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The Relative Importance of Spaces and Meaning in Reading

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Abstract

The relative importance of meaning (semantic context) and spaces between words during reading was investigated. Subjects read paragraphs of coherent or incoherent text aloud; some paragraphs were presented normally, others with spaces between words removed. Coherent paragraphs were taken from a short story. Incoherent paragraphs had the same words and punctuation as the coherent paragraphs, but the order of these words was randomized, resulting in text devoid of meaning normally provided by context and syntactical structure. As expected, spaced text was read faster and with fewer pronunciation errors than unspaced text, and coherent text was read faster and with fewer pronunciation errors than incoherent text, regardless of the presence or absence of spaces between words. Removing spaces slowed reading down less and caused fewer pronunciation errors when the text was meaningful (coherent), than when the text was meaningless (incoherent), so spaces helped more when the text was meaningless than when the text was meaningful. The fact that spaces between words were more important for reading meaningless text than for reading meaningful text suggests that semantics, rather than spaces, are the more important determinants of reading speed and errors.

Introduction

Current theories of reading stress the importance of gross visual features of the text, namely, spaces between words (interword spaces), for guiding saccades as the text is read (*e.g.* Pollatsek & Rayner, 1982; Morris, Rayner, & Pollatsek, 1990, Rayner, 1993; O'Regan, 1990; Rayner & Pollatsek, in press). This claim has been questioned recently. Epelboim, Booth & Steinman (1994; in press) found that subjects could read texts from which interword spaces were removed with only modest decrements in reading speed. Two subjects even read unspaced texts as quickly as they read spaced texts, despite the fact that they had had no prior experience reading unspaced texts.

Epelboim *et al.* (1994) also found no differences in where, within words, subjects fixated, or in the percentage of their regressions, a widely-used measure of reading difficulty. These and other results allowed Epelboim *et al.* (1994) to conclude that the same oculomotor strategy was used for reading spaced and unspaced texts, and that cognitive factors, such as word recognition, rather than gross physical features of the texts, such as spaces, were the primary determinants of saccadic programming and reading rates.

These findings should not come as a surprise because many ancient, as well as modern languages, such as Thai and Japanese (see Fig. 1), do not place spaces between words

ดอยตุงคือชื่อของเทือกเขาสูงทางตอน
เหนือของจังหวัดเชียงราย ดินแดน
สูงสุดยอดในสยาม
ณ เทือกเขาสูงชันแห่งนี้เป็นอาณา
จักรของการผสานกลมกลืนระหว่างภูมิ
อากาศที่หนาวเหน็บ และความงดงามของ
ทิวเขาสูงชันที่ลดหลั่นไล่เรียงกันไปบน
พื้นที่กว่าเก้าหมื่นไร่ในเขตอำเภอแม่จัน
และแม่สายของจังหวัดเชียงราย

Figure 1: A passage of Thai text. Thai is an alphabetic language containing 44 letters. Small symbols that appear above some of the letters are part of the letters, and cannot, by themselves, indicate word boundaries. Spaces in Thai text (there are 3 in this passage) are used to separate phrases, not single words. The English paraphrase of this passage is: "Doi Tung is the name of a high mountain north of Chiang Rai, Thailand's northern most province. Covering an area of some 90,000 rai in Mae Chan and Mai Sei districts, the mountain has cold climate and picturesque scenery."

in text. Some modern languages, such as Dutch and German, are sparsely-spaced — they contain many very long, compound nouns. Consider the following Dutch sentence and its literal English translation:

> Op het treinmachinistencongres waren
> vertegenwoordigers van de arbeidsinspectiedienst
> van spoorwegpersoneel maar ook
> perronkaartjesverkopers en fietsenstallingbewakers.

> At the train drivers congress were representatives
> of the labor inspection service of railway employees
> but also platform ticket sellers and bicycle shack
> custodians.

A reader, relying on spaces for saccadic programming, would have difficulty reading this Dutch sentence. Although it is possible that readers of generously-spaced languages, such as English, depend on spaces for saccadic programming, and that some other oculomotor strategy is used for unspaced or sparsely-spaced languages, a more parsimonious theory of reading is possible. It only requires emphasizing words, recognized or anticipated on the basis of meaning derived from context (syntax and semantics), rather than placing emphasis on spaces between unprocessed groups of letters, to guide the line of sight through the text.

Semantics is a defining feature of all languages and its importance in reading has been known for a long time. Huey (1900) showed that meaning increases the rate with which progressive saccades can be made. This finding was confirmed recently by Kowler, Pizlo, Zhu, Erkelens, Steinman & Collewijn (1992). Both studies showed that making reading-like saccades through a "text", where all but the first letter of each word was blocked out, was slower than reading the same text with the words intact and meaning preserved.

Removing spaces between words influences semantics, as well as changes the physical appearance of the text. Letters around word boundaries in unspaced texts can be grouped incorrectly, altering the meaning of a phrase being read (see Jusczyk, 1986, p. 27-2). It has been shown that many kinds of transformed texts can be read fairly easily as long as familiar letter patterns (words or morphemes) are not disturbed. When letter patterns are disturbed, however, reading becomes very difficult (Kowler & Anton, 1987; Kolers, 1968). These considerations suggest that word recognition, not saccadic programming, limits reading speed. Unspaced texts are read more slowly than spaced texts because when spaces are removed, word recognition becomes more difficult. Epelboim *et al.* (1994) supported this idea by showing that keeping words intact was more important than having spaces in a text. Removing interword spaces from a meaningful text did not reduce reading rates nearly as much as keeping spaces, but putting them at inappropriate places in the text. The latter made reading nearly impossible.

The goal of the present study was to determine the relative importance of spaces and meaning for reading. It had been shown previously that reading lists of unrelated words takes longer than reading the same words presented as meaningful text (Biemiller, 1977-78), suggesting that a meaningful context facilitates word recognition. If difficulty in *word recognition* slows reading of unspaced text more than spaced text, meaningless unspaced text should be harder to read than meaningful, unspaced text. If, however, removing spaces disturbs *saccadic programming*, differences between spaced and unspaced reading rates should be the same regardless of whether the text is meaningful or meaningless. This proved *not* to be the case.

Method

Subjects

Four undergraduate students in the University Honors Program and three graduate students at the University of Maryland served as subjects. All were native English speakers with normal or corrected to normal vision, and were naive as to the purpose of the experiment.

Materials

Text, presented white on a blue background, was taken from "The Blue Cross" in *The Innocence of Father Brown* by G.K.

Spaced Coherent

```
Between the silver ribbon of morning
and the green glittering ribbon of sea,
the boat touched Harwich and let loose
a swarm of folk like flies, among whom
the man we must follow was by no means
conspicuous -- nor wished to be.
```

Spaced Incoherent

```
Papered for strong Castor to element
had and stand ridiculous really up and,
but they instant robbery sea his brown
I still he face turn brain, early then
and was he show wisdom one of do judge
peppermints -- had splash he it.
```

Unspaced Coherent

```
Probablyhewouldtravelassomeminor
clerkorsecretaryconnectedwithit;
but,ofcourse,Valentincouldnotbe
certain;nobodycouldbecertainabout
Flambeau.
```

Unspaced Incoherent

```
Valentinorfirstsecondheweretalks
whileheeagernesstangerinetheyat;
and,hesprang,colossusnamedtheit
snail's;motorsotherhefeelingspell
suddenly.
```

Figure 2: Different kinds of text used in the experiments.

Chesterton. The paragraph structure of the story was altered so that each paragraph contained between 9 and 11 lines of text that were presented, double-spaced, on a computer monitor (IBM 486DX). These paragraphs served as "coherent", meaningful text. The text chosen for this experiment was fairly difficult. Difficult text was used deliberately in order to avoid ceiling effects, which would be a problem with easy text in which reading speed would be determined by the speed with which subjects could pronounce the words as they read normal text aloud, rather than by inherent differences in the experimental variables of interest, *i.e.* spaces and meaning.

"Incoherent", meaningless, text was created by replacing each word in the "coherent" text with a word of equal length taken randomly, without replacement, from within the entire story (65 paragraphs). This procedure equated word frequencies and the placement of spaces. Punctuation marks and capitals were also preserved. As a result, coherent and incoherent paragraphs had similar gross visual characteristics, word lengths and word frequencies.

Coherent and incoherent paragraphs were presented both with spaces between words and with spaces removed (see Fig. 2). Displays of spaced texts were about 60 characters wide. Spaces were taken out without readjusting line-width, leaving the mean number of words per line the same in both spaced and unspaced texts, but a line of spaced text was about 15% wider than a line of unspaced text. Coherent and incoherent conditions were run in separate blocks, with a 10 minute break

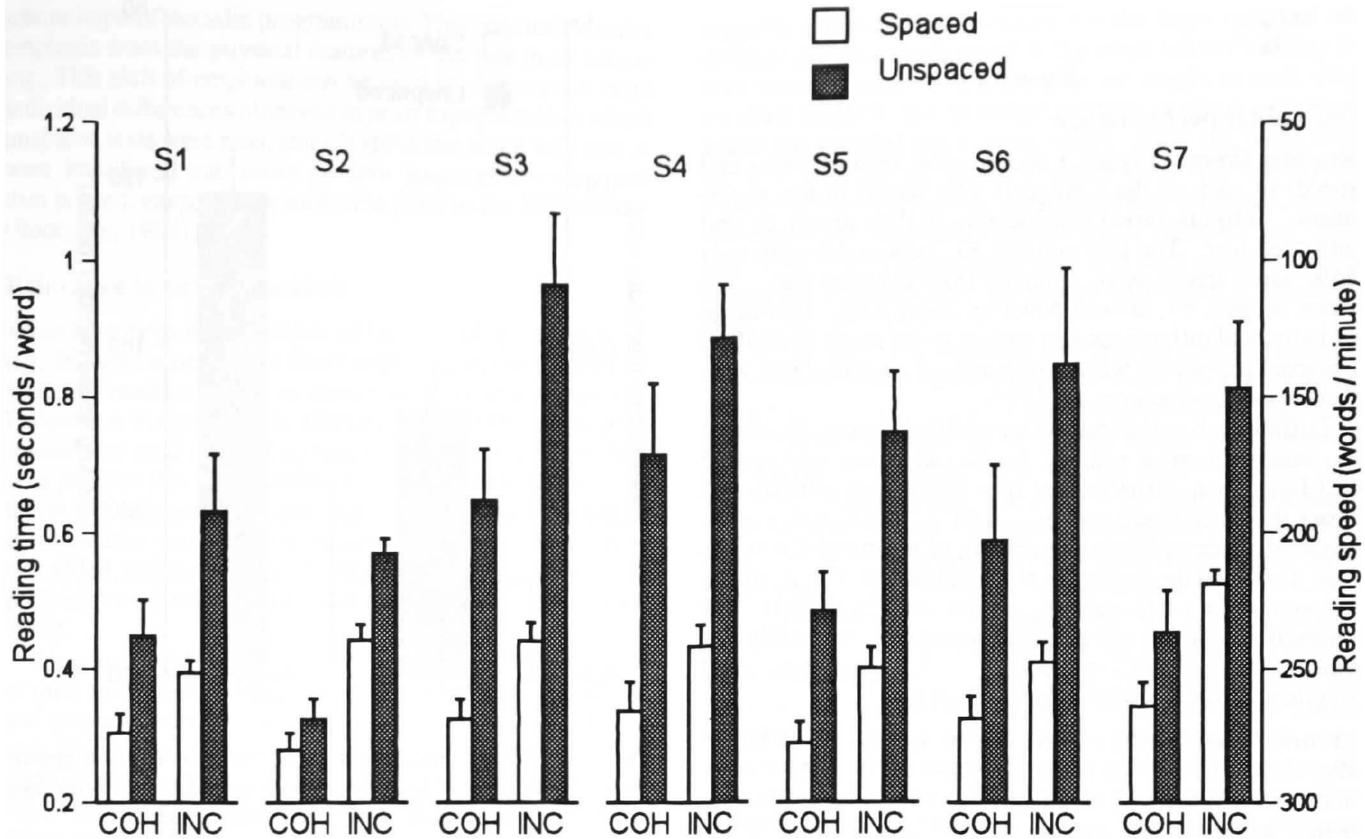

Figure 3: Mean reading times (seconds/word — left ordinate) and speeds (words/minute — right ordinate) for 7 individual subjects (labeled S1–S7 on top) reading coherent (COH) and incoherent (INC) paragraphs. Open bars show means for spaced text, filled bars show means for unspaced text. Error bars show 1 SD. Each bar is based on 10 paragraphs.

in between. Within each text condition, each subject read 10 paragraphs in alternating pairs of 2 spaced and 2 unspaced paragraphs.

Procedure

Before the start of each session, the subject positioned the chair and the display screen such that the text was clearly visible. Subjects were told not to start a trial unless they could clearly see a sentence indicating the nature of the upcoming paragraph ("The next paragraph will be spaced" or "Thenextparagraphwillbeunspaced"). Subjects fixated on the capital "T", the first letter of this introductory sentence, which appeared at the upper left corner of the screen. This position corresponded to the location of the first letter of the upcoming paragraph. The space-bar was pressed when ready to read, and pressed again as soon as the paragraph had been read, at which time the paragraph disappeared. Reading time of each paragraph (bar press to bar press) was recorded to the nearest 10 ms.

Blocks started with 2 spaced and 2 unspaced practice paragraphs followed by 20 test paragraphs. Subjects read aloud and their speech was recorded. They were told to read with meaning, to articulate each word, and that they would have to summarize the story later.

All paragraphs were read aloud and the subjects' speech was recorded. Reading aloud provides an unambiquous and continuous measure of reading competence, that is, the speech can be scored for errors in pronunciation and intonation. This measure was particularly important for reading incoherent text, where comprehension could not be measured in any other way. In our view, reading aloud is the best way to study reading, especially when processing meaning is an important feature, as it is in our experiment, because asking subjects to read aloud provides the only way to monitor comprehension as text is actually being read. Posthoc questioning, the only way to test silent reading, continues to be controversial (*e.g.* Katz, Blackburn & Lautenschlager, 1991; Freedle & Kostin, 1994; Katz & Lautenschlager, 1995). Inasmuch as there is no evidence that reading silently and reading aloud are fundamentally different (see Epelboim *et al.*, 1994, for a recent comparison of silent reading and reading aloud), we believe that reading aloud should be the preferred paradigm in reading research. Although most reading in everyday life is silent, it is difficult to understand the role of variables in the text being read, such as spaces and meaning, if comprehension cannot be indexed as the reader proceeds through the text. This is not possible when text is read silently.

Pronunciation of each word was scored for accuracy into 4 categories: 1) "Errors" — words pronounced incorrectly; 2) "Hang-ups" — words repeated inappropriately, but eventually pronounced correctly; 3) "Deletions" — words not articulated; and 4) "Additions" — words articulated, but not in the text.

Results

Individual performance

Reading times. Figure 3 shows mean reading times and speeds of each of the 7 subjects who served in this experiment. Subjects varied considerably in their ability to read unspaced text. The best subject, S2, slowed down by only 14% when spaces were removed from coherent text. The worst subject, S4, slowed down by about 53%. This range of individual differences was similar to the range (0 to 48%) observed previously when paragraphs of unspaced text were read aloud (Epelboim *et al.*, 1994).

Despite such within subject variability, all subjects showed the same pattern of results. Specifically, they read spaced text faster than unspaced text ($p < 0.001$) and coherent text faster than incoherent text ($p < 0.001$). In addition, the absence of spaces affected the reading of meaningful text less than it affected the reading of meaningless text, that is, spaces helped more when no meaning was provided by context. This interaction between spaces and meaning was statistically significant for 6 of the 7 subjects ($p < 0.01$) and approached significance for the other subject (S4, $p < 0.1$).

Errors. Only pronunciation errors, type 1 (see Method above), will be considered here because the number of deletions and additions were too small to allow meaningful statistical analyses. The number of hang-ups, although larger, showed only the main effect for spaced vs. unspaced reading. The percentage of type 1 errors ranged from 0 to 9%.

The pattern of errors was the same as the pattern of reading rates, that is, the subjects made more errors with unspaced than with spaced text, and more errors with meaningless than with meaningful text. The effect of spaces was statistically significant for all six subjects, whose errors were scored ($p < 0.001$; pronunciation data for S7 could not be reported because of a recorder problem). The effect of meaning was statistically significant for 4 of these subjects ($p < 0.001$) and approached significance for the other 2 ($p < 0.1$). As with reading times, the absence of spaces increased the number of errors more when the text had no meaning. This interaction between spaces and meaning was statistically significant for S1 and S2 ($p < 0.05$), approached significance for S3 and S6 ($p < 0.1$), and was not significant for S4 and S5.

The pattern of reading times and errors for individual subjects reported just above supports our hypothesis that meaning and word recognition are more important for reading than spaces and saccadic programming.

Group performance

A common approach in reading research is to report data averaged over all subjects with no discussion of the data of individual subjects or indication of the within-subject variability. This approach is unfortunate because reading characteristics are long known to vary greatly among individuals (*e.g.* Buswell, in Kolers, 1976), which means that the pattern of results observed with averaged data need not be indicative of what individual subjects actually did. The next section is included to present a summary of the data averaged over all subjects for those readers accustomed to considering reading data presented in this form. In our experiment, grouping the data, fortunately, did not distort the pattern of results observed with each individual subject in any way.

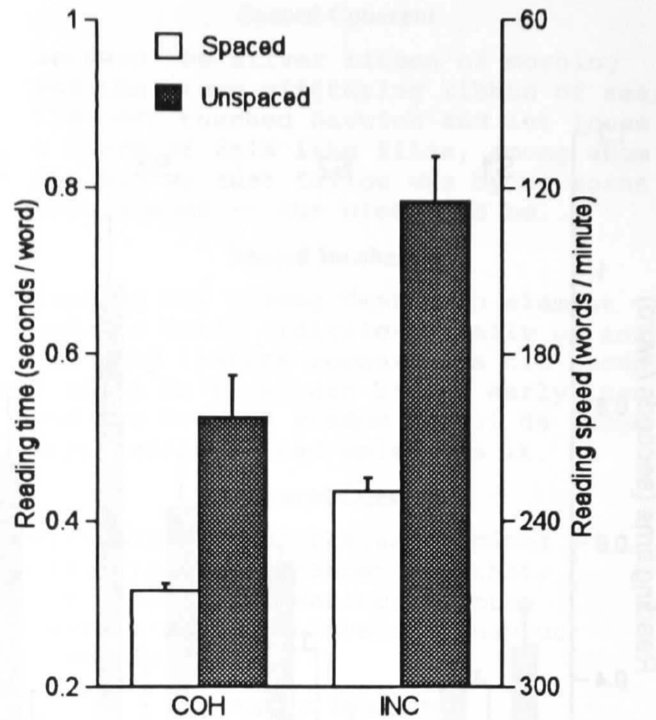

Figure 4: Mean reading times (seconds/word) and speeds (words/minute) averaged over all seven subjects. Error bars show 1 SE based on the individual subject means.

Reading times. The mean reading times and speeds averaged over all seven subjects are shown in Fig. 4. The pattern of group performance was similar to the performance of the individual subjects. As a group, subjects read spaced text faster than unspaced text ($F(1,256)=379.74, p < 0.001$), and read meaningful text faster than meaningless text ($F(1,256)=158.39, p < 0.001$). As was the case with individual subjects, spaces and meaning interacted ($F(1,256)=27.25, p < 0.001$).

Errors. The group pattern of errors was also the same as the pattern for reading times. Subjects made fewer errors when they read spaced text than when they read unspaced text ($F(1,256)=108.04$, $p < 0.001$) and fewer errors when they read meaningful text than when they read meaningless text ($F(1,256)=43.67$, $p < 0.001$). The interaction between spaces and meaning was also significant ($F(1,256)=17.71, p < 0.001$).

Discussion

Reading times and error rates were influenced by the absence of spaces more when the text being read had no meaning. Furthermore, meaningless text benefitted more from inter-word spaces than meaningful text. These findings support the hypothesis that reading slows down when spaces are removed because removing spaces impairs word recognition when letter groupings become ambiguous, and not because removing spaces impairs saccadic programming. This conclusion shifts emphasis from the physical features of the text to its meaning. This shift of emphasis can be used to: (1) explain large individual differences observed in prior experiments in which unspaced texts were read, and (2) speculate about why spaces were introduced into many modern languages, written and then printed, unspaced for millennia prior to the 16^{th} century (Boorstein, 1983).

Relevance to prior research

There have been many studies of the role of spaces in reading. In most, spaces were filled with a variety of characters, including random letters, random numbers and gratings (*e.g.* Pollatsek & Rayner, 1982; Morris *et al.*, 1990). Most prior studies also used isolated sentences rather than coherent text — a practice that de-emphasizes meaning conveyed by context in ordinary text. The only experiments, to our knowledge, in which interword spaces were simply removed with nothing else added, and in which coherent paragraphs were read, were performed by Fisher and his collaborators (reviewed in Fisher, 1976).

Spragins, Lefton & Fisher (1976) measured reading rates of third-graders, fifth-graders and adults as they read normal and unspaced paragraphs. Third-graders read unspaced texts only 26% slower than they read spaced texts, whereas adults and fifth-graders read unspaced text about 49% slower. Reading unspaced text became *poorer* as reading skills improved! Spragins *et al.* explained this result by suggesting that the younger children suffered less from the removal of spaces because they did not use peripheral visual information about the gross shapes of the words to the right of fixation. According to this hypothesis the children read letter-by-letter or, at best, one word at a time.

An alternative explanation, based on our results and other recent developmental research is possible. Once emphasis is placed on the meaning of the text rather than on its physical appearance, the results of Spragins *et al.* can be explained differently. Namely, it is well-known that younger children use context information about meaning more during reading than adults and older children (Schwantes, 1991; Stanovich, 1980). Thus, when third-graders read unspaced texts, they benefited more from the context of the paragraph than older children or adults. Older children and adults rely more on recognizing individual words than on context when they read. They discriminate words more easily and guess less about what is coming up in the text. When interword spaces are removed, however, some letters may be grouped inappropriately to form words that do not fit within the context of the paragraph. Having to resolve conflicts between the meaning of the text and the words being recognized visually takes time, which results in slower reading. When letter-grouping errors occur in meaningless, incoherent text, they are more difficult to resolve because there is no context to help the reader decide which grouping forms *the* appropriate word. For this reason reading without spaces is more difficult when the text has no meaning.

Individual Differences

The tendency to use context less as reading becomes more skilled, well-documented in the Developmental literature, suggests a plausible explanation for the large range of individual differences observed in the adult subject's ability to read unspaced text. When children are taught to read, they are often taught by the "phonics" method, in which individual letters are sounded out to form words. Early on, when they are slow at sounding letters, children must rely heavily on context to recognize words. As reading skill increases, words are recognized more easily and context is relied on less. This allows reading of meaningless text and even allows reading of text not understood by the reader (Allington & Fleming, 1978; Doehring, 1976).

N.B. The widely-used phonics method for teaching reading is not without controversy, going in and out of vogue cyclicly. Huey, back in 1900, criticized the phonics method, suggesting that children should be taught to read whole words or even phrases, rather than to sound words one letter at a time. Thai children, whose language is unspaced, are taught in the manner suggested by Huey. They are first taught to read individual words, but when sentences are introduced, words within them are unspaced from their very first appearance.

It is possible that some people, like our subjects S2 and S7 (our "best" unspaced readers), retain into adulthood their ability to benefit from context when they read. S2 and S7 slowed down by only 14% and 23%, respectively, when spaces were removed from coherent text. S2 and S7, however, were our "worst" subjects when meaning was removed from spaced text, slowing down by 38% and 35%, respectively. This observation also supports the suggestion that these subjects relied on context more than the other five subjects.

Epelboim *et al.* (1994) also found that some readers were better than others in reading unspaced texts. Their best unspaced-reader was a Dutchman. He read spaced and unspaced Dutch text equally quickly, and unspaced English text only 18% slower than spaced English text. His exceptional ability to read without spaces in both his native and a second language, may have been the result of a lifetime of reading a native language, Dutch, which is sparsely-spaced as compared to English or the Romance languages.

We believe that a *cognitive* explanation of the individual differences in the observed ability to read unspaced text is both more plausible and more satisfying than an explanation that relies on differences in *eye movement strategies*. It seems likely that the large range of abilities observed when unspaced text is read arises from the more efficient use of context, or, from better word recognition skills, or, from a larger available vocabulary, or, from a higher level of reading comprehension, or, from better visual acuity (the hypothesis proposed in Epelboim *et al.*, 1994). All of these cognitive and sensory, rather than oculomotor, characteristics are known to vary widely among individuals. On the other hand, the eye movements of normal readers of different languages show little variability except in global parameters, such as saccade length or direction.

What are spaces for?

Epelboim *et al.* (1994) suggested that one reason spaces between words may have been introduced was to allow reading under poor lighting conditions or with less than perfect vision. Blurry strings of letters separated by spaces can be read more easily than blurry strings of letters not separated by spaces. Another reason, suggested by the present study, may have been to allow people to "read" text they do not understand. Illiterate copiers of manuscripts often put spaces into texts inappropriately for aesthetic reasons, rather than to separate actual words (Boorstin, 1983). These inappropriate spaces, which may have been aesthetically pleasing to illiterate scribes, surely made reading more difficult for those who could understand what they read. Spaces between words, in this view, were introduced into text first to reduce errors in hand-copying by illiterate scribes and then to help illiterate typesetters set and proof text after printing was invented.

Conclusion

Much emphasis in recent years has been placed on the importance of visual features as guides for eye movements during reading. This emphasis derives from the ease with which eye movements can be recorded with modern instruments, and with which texts can be displayed and perturbed contingent on the approximate locus of the line of sight within the text. The role of meaning has not been emphasized despite Buswell's sage pronouncement that "reading is the process of comprehending meanings" (in Kolers, 1976). Our study shows that it may finally be time to accept long known, and rather obvious, facts, and face squarely the message clear in our data, as well as in the history of written languages: *meaning matters*.

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