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Eye movements during reading: some current controversies

Matthew S. Starr and Keith Rayner

For many researchers, eye-movement measures have become instrumental in revealing the moment-to-moment activity of the mind during reading. In general, there has been a great deal of consistency across studies within the eye-movement literature, and researchers have discovered and examined many variables involved in the reading process that affect the nature of readers' eye movements. Despite remarkable progress, however, there are still a number of issues to be resolved. In this article, we discuss three controversial issues: (1) the extent to which eye-movement behavior is affected by low-level oculomotor factors versus higher-level cognitive processes; (2) how much information is extracted from the right of fixation; and (3) whether readers process information from more than one word at a time.

Although researchers have measured eye movements since 1879, recent technological innovations have allowed scientists a much more accurate view of the relationship between eye movements and reading[1]. Prior to about 1975, researchers tended to focus primarily on the observable surface aspects of eye movements in reading and there were few attempts to use eye-movement data to infer underlying cognitive processes in reading[2]. However, recent research on eye movements during reading has undergone both a paradigm shift and a resurgence – instead of being viewed as a simple observable behavior that is unrelated to reading, many researchers now use eye-movement data as a vital tool for understanding the on-line operations involved in the reading process. For the most part, eye-movement data have proved to be highly reliable and useful in inferring the moment-to-moment processing of individual words and larger segments of text. However, a

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number of debates have also emerged from the study of eye movements, and our goal in this article is to delineate three of these controversies. We hope that by outlining some of the more contentious issues, researchers will become more aware of the prominent questions which need to be resolved before we can develop a comprehensive model of eye movements in reading.

Prior to discussing these controversies, we will provide some background information on eye movements in reading. Although it might seem as if our eyes sweep smoothly across the page as we read, in reality, reading consists of a series of saccades (whereby the eyes jump from one location to another) and fixations (during which the eyes remain relatively stable). For skilled readers, the average saccade length is 7–9 letter spaces and the average fixation duration is 200–250 ms. About 10–15% of the time, skilled readers make 'regressions' back to previously read text (see Box 1). During fluent reading, saccades move the eyes so that a word can be focused on the retina so that it can be more effectively processed (see Box 2). However, both saccade length and fixation duration fluctuate considerably from word to word, and a goal of eye-movement research is to account for this variability.

The three controversies we discuss range from relatively low-level perceptual concerns to higher-level questions involving theoretical/computational models of eye-movement control in reading. One sustained and prevalent controversy has been whether eye movements during reading are controlled by low-level oculomotor (i.e. mechanical) strategies or whether they are influenced by moment-to-moment cognitive processes. A second controversy deals with the types of information extracted from parafoveal vision in reading. Although most researchers agree that low-level information is obtained from the word to the right of fixation in reading, there is some disagreement regarding whether higher-level information (e.g. word meaning) is obtained. A third controversy concerns the relationship between attention and eye movements. Many current models assume that words are processed serially and that attention moves sequentially from one word to the next. However, some recent findings appear to challenge this assumption.

Oculomotor versus processing models

We mentioned above that many researchers view eye movements as a valid measure of on-line cognitive processing during reading. However, not all researchers share this opinion[3,4]. In general, two categories of eye-movement control models have emerged: oculomotor models and processing models. Researchers favoring low-level oculomotor accounts claim that eye movements are only obliquely associated with higher-level processing (e.g. lexical, syntactic, contextual) and that the decisions of *when* and *where* to move the eyes are primarily determined by low-level (non-linguistic) visuomotor factors[3–5]. As such, the decision of where to move the eyes is said to be determined by visual properties of text (e.g. word length, spaces between words) and by limitations in visual acuity. In addition, fixation durations are posited to be primarily a function of where the eyes fixate within a word. In support of an oculomotor approach, studies which have examined landing positions within words have found that the location of fixations within words is not random, rather there is a preferred viewing location – readers' eyes tend to land somewhere between the middle and the beginning of words[6–8]. Moreover, for long words, readers initially fixate near the beginning of the word and then make a refixation near the end of the word[9–13].

Strategy-tactics model

The 'strategy-tactics model'[4,5,14,15] is one of the more prominent oculomotor models. Proponents of this model account for landing position effects by positing that words are identified most accurately and are less likely to be refixated when they are fixated just to the left of the middle of the word (where identification is maximal in isolated word recognition experiments). As such, according to the 'risky' strategy inherent in the model, readers move their eyes in order to fixate on this optimal viewing position within each word. Readers may also adopt a more 'careful' strategy: when the eyes land on a nonoptimal location, a refixation is needed and the eyes are moved to the other end of the word. Thus, the probability of refixation is a function of lower level visual factors (i.e. where the eyes landed in the word) and does not depend on higher-level lexical processes. Moreover, lexical factors (such as word frequency) only influence fixation durations in two cases: when there is a single long fixation on a word or when there are two fixations (the second of these fixations may then be modulated by linguistic factors).

Counter to these predictions, Rayner *et al.* found that readers were more likely to refixate on low-frequency words than on high-frequency words[16]. In addition, word frequency was found to have an effect on the first of two fixations in cases where readers made two fixations on a word. Thus, although oculomotor models have been instrumental in revealing the relationship between eye movements and reading processes, they appear to be limited in scope. Specifically, such models have focused almost exclusively on the lower lever oculomotor factors involved in reading, but have not addressed the influence of higher-level cognitive factors. In support of the oculomotor approach, low-level variables such as word length have been found to strongly influence both where readers fixate next and the amount of time a reader fixates on a word[16–18]. Moreover, when readers are asked to move their eyes over text-like material (where all letters in the text have been replaced with z's), many of the characteristics of eye movements in reading are preserved[19], although there

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Box 1. Eye-movement characteristics

Jerry is usually quite grouchy until he has had his morning coffee and read the paper.

Fixations	*	*	*	*	*	*	*	*	*	*	*	*	*
Order	1	2	3	4	5	7	6	8	9	10	11	13	12
Duration (ms)	311	218	266	202	182	233	178	193	215	227	233	145	288

Fig. I. An example of a reader's eye fixations during reading. Note that there is considerable variability in fixation time (fixation durations range from 145 ms to 311 ms) and saccade length (which ranges between 3 and 15 letter spaces). Average fixation duration is 222 ms and average forward saccade length is 8.1 letter spaces. Of the 13 fixations, two (fixations 7 and 13) are regressions (with an average saccade length of 7.5 letter spaces).

As readers become more proficient, their eye-movement behavior changes (see Table I). Less skilled readers (beginner, poor, and dyslexic readers) typically have longer fixations, shorter saccades, and make more fixations (including regressions) than skilled readers. Although it has been suggested that faulty eye movements cause reading problems, it is more likely that eye movements are a reflection of reading problems and not the cause of them[a].

Saccade size in reading can be measured in terms of degrees of visual angle or in terms of number of letter spaces. The appropriate measure to use is letter spaces since the number of letters traversed by saccades is relatively invariant when the same text is read at different distances, even though the letter spaces subtend different visual angles[b,c].

One might infer from Table I that skilled readers fixate nearly every word while they read (because they make 94 fixations per 100 words). However, although most words are fixated, many are skipped (so fixation of each word is not necessary) and some are fixated more than once. Content words are fixated about 85% of the time, although function words (which are shorter) are fixated only about 35% of the time[d,e]. As word length increases, the probability of fixating (and refixating) a word increases[f]; 2–3 letter words are fixated around 25% of the time, whereas words 8 letters or longer are almost always fixated (and are often refixated).

The fact that some words are skipped and some are refixated makes it difficult to measure processing time for a word[g]. Using mean fixation duration is inadequate because it underestimates the time the eyes are on a word. For example, in Fig. I, the word *grouchy* has two fixations (for 202 ms and 182 ms; thus, the average fixation duration would be 192 ms) before the eyes move to the next word. Using only words that are fixated once (single fixation duration) is problematic because some words are refixated (*grouchy*) and many words are skipped. Therefore, the most common measures used are first fixation duration (the duration of the first fixation on a word regardless of whether it is the only fixation or the first of multiple fixations; 202 ms for *grouchy*) and gaze duration (the sum of all fixations on a word prior to moving to another word; 384 ms for *grouchy*). A final measure is the total time on the word, including regressions (378 ms for *read*). Because total time includes subsequent regressive fixations, it is not diagnostic of initial processing time. Other measures, such as the probability of skipping, the probability of regression, initial landing position, spillover time (duration of the fixation following the target word) and so on, are also typically examined.

In cases when the unit of analysis is larger than a word, first pass reading time (the sum of the individual fixations) is generally used as the primary measure. However, there is controversy about how to best analyze larger regions of text, particularly when readers make regressions[a,h]. In general, it is important to distinguish between first-pass and second-pass (re-reading) time for the region. When regressions occur, it is appropriate to use a procedure in which first pass reading time represents the sum of all fixations starting in a region and ending with the first forward saccade past the region under consideration[h,i].

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Table I. Developmental characteristics of eye movements during reading

	Grade level[a]						
	1	2	3	4	5	6	Adult
Fixation duration (ms)	355	306	286	266	255	240	233
Fixations per 100 words	191	151	131	121	117	106	94
Frequency of regressions (%)	28	26	25	26	26	22	14

[a] Grade 1 children in the US are typically 6 years old, when reading instruction begins.

are some clear differences in fixation times[20]. However, fixation times have also been found to be affected by a number of lexical, syntactic, and discourse variables[21–24]. Even when low-level factors such as word length are held constant, word frequency, in particular, has been shown to have a profound effect on fixation times as readers spend more time fixating lower frequency words, which are less likely to be encountered during reading, and less time fixating higher frequency words[16,25–28]. In addition, when words are highly predictable from previous context, readers tend to fixate on them for less time[21–24].

Box 2. Perceptual span issues

The main reason we make saccades so frequently is because of acuity limitations. In reading, our visual field can be divided into three different regions with respect to our fixation point: foveal, parafoveal and peripheral. Although acuity is very good in the fovea (the central 2 degrees of vision), it is not nearly as good in the parafovea (which extends to 5 degrees on either side of fixation), and it is even poorer in the periphery (the region beyond the parafovea). Hence, we move our eyes to place the fovea on that part of the text we want to see clearly.

How much information can be obtained in a given eye fixation? To determine the answer to this question, the classic eye-contingent display change techniques were developed (see Fig. I). In the moving-window technique, the text is perturbed except for an experimenter-defined window region around the point of fixation[a]. Readers are free to move their eyes wherever they wish, but the amount of information that is available on each fixation is controlled in that wherever the reader looks, text is visible within the window (but the text outside of the window is perturbed). In the example in Fig. I, the spaces between words are not preserved outside this window, whereas in other cases, the spaces are preserved. In the moving-mask technique, wherever the reader fixates, a mask obscures the text around fixation whilst normal text is presented beyond the mask region[b]. Just as with the moving window, the size of the mask can be varied. In the boundary technique, a single critical target word is initially replaced by a non-word or by another word[c]. When the reader's saccade crosses over an invisible boundary location in the text, the initially displayed stimulus is replaced by the target word. If a reader obtained information from the initially presented stimulus, any inconsistency between what was available on the fixation after crossing the boundary and what was processed on the prior fixation (when information about the initial stimulus was processed) should be reflected in the fixation time on the target word.

Studies using these techniques have indicated that the perceptual span is relatively small (see Ref. d for a summary). For readers of English, the span extends from the beginning of the currently fixated word (but no more than 3–4 letters to the left of fixation) to about 14–15 letter spaces to the right of fixation. However, information needed to identify words is obtained only out to about 7–8 letters to the right of fixation. Readers also focus their attention so that information is not acquired from below the currently fixated line[e]. Finally, the characteristics of the writing system and reading skill have major impacts on the size of the perceptual span[d].

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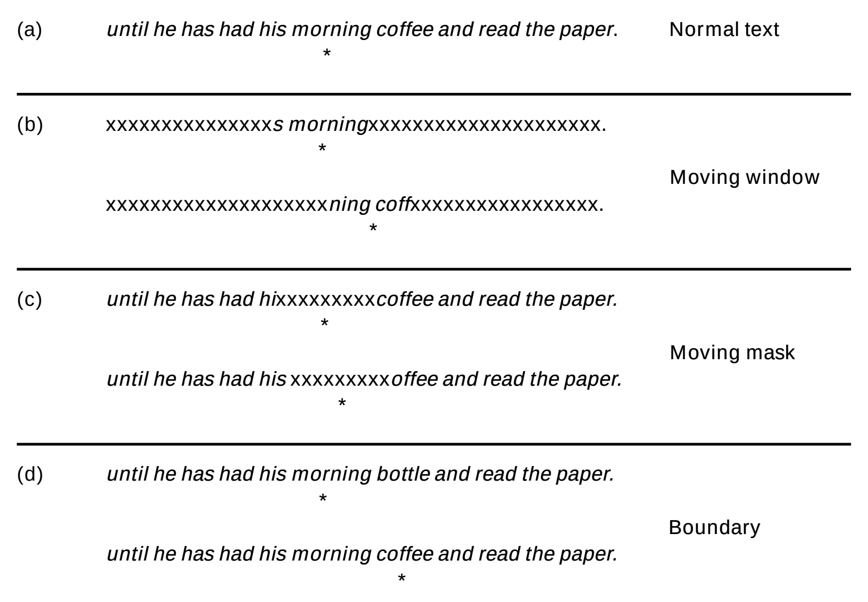

(a) *until he has had his morning coffee and read the paper.* Normal text

*

(b) xxxxxxxxxxxxxxxx*s morning*xxxxxxxxxxxxxxxxxxxxxx.

*

Moving window

xxxxxxxxxxxxxxxxxxxxx*ning coff*xxxxxxxxxxxxxxxxx.

*

(c) *until he has had hi*xxxxxxxxx*coffee and read the paper.*

*

Moving mask

until he has had his xxxxxxxxx*offee and read the paper.*

*

(d) *until he has had his morning bottle and read the paper.*

*

Boundary

until he has had his morning coffee and read the paper.

*

Fig. I. Examples of the moving window, moving mask, and boundary paradigms. The first line shows a normal line of text with the fixation location marked by an asterisk. The next two lines show an example of two consecutive fixations with a window of 9 letter spaces (with other letters and spaces replaced by x's). The next two lines are an example of two consecutive fixations with a moving mask. The bottom two lines show an example with the boundary paradigm. The first line in the boundary example shows the text prior to the display change. When the reader's saccade crosses and invisible boundary location (the *g* in *morning*), the initially displayed stimulus (*bottle*) is replaced by the target word (*coffee*). The change occurs during the saccade so that the reader is not aware of the change.

Given that frequency and predictability influence fixation time, researchers favoring a processing account believe that fixation times are primarily influenced by lexical factors and moment-to-moment comprehension processes. In general, processing theorists don't exclude the influence of low-level oculomotor factors, but they think that their influence on fixation time is small relative to the influence of cognitive factors. Thus, although they believe that the decision of when to move the eyes (how long to fixate) is strongly influenced by cognitive processing, the decision of where to move the eyes is primarily a function of oculomotor and visual factors[29] (with perhaps some influence from linguistic factors).

E-Z Reader Model

One recent processing model which embodies such a framework is the 'E-Z Reader'[29–32] (and see also

Ref. 33 for a precursor of the model). In its current instantiation, E-Z Reader accounts for a number of variables which have been found to influence both the when and where of eye movements, and it has been implemented as a computational model (and can hence be used to both simulate and predict eye-movement behavior). In general, E-Z Reader includes four processes: a familiarity check, the completion of lexical access, the programming of saccades, and the saccades themselves. Upon first fixating a word, the familiarity check begins. At the same time, lexical access (i.e. word recognition) of the fixated word begins, but the familiarity check is completed first. Once the familiarity check has been completed, an initial eye-movement program to the next word is initiated and the lexical access process continues (in parallel), either of which may be completed first. Finally, lexical access is completed (the word is recognized). Although a thorough description of the model is beyond the scope of this article, E-Z Reader has been able to account for many findings from the eye-movement literature.

Although there have been some attempts to implement oculomotor models[15], such endeavors have not accounted for as wide a range of eye-movement phenomena as has E-Z Reader. The onus is thus on proponents of oculomotor models to provide the degree of formalism and testability that has arisen from processing models[34].

The extraction of information from parafoveal vision

Recently, there has been growing interest in the type of information obtained from parafoveal vision. One simple indication that readers process parafoveal words in some fashion is that short function words[35–38] and words that are highly predictable from the preceding context are more likely to be skipped[21–23] than are words which are not predictable. Such a pattern in skipping rates indicates that readers obtain information from not only the currently fixated word, but from the next (parafoveal) word as well.

In addition to skipping, parafoveal information clearly affects how far readers move their eyes and where the eyes land in a word. Thus, saccade length is influenced by both the length of the fixated word and the word to the right of fixation[6,35,39]. Likewise, where the eyes land in a word is influenced by how far away from the word the eyes were on the prior fixation (the launch site): if the launch site is further away, the eyes tend to land closer to the beginning of the newly fixated word than if the launch site is closer to the beginning of that word[7,16]. Also, if the beginning of a word contains an orthographically irregular letter cluster, the initial landing position of the eyes deviates towards the beginning of the word[40,41]. These effects are all due to low-level factors. However, to what extent does higher-order semantic information influence where the eyes land? Underwood *et al.* embedded two types of target words in sentences[13]: those that were either highly identifiable from their beginning letters (e.g. *quarantine*) or from their ending letters (e.g. *underneath*). They found that saccades into parafoveal words were longer when the informative information was located towards the end of the word compared with the beginning, suggesting that some aspect of meaning was processed in the parafovea. However, this result was not replicated in more finely controlled experiments[11,40]. More recently, it was found that readers' initial fixations were shifted towards the ends of words which were preceded by semantically associated prime words, although the effect was only found for high-frequency targets (and when the preceding fixation was close to the beginning of the target word)[42]. On the other hand, other recent studies confirmed that although predictable words are skipped more frequently than unpredictable words, the landing position in the word is little influenced by predictability or contextual constraint[16,43].

Parafoveal-preview benefit

There is also interest in the extent to which parafoveal words influence fixation times and how word information that is partially processed on one fixation is completed on the next[1,44]. Given that both the bounds of visual acuity and the width of the perceptual span (see Box 2) allow readers to perceive information in the parafovea, it is not surprising that information is obtained from the word to the right of the currently fixated word. Specifically, in experiments using the paradigms described in Box 2, it has been demonstrated that useful information is obtained from parafoveal words on fixation *n* that facilitates processing of that word on fixation *n+1*. Furthermore, if parafoveal information is denied, reading rates decrease rapidly[45]. This advantage gained by the availability of useful information in the parafovea is termed 'parafoveal-preview benefit'. However, although it is clear that readers process some degree of information from the parafovea, there is controversy as to the conditions and/or limits of such processing.

The earliest experiment using the boundary paradigm (Box 2) indicated that readers at least glean some low-level information from the parafovea[46]. A number of studies have also found that readers obtain sub-lexical information from the parafovea such as partial word information[47,48] (i.e. from the first three letters of the parafoveal word) and phonological information[49]. However, one important question is whether higher-level processing of lexical and semantic information takes place parafoveally. Inhoff and Rayner found that more information is extracted from a high-frequency parafoveal word compared with a low-frequency parafoveal word indicating that some level of

Box 3. Display change effects

Many studies involve eye-movement contingent display changes (see Box 2). In such studies, text displayed on a computer screen is manipulated as a function of where the eyes are fixated. One important issue is whether the 'flashes' (i.e. phosphor persistence) from display changes themselves influence eye-movement behavior. If this were the case, the utilization of display changes could introduce an unwanted artifact into the results[a].

A number of factors indicate that display changes *per se* do not influence eye-movement behavior. Although the speed of display changes in early studies was limited, current technology has improved to a point where display changes may be implemented within approximately 5–7 ms. Given the speed of the display change, in moving window experiments, readers remain unaware that a display change took place as long as the mask outside the window is not too distinctive[b]. Moreover, in a more direct study of display changes, Inhoff *et al.* manipulated both the refresh rate of the computer screen (with faster refresh rates corresponding to less flicker) as well as phosphor persistence (i.e. how long the masked word's luminance persisted after the mask was presented) and found that effects resulting from display changes were not affected by flicker or persistence for display change rates that are typically used[c].

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parafoveal lexical processing is possible[26]. Balota *et al.* also found that the degree of contextual constraint affected subsequent fixation times on parafoveal words[21]. Specifically, the extraction of information from the parafovea was more efficient when parafoveal words were highly constrained by sentential context compared with when they were not.

Despite the finding that lexical and sub-lexical information may be gleaned from the parafovea, it appears that semantic information (i.e. meaning) is not integrated across consecutive fixations. Rayner *et al.* used the boundary paradigm (see Boxes 2 and 3) and presented readers with four types of parafoveal previews to the right of a currently fixated target word[50]: baseline (*tune*), orthographically similar (*turc*), semantically related (*song*), or semantically unrelated (*door*). They only found parafoveal-preview benefit in the baseline and orthographically similar conditions, and there was no difference in preview benefit between the semantically related and unrelated conditions. They concluded that semantic information was not obtained from the parafovea. More recently, Altarriba *et al.* used fluent Spanish–English bilinguals in a boundary study[51] in which previews were either cognates (*crema* was a preview for *cream*), non-cognate translations (*fuerte*, which means strong, was a preview for *strong*), pseudo-cognates (words that are unrelated except that they are orthographically similar such as *grasa* as a preview for *grass*), or unrelated words (*grito* as a preview for *sweet*). There was no preview benefit from non-cognate translations and whatever benefit accrued from cognates was due to orthographic overlap of preview and target as there was as much preview benefit for the pseudo-cognates as for the cognates. The finding that there is no benefit from meaning overlap is surprising since there are many studies showing that a semantically related prime presented in the fovea facilitates processing of a subsequently presented target word (using priming paradigms)[52]. Perhaps the difference is due to the fact that the quality of information obtained from parafoveal vision is not as precise as that which can be obtained from the fovea.

Finally, Henderson and Ferriera found that when processing of the currently fixated word is difficult (as in the case of a low-frequency word), parafoveal processing becomes less efficient and parafoveal-preview benefits disappear[25] (see also Ref. 53). However, another study showed that this effect was limited to cases where the eyes fixated on the last three characters of the foveal word[54]. Hence, one task for researchers interested in the extent of parafoveal processing is to not only determine the extent or limitations of parafoveal processing, but to delineate the conditions under which parafoveal processing is minimal or optimal.

Is word processing in reading serial or parallel?

Most of the research done to examine parafoveal processing has focused on the fact that information extracted from the parafoveal word decreases fixation time on that word when it is subsequently fixated. However, relatively few studies have examined whether information located in the parafovea influences the processing of the currently fixated word or, in similar terms, whether two or more words may be processed in parallel during reading. Some models of reading, like E-Z Reader, posit that attention during reading acts like a spotlight shifting from word to word in a serial fashion. Given this general framework, parafoveal preview benefits are obtained when attention shifts off the currently fixated word to the next word in the text. Hence, even though the eyes remain on the currently fixated word, attention moves to the word to the right of fixation, and processing of that word begins. However, since processing may not take place in the absence of attention, current models presume that information from the right parafoveal region doesn't have an effect on processing of the currently fixated word.

Until recently, many researchers agreed that word processing during reading was serial. Carpenter and Just used linear regression techniques to examine the influence of word length and frequency of parafoveal words[55]; they concluded

Questions for future research

- What are the relative influences of low-level perceptual factors and higher-level cognitive factors on eye movements during reading?
- What causes regressive eye movements during reading?
- What precisely influences skipping and refixations on words?
- How much and what kinds of information can be extracted from the parafovea? Why doesn't semantic information in the parafovea affect where readers fixate within words and for how long? Are there circumstances when semantic information does have an effect?
- What are the limits of processing during reading? Can two or more words be processed in parallel, or are readers always limited to processing one word at a time?

that the word to the right of fixation had only small effects on the processing of the currently fixated word. Similarly, other experiments have found that the frequency of the word to the right of fixation had no effect on the fixation time on the currently fixated word[56,57].

Evidence for parallel processing

In contrast to these studies, some recent findings have indicated that words may be, to some extent and under some circumstances, processed in parallel. Murray used a word comparison task in which readers had to detect a one-word difference in meaning between two sentences[58]. Fixation times on target words were shorter when the word to the right of the currently fixated word constituted a plausible continuation of the sentence as compared with an implausible continuation. Similarly, Kennedy instructed participants to judge whether successively fixated words were identical or synonymous to one another, and found that viewing durations on target words were longer when the first three letters of the word to the right of fixation had a high frequency of occurrence as compared with a low frequency of occurrence[59].

Although these findings seem to indicate that two words can be processed in parallel, it is possible that such effects only emerge in 'non-natural' reading tasks. Specifically, it could be argued that studies that have failed to find parallel processing during reading have used tasks which required readers to read sentences, whereas studies that have succeeded in finding such effects have used tasks that do not mimic reading so clearly. However, Inhoff *et al.* used a normal reading task and found that fixation times on target words were a function of information to the right of the target, although the influence of such information was limited[60]. Fixation times were shorter when the word to the right of fixation was consistent with prior sentence context compared with when the word to the right of fixation simply consisted of a random letter string, indicating that readers extracted some information from the right of fixation while concurrently processing target words.

If two words were processed in parallel, this would be problematic for serial attention-shift models (such as E-Z Reader). Research has demonstrated that low-level visual features and some forms of sub-lexical information (e.g. partial word identity, beginning letters) are extracted from the parafoveal word in parallel with processing the currently fixated word. If such concurrent parafoveal-on-foveal effects are limited to the processing of low-level information, there would be no inconsistency with serial models. Thus, in addition to the serial (spotlight) attention mechanism currently implemented by the E-Z Reader model, a second attention mechanism dealing solely with low-level processing could be invoked; such an idea would not be inconsistent with the model. However, if higher-level semantic information is extracted from foveal and parafoveal words simultaneously, then more major modifications to serial spotlight models will be necessary. One potential solution would be to abandon the serial framework of attention in models of eye-movement control and replace it with a parallel mechanism. One viable candidate for such a mechanism might be some type of gradient model. Here, attentional resources would be distributed along a gradient similar to a normal distribution curve, with maximal attentional resources peaking at or near the fixated area and gradually decreasing towards the periphery. Words would thus be processed in parallel, although the processing of information would be most accurate at the center of the attentional distribution, and the shape of the attentional distribution would change with task demands. However, such a model seems rather complicated and would be difficult to implement in a computational model. Thus, a challenge for proponents of a parallel mechanism of attention during reading is to delineate the parameters of such a framework.

Conclusions

Although the use of eye-movement data has greatly enhanced our understanding of the reading process, there are still a number of outstanding issues that need to be addressed. We have delineated three of the more prominent controversies, including the nature of eye-movement control itself, the extent of parafoveal processing, and whether words are processed serially or in parallel. Better understanding of these issues will not only help researchers focus on the more contentious issues in eye-movement research, but will also aid in the understanding of the reading process in general.

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