been done in the past (e.g. Rayner, 1979; O'Regan, 1990). R&P apparently did not realize that the main point of our analysis was to show that even when there was evidence for a PLP, it did not require spaces in the text. We saw this as another reason to play down the importance of spaces in guiding reading eye movements and included it in our paper for this reason.

R&P also did not appreciate the significance of our switched-text simulation (Fig. 11, pp. 1761–1762). This simulation showed that the existence of a PLP need not reflect an oculomotor strategy in which a separate calculation is performed to determine the endpoint for each saccade. This simulation showed that the PLP can reflect a global, rather than local, strategy because there is a good match between global eye movement parameters and global attributes of normal texts, such as average word length or conceptual difficulty.

R&P also made mistakes. They are wrong when they say that "Less accurate [eye movement recording] systems should have produced noisier data." We assume that by "noisier data" they mean that less precise eye movement monitors should, for example, produce more ragged-looking PLP curves. The smooth appearance of curves based on data depends both on the precision of the measuring instrument and on the source of the noise. If the source of the noise is the reader's oculomotor system, and the amplitude of the oculomotor noise is smaller than the eye movement monitor's resolution, a less precise monitor will produce "cleaner-looking" (smoother) curves that do *not* reflect the subjects' actual oculomotor behavior. Furthermore, the practice of averaging subjects can give the appearance of "cleaning up" data that is intrinsically noisy. Averaging subjects and omitting error bars from graphs, customary in too much reading eye movement research, can also give misleading impressions of both the size and precision of effects. In our view, attention to using appropriate conventions when reporting measurements will do more for the field than criticism of vagaries of verbal usage.

For example, R&P criticize our use of "nebulous" terms such as "relatively easy", "important role" and "easier than anticipated". We did use such qualitative terms to express the conclusions we drew from the data, but our paper was not short on quantitative statements, supporting their use. There are 11 figures, 3 tables and a large number of statistical analyses. The interested reader can use this information to interpret our "nebulous" descriptive statements.

REFERENCES

Biemiller, A. (1977–1978). Relationships between oral reading rates for letters, words, and simple text in the development of reading achievement. *Reading Research Quarterly*, *2*, 223–253.

Booth, J. R., Epelboim, J. & Steinman, R. M. (1995). The relative importance of spaces and meaning in reding. *Proceedings of the Cognitive Science Society*, *17*, 533–538.

Epelboim, J., Booth, J. R. & Steinman, R. M. (1994). Reading unspaced text: Implications for theories of eye movements. *Vision Research*, *34*, 1735–1766.

Fisher, D. (1976). Spatial factors in reading and search: The case for space. In Monty, A. & Senders, W. (Eds), *Eye movements and psychological processes* (pp. 417–27). Hillsdale, N.J.: Erlbaum.

Jusczyk, P. (1986). Speech perception. In Boff, K., Kaufman, L. & Thomas, J. (Eds), *Handbook of perception and performance* (Vol. 2, Chap. 27). New York: Wiley.

Kolers, P. A. (1968). The recognition of geometrically transformed text. *Perception & Psychophysics*, *3*, 57–4.

Kowler, E. & Anton, S. (1987). Reading twisted text: Implications for the role of saccades. *Vision Research*, *27*, 45–60.

Morris, R. K., Rayner, K. & Pollatsek, A. (1990). Eye movement guidance in reading: The role of parafoveal letter and space information. *Journal of Experimental Psychology: Human Perception and Performance*, *16*, 268–81.

O'Regan, J. K. (1990). Eye movements in reading. In Kowler, E. (Ed.), *Eye movements and their role in visual and cognitive processes* (pp. 395–53). Amsterdam: Elsevier.

Pollatsek, A. & Rayner, K. (1982). Eye movement control in reading: The role of word boundaries. *Journal of Experimental Psychology: Human Perception and Performance*, *8*, 817–833.

Rayner, K. (1979). Eye guidance in reading: Fixation locations within words. *Perception*, *8*, 21–1.

Rayner, K. & Pollatsek, A. (1996). Reading unspaced text is not easy: Comments on the implications of Epelboim *et al.*'s study (1994) for models of eye movement control in reading. *Vision Research*, *36*, 461–465.

Schwantes, F. M. (1991). Children's use of semantic and syntactic information for word recognition and determination of sentence meaningfulness. *Journal of Reading Behavior*, *23*, 335–50.

Sperling, G. (1990) Comparison of perception in the moving and stationary eye. In Kowler, E. (Ed.), *Eye movements and their role in visual and cognitive processes* (pp. 307–51). Amsterdam: Elsevier.

Spragins, A. B., Lefton, L. A. & Fisher, D. F. (1976). Eye movements while reading and searching spatially transformed text: A developmental examination. *Memory and Cognition*, *4*, 36–2.

Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly*, *16*, 32–1.

Suppes, P. (1990). Eye-movement models for arithmetic and reading performance. In Kowler, E. (Ed.), *Eye movements and their role in visual and cognitive processes* (pp. 455–77). Amsterdam: Elsevier.

Viviani, P. (1990). Eye movements in visual search: Cognitive, perceptual and motor aspects. In Kowler, E. (Ed.), *Eye movements and their role in visual and cognitive processes* (pp. 353–393). Amsterdam: Elsevier.

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