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Letters to the Editor

Reading Unspaced Text is Not Easy: Comments on the Implications of Epelboim *et al.*'s (1994) Study for Models of Eye Movement Control in Reading

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Epelboim, Booth, and Steinman [1994 *Vision Research*, *34*, 1735–1766] recently published an article in this journal in which they argued that "unspaced text is relatively easy to read" (p. 1760). From this they concluded that the spaces between words "are relatively unimportant for guiding reading eye movements" (p. 1760). We have serious reservations concerning these conclusions. In this letter we argue that (1) reading unspaced text is not easy for most readers and (2) there are more diagnostic ways to examine the role of spacing. We also comment on the implications for models of eye movements in reading.

Eye movements Reading Saccades Unspaced text

READING UNSPACED TEXT IS NOT EASY

Epelboim, Booth, and Steinmann (1994) imply (see p. 1739) that their study is quite novel. However, they overlooked a study reported by Spragins, Lefton, and Fisher (1976) which was conceptually very similar to theirs.‡ Epelboim *et al.*'s primary manipulation was simply to present text with and without spaces, and the major case for unspaced text being "relatively easy" was a comparison of reading rates for spaced and unspaced text. However, Spragins *et al.* (1976) had exactly the same kind of manipulation with more subjects than Epelboim *et al.* used and with somewhat different conclusions (see below). Moreover, two experiments that we discuss later (Morris, Rayner, & Pollatsek, 1990; Pollatsek & Rayner, 1982) examined how space information influences eye movements using a subtler manipulation than conjoining all the words on a line of text. Where Epelboim *et al.* go beyond the prior literature is in their analysis of saccade lengths and landing positions in words. However, for reasons we discuss later, we are not sure that the pattern of data substantially alters the general conclusions that can be drawn from the study.

From their data, Epelboim *et al.* concluded that (1) "spaces...do not play an important role in the programming of reading eye movements" (p. 1764); (2) "unspaced text is relatively easy to read" (p. 1760); and (3) "subjects found reading unspaced texts easier than anticipated" (p. 1742). These conclusions are difficult to refute because they rely on nebulous terms such as "important role", "relatively easy", and "easier than anticipated". However, they convey the impression that reading unspaced text was about as easy as reading normal text.

We believe this conclusion is misleading in two ways. First, it is inconsistent with the data and conclusions of earlier studies in which unspaced text was read. Second, it is an accurate representation of only one, or at most three, of the subjects in Epelboim *et al.*'s experiment. Consider the most comparable experiment in the literature by Spragins *et al.* (1976). Spragins *et al.* found (see Table 1) that the average reading rate with unspaced text was about half that of text with normal spacing (a 48% decrease for unspaced texts, 256 vs 134 wpm). In Table 1 we've also presented data from control conditions of Morris *et al.* (1990) and Pollatsek and Rayner (1982). In these conditions, subjects read text with spaces filled with either random letters, digits, or Xs between the words. As can be seen in Table 1, the data from these experiments are consistent with those reported by Spragins *et al.*

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‡Epelboim *et al.* did cite a chapter by Fisher (1976) which contains some preliminary results of the study reported by Spragins *et al.* However, Epelboim *et al.* incorrectly noted that Fisher found that "even first grade children were able to read texts with spaces removed" (p. 1739). First, the subjects in the experiment were third-grade children (not first-graders), fifth-grade children, and adults. Second, there was a 25% decrease in reading rate when the third-grade children read unspaced text compared to normal text. In the remainder of this letter we will focus on the adult subjects for comparability with Epelboim *et al.*'s subjects.

TABLE 1. Reading rate (wpm) for normal and unspaced text

	Normal	Unspaced
Spragins et al. (12 subjects)	256	134
Epelboim et al.		
JE	242	130
ME	232	189
RS	270	260
AG*	180	120
BG*	245	120
CL*	200	110
SS*	195	160
Pollatsek & Rayner (11 subjects)		
Letter fillers	305	129
Pollatsek & Rayner (11 subjects)		
Digit fillers	305	177
Morris et al. (14 subjects)		
Xs as fillers	296	204

The subjects marked with an asterisk read the text aloud (all other data values are based on silent reading); their reading rates are based on our "eyeballing" the histograms shown in Epelboim *et al.*'s Fig. 3.

Now, consider the Epelboim *et al.* experiment. There were seven subjects* in the experiment: three who read both aloud and silently (RS, ME, and JE) and four who read aloud only (AG, BG, CL, and SS). Four (JE, AG, BG, and CL) showed similar effects as the subjects of Spragins *et al.*, two (SS and ME) showed only about a 15–20% decrease in reading speed with unspaced text, and one (RS) showed no decrease in reading speed with unspaced text (see Table 1). Averaged over all seven subjects, this was a 30% decrease for unspaced texts and averaged over the subjects except for RS, this was a 36% decrease. Thus, the findings of Epelboim *et al.* do not differ substantially from those of the earlier study. At most, they may indicate that there are a few individuals for whom reading unspaced text comes relatively easy.

Given that the Epelboim *et al.* data are roughly consistent with the other studies in Table 1, it's not clear what their data add to the literature. We already knew that subjects can read with normal comprehension (but with reduced rates) with various sorts of mutilated texts (Kolers, 1968; Kowler & Anton, 1987; Inhoff, Pollatsek, Posner, & Rayner, 1989). For example, when letters within words are normal but the words are ordered from right to left, reading speed is slowed down by about 30% (Inhoff *et al.*, 1989). Or in a moving window situation (using eye-contingent display change techniques to control the amount of information available on each fixation), when the only letter information available to the reader is the fixated word, reading speed is also slowed down by about 40% (Rayner, Well, Pollatsek, & Bertera, 1982). (Comprehension is normal in both cases as it is in the Epelboim *et al.* study.) What would normally be concluded from such findings are, respectively, that readers do use (1) left-to-right word order and (2) information beyond the fixated word in normal reading, although these forms of information are not necessary for the reader to extract meaning from print.

In contrast, Epelboim *et al.* find that readers do worse when spaces are removed, but (because the decrement is not catastrophic) conclude that spaces are not used or, at least are not important, in guiding the eyes in reading. This seems like a strange conclusion to draw from the data. The fact that readers can soldier on and read reasonably fluently without this information is clearly of interest; it indicates that space information (like information to the right of the fixated word) is not absolutely necessary in reading. (The historical review provided by Epelboim *et al.* documents this nicely.) However, the fact that readers are substantially slowed when space information is removed indicates that it is typically used.

A BETTER DIAGNOSIS OF THE ROLE OF SPACING IS POSSIBLE

The focus of the Epelboim *et al.* article is on models of eye control in which the target for the saccade from word N (the fixated word) to word $N + 1$ is provided by the spaces surrounding word $N + 1$. Largely on the basis of (1) their analyses of their reading rate data and (2) analyses indicating that the pattern of saccade sizes and landing positions in words was not very different between spaced and unspaced texts, Epelboim *et al.* concluded that space information is not important in reading normal text. We have criticized this conclusion above because their own data and that of Spragins *et al.* have in fact shown that most readers are slowed down appreciably when reading unspaced text.

Difficulty with unspaced text does not necessarily mean, however, that providing a target for aiming a saccade to the next word is important for reading at normal speed. Removing the spaces from text, as Spragins *et al.* and Epelboim *et al.* did, degrades the text in many different ways. One obvious way in which spaced and unspaced text differ is that removing the spaces makes it harder to tell where the beginnings and ends of words are; this would make lexical access more difficult, even lexical access of the word that is fixated. If so, then removing spaces may make reading more difficult for reasons at least one step removed from guiding eye movements.

As noted earlier, we conducted two studies (Morris *et al.*, 1990; Pollatsek & Rayner, 1982) in which we attempted to determine why removing space information impaired reading. We make no claims that these experiments are definitive, as it is difficult to completely unconfound variables in reading. However, we think they help to advance what we know beyond what can be learned from the Spragins *et al.* and Epelboim *et al.* studies.

Our studies are briefly cited by Epelboim *et al.* but then are dismissed as employing eye-contingent displays and thus highly suspect due to the presence of (a) interference from the subject "noticing" display changes

*In addition to the seven subjects mentioned here, two other bilingual subjects (CE and ZP) read spaced and unspaced text aloud in their native tongue and in English. CE showed no difference between spaced and unspaced text when reading Dutch, but read English unspaced text slower than spaced text; ZP read unspaced text slower than spaced text in both Polish and English.

and/or (b) phosphor persistence artifacts.* This dismissal, however, appears to be based on a very superficial understanding of these studies. [To keep the discussion brief, we will confine ourselves to the earlier study by Pollatsek and Rayner (1982).] First, there were baseline conditions (see Table 1) in which display changes were made only during saccades (when they are virtually never noticed by the subjects). Second, all display changes in the Pollatsek and Rayner (1982) study involved *adding* points to the display (replacing blank spaces with space-filling material). Hence there was no phosphor to decay and no phosphor decay artifact.

The logic of the experiments was as follows. We varied both the type of space-filling material and its location to assess what aspects of space information were important to reading. The use of display changes was to assess when in a fixation space information was being extracted. In these experiments, the words in the text were never directly joined as in Epelboim *et al.*; instead, they either appeared with the normal space between the words or else the space was filled in with either a letter, digit, or grating (which was not letter-like). No manipulation is perfect, but manipulating the *type* of information that is filling the space allows some conclusions to be drawn about what is important about space information.

In the condition in which spaces were filled with digits, these space fillers should have afforded reasonably good information about where words began and ended (in order to guide lexical access) but should have disrupted eye guidance because the space between words was no longer present. We found that reading in such conditions (when there was no display change during a fixation) was slowed by about 40%; this suggests that the lack of space information itself (rather than not having information to indicate where the end of the fixated word was) is likely to be important in reading (see Table 1). In the conditions in which letters filled the spaces and hence lexical access was likely to be severely disrupted (as in the Epelboim *et al.* study), reading was slowed by about 60% (see Table 1). In Expt 2 we introduced another condition in which the spaces were filled with a grating which looked even less like a letter than one of the symbols on the top row of a typewriter keyboard. This space filler should have had less effect on lexical access than a digit space filler and yet its deleterious effect on reading (relative to when letters filled the spaces) was roughly the same as that of the digits in Expt 1.

We must concede, however, that Expt 2 only had conditions in which the spaces were filled in at some time after the beginning of a fixation. Thus it is possible that a display change during a fixation could have been disruptive (in and of itself) independent of the information content of the display change. Two aspects of the data argued against this. First, the data of both Expts 1 and 2 indicated that reading performance was worse the earlier in the fixation the space filling information occurred and was worst when the space filling material appeared with zero delay (i.e. was filled in during the saccade). Thus, it appeared that the primary determinant of reading performance was how long the reader had to process the space information and not whether the display change itself was interfering. If the disruptive nature of the delay change was important, reading in the zero display conditions (where there was no noticeable display change) should have been better than the conditions when the display change occurred during the fixation; in fact reading was slowest in those conditions. Second, we introduced a condition in Expt 2 in which a separated version of the grating appeared: half of it was just above the line of text and the other half was just below the line of text. Reading in this condition was essentially the same as in the control condition (normal text). This also indicates that the mere presence of foreign material in the display and its onset after the beginning of fixation had little or no effect on reading.†

We should add that the contingent display technology also allowed us to be diagnostic about which spaces were important. In particular, we had two spatial conditions: one in which all spaces to the right of the fixated word were filled in (*all spaces filled*) and those in which the first space (the one between word N and word $N + 1$) was preserved (*first space preserved*). Basically, what we found was that subjects could read appreciably better in the first space preserved conditions, although readers were still about 10% slower in the zero delay first space preserved conditions than when reading normal text. Thus, it appears that although the absence of spaces to the right of word $N + 1$ plays some part in reading, the absence of the first space (the one between words N and $N + 1$) is the primary space information used by readers of English.

Even though these data provide a clearer picture of the use of space information than those of Spragins *et al.* and Epelboim *et al.*, one still needs to be cautious about an interpretation. That is, although we tried to fill in spaces with information that would minimally disrupt

*Phosphor persistence is admittedly a potential problem in most display change experiments. However, the following points should be noted: (1) in some well-known display change experiments, there was virtually no difference between conditions in which the case of the letters changed and those in which the case of the letters did change (Rayner, McConkie, & Zola, 1980; McConkie & Zola, 1979)—a result which indicates that phosphor persistence is unlikely to be important; (2) Briihl and Inhoff (1995) argued that if display changes affect the data in contingent display change experiments, certain conditions (those in which the change from one fixation to another is greater) should yield more interference than others—they found that such interference was not evident in the data they examined from a display change experiment.

†We are not claiming that people were not aware of the display changes made during the fixations; they were probably aware of almost all of them. However, the data indicate (as we argue in the text) that these changes appeared to have little effect on their reading behavior. In contrast, when display changes are made during saccades, subjects are virtually never aware of them when they are reading for comprehension. In fact, even in conditions when there was a single word in the display and the primary task was to judge whether a display change had occurred or not, and the display change was relatively subtle, ds were < 1 (Rayner, 1978). (In these kinds of conditions, subjects may be detecting many of the display changes by noticing phosphor persistence.)

lexical access, we have no guarantee that filling in the space between words N and $N+1$ did not have an important effect on lexical access of word N. For example, it could be that the space to the right of the word is an integral part of the orthographic sequence used to access the word. In fact, internal examination of our data (essentially the time–course data) convinced us that at least part of the interference caused by filling in the space between words N and $N+1$ was due to interfering with lexical access of word N.

Thus, Epelboim *et al.* may be partially correct in their conclusions. That is, although filling in spaces does have a marked effect on reading, the effect may have little to do directly with the control of eye movements. We now turn to what one can say about that from such experiments.

MODELS OF EYE CONTROL

Space does not permit a discussion of the analyses provided by Epelboim *et al.* on the details of the eye movement records. Essentially, what they found is that the spatial aspects of the eye movement record (saccade length and landing positions in words) looked similar with and without spaces. Thus they concluded that spaces are of little importance in guiding eye movements. The logic that Epelboim *et al.* use is not strong as the most plausible alternative to accepting the null hypothesis that space information is not used in normal reading is hard to discriminate from the null hypothesis (see below).

Consider for a moment the model of eye movement control in reading proposed by Morrison (1984). Essentially, it claims that lexical access of each word (possibly modulated by text factors) drives the eyes. When each word is accessed, it sends a signal to process "the next word" in the text. With additional assumptions based on Becker and Jurgens (1979), this model also nicely explains how words are skipped and why some fixations fall on the spaces between words (Rayner & McConkie, 1976). We believe that the data (McConkie, Kerr, Reddix, & Zola, 1988; O'Regan, 1981; Rayner, 1979) show that in most places in reading, the translation of "the next word" sent to the visual system is: fixate the middle of the string of letters between the first and second spaces to the right of fixation. This command is not executed without noise, of course; there are both consistent errors (a tendency to undershoot) and random variation. It should be pointed out that even in normal reading, this is not the invariable command sent to the visual system when a word has been successfully processed and, at return sweeps, the visual system must somehow perform a more complex act to fixate near the beginning of the next line or at the top of the next page.

What would be the most plausible strategy if the visual information that would support such a strategy was removed? It would seem likely that the reader would attempt to move ahead roughly the distance of an average word, or possibly a little more if, on some occasions, more than one word is processed on a fixation. If that were the case, one would predict that the average saccade length would not be terribly different when space information is present and when it is absent. Thus, a finding that the measures reported by Epelboim *et al.* (such as average saccade length) were not much influenced by the absence of spaces would not be strong evidence that spaces are not used in normal reading. In fact, in our study (Pollatsek & Rayner, 1982), we found that eliminating the second space (the one between words $N+1$ and $N+2$) had as its primary effect increasing fixation time rather than decreasing saccade length. This would be consistent with our discussion above. That is, deprivation of space information causes subjects to perform a more effortful calculation of where to go, but the eyes go more or less to the same place as when the space information is present.

Finally, Epelboim *et al.* concluded from many of the details of their analyses that there is only marginal evidence that eye movements are guided by moment-to-moment aspects of the text. Again, space does not permit a discussion of most of their analyses. One analysis is worth mentioning, however, because their analyses are to some extent divergent from other data in the literature. Numerous experiments (McConkie *et al.*, 1988; O'Regan, 1981; Rayner, 1979; Vitu, O'Regan, & Mittau, 1990) have found that readers tend to land most frequently between the beginning and the middle of a word in reading. Epelboim *et al.* concluded that their data "provide only ambiguous support for the importance of the OVP" (p. 1760; ovp stands for "optimal viewing position"). However, examination of their Fig. 9 suggests to us that JE, and to some extent ME, show patterns of landing positions that are fairly typical of what has been reported in the past. It is only RS who appears deviant. Although Epelboim *et al.* used a highly accurate eye recording system, we can not see how the differences could be ascribed to the somewhat greater accuracy of their eye movement apparatus; less accurate systems should have produced noisier data.

SUMMARY

In this comment we have been fairly critical of Epelboim *et al.* (1994). We would like to point out that many of the analyses that they conducted detailing the characteristics of saccades during reading unspaced text are interesting and that they have provided some useful information. However, we also think that they made some serious errors. In particular, as we have noted here, they overlooked some relevant research (Pollatsek & Rayner, 1982; Spragins *et al.*, 1976) and the conclusions that they reached are largely based on one subject. It seems pretty evident that a careful analysis of their own data as well as prior experiments makes it clear that reading unspaced text is *not easy* for most readers. We would also argue that while readers may be able to read without spaces (albeit with some difficulty), when space information is available it is most likely that readers utilize it in programming saccades.

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