other. If this mechanism sometimes shows evidence of parafoveal-on-foveal effects, that constitutes a priori evidence that such a process is possible (but not always necessary) in normal reading, just as we assume that syntactic or pragmatic effects sometimes reflected in first fixation durations on a critical word reflect a part of the normal reading process, despite the fact that such early effects are not always found.

It is no exaggeration to say that the time course of syntactic and pragmatic effects can be frustratingly variable. Some investigators, in some experiments (e.g. Traxler & Pickering 1996), tend to find them only "downstream" – in later measures, such as gaze duration, regional reading time, or probability of regressions. Yet other experiments demonstrate very early effects of the self-same phenomena, sometimes on the duration of the first fixation falling on the critical word. Two points are worth making: As mentioned above, variability in the time-course of these phenomena (or the fact that they sometimes show up in longer inspection times and sometimes only as increased regressions) has never been used to call into question the possibility of their (early) existence in normal reading. The second and more critical point is that early effects of this sort should not exist, according to E-Z Reader. It should not be possible for syntactic or pragmatic factors to influence the duration of the first fixation falling on a word, but there is plenty of evidence that they can (see Murray & Liversedge [1994] and Murray & Rowan [1998] for examples, but also many other studies).

When the engine that drives the saccade is 67% of word recognition, how can the timing of that saccade be affected by the nature of the syntactic or semantic combination of the identified form of that word and other words in the text? Even adopting the generous assumption that combinations of this sort start to be computed before complete recognition of the critical word, is it plausible that the consequences of that combination could then be used, within the time frame envisaged, to drive the saccadic mechanism?

The authors state that they wish to begin to incorporate an ability to account for other established linguistic phenomena into E-Z Reader. It is very difficult to see how results such as these could be incorporated, and indeed they call into question basic assumptions regarding the engine. It seems that it is driven more variably across tasks or texts, and sometimes by the properties of more than one word.

On the perceptual and neural correlates of reading models

Naoyuki Osaka

Department of Psychology, Graduate School of Letters, Kyoto University, Kyoto 606-8501, Japan. **osaka@psy.bun.kyoto-u.ac.jp**
http://www.psy.bun.kyoto-u.ac.jp/~osaka/

Abstract: The current model appears comprehensive but is probably not applicable to a writing system like Japanese, which has unspaced text, because the model is mainly based on English. The span size difference (smaller for Japanese than for English) may be a result of high-level working memory-based attentional processing and not of low-level processing. Further, neural correlates of the model are discussed in terms of central executive function.

In introducing the E-Z Reader model of reading, Reichle et al. reviewed the models that explain "the interface between vision and low-level aspects of language processing" (target article, sect. 1) in terms of eye-movement control and visuospatial attention. My first argument is based on the perceptual span and the second one is based on neural correlates of the model. The current model appears comprehensive but is probably not applicable to a writing system like Japanese, because the model is mainly based on English and other Roman alphabet-based script. Regarding perceptual span, for example, measured using the moving-window technique, the size of the span appears smaller for Japanese (about 3–4 character spaces to the right of fixation: Osaka 1992; Osaka & Oda 1994) than for English (about 14–15 character spaces to the right of fixation: McConkie & Rayner 1975). Does this difference in writing systems come from low-level eye-movement control or high-level processing involving attentional dynamics? Moreover, the model expects that the boundary of each word can be easily separated by blank spaces, as in English; that is why Reichle et al. hypothesize that the reader moves her/his eyes guided by the spaces under oculomotor control, as shown in Figures 3 and 5. However, writing systems like Japanese, Chinese, and other oriental languages lack the blank spaces between words in the text (causing a lower spatial frequency region, whereas languages like English involve high spatial frequency); this might introduce difficulty in interpreting eye-movement control tactics in Japanese in the same way as is done with English.

During eye-movement control while reading unspaced text, it was found that the eyes land on the Kanji characters (logographic symbols) more frequently than on Hiragana characters (phonetics symbols) (cf. Kajii et al. 2001) for extraction of meaning during reading. Furthermore, the systematic errors (SRE) estimated in Equation 4 of the target article were derived from English readers whose oculomotor systems "prefer" to make saccades that are seven character spaces in length, according to Reichle et al. However, this value would be influenced by differences in writing style, and most likely be different for different scripts, as described above. An alternative possible tactic under cognitive control is that the phonological loop in working memory determines when to move the eyes in the text. The identification of the currently fixated word may initiate the attentional spotlight (driven by phonological loop) to move to the next word, which in turn initiates the oculomotor system to begin programming a saccade to the next word (Morrison 1984). Further, a longer word takes a longer time to identify than a short word because the phonological loop takes longer for the former during reading, which is explicitly shown as parameter N in Equation 1. Therefore, the validity of a model applicable to a writing system *without* blank spaces might be expected to contribute toward a unified model of reading.

The second argument is based on the neural basis of visuospatial attention. Reichle et al. speak of a "low-level of language processing," not "high-level," when they refer to attention. However, visuospatial attention is not likely to be "low-level." Rather, it might involve more "high-level" processing based on the executive function of the prefrontal brain. Regarding the neural correlates of the model, the E-Z Reader model suggests an attentional neural network in the region around the intraparietal sulci and angular gyrus in the parietal brain; primary and extrastriate visual cortex in the occipital brain, inferior temporal gyrus in the temporal brain, and eye movement-related motor area (BA6 /8) in the frontal brain, are just described in Figure 14. However, the cognitive component of attentional control – that is, executive function, in the prefrontal region (i.e., BA 46/44/9 in the left brain), other than the motor component – seems more closely related to dynamic properties of visuospatial attention during reading. For example, the length of the span that is influenced by the dynamics of allocation of visuospatial attention appears to be increased for subjects with high working memory, with efficient attentional control, compared to that of subjects with low working memory (Osaka & Osaka 2002). This suggests that eye-movement control could also be influenced by attentional control by high-span subjects; in other words, working memory plays an important role in eye-movement control during reading.

Osaka et al. (2003) showed a strong functional connectivity between ACC (anterior-cingulate cortex) and left DLPFC (dorsolateral prefrontal cortex) for attention control during sentence reading: They reported that subjects with high working memory capacity (high reading span score) showed higher efficiency in controlling attention than did low capacity subjects. This was confirmed by a "focus word" experiment performed subsequently

(Osaka et al. 2002). Thus, it is likely that "higher-level" visuospatial attention appears to control optimal eye movement. Phonological store and phonological loop (each assumed to be located in the supramarginal gyrus and inferior frontal gyrus [Broca's area BA44], respectively) are subcomponents of the central executive during sentence reading that could be "interfaced" with the cognitive components of working memory. "Interfacing" refers, in my opinion, to a resource-limited attentional mechanism with executive function (Osaka et al. 2003). Therefore, it is likely that the phonological loop influences eye movements. These data suggest that the eye movement might be influenced both by the writing system and by individual working memory capacity.

Linguistically guided refixations

Jeremy Pacht

Department of Psychology, Glasgow University, Glasgow G12 8QB, United Kingdom. **jeremy@psy.gla.ac.uk**

Abstract: I discuss evidence for direct linguistic control of refixations and argue that the E-Z Reader model's account of refixations requires elaboration or revision.

What are the proximal causes of consecutive fixations on a word in reading? Four suggestions have been advanced: (1) Refixations may be due to oculomotor error in saccades targeted at another word (e.g., McConkie et al. 1989; Pollatsek & Rayner 1990); (2) Refixations may be guided by low-level, nonlinguistic information such as word length (e.g., O'Regan 1992a; Vergilino & Beauvillain 2000); (3) Refixations may reflect a trade-off between linguistically guided decisions to maintain fixation on the current word and to move the eyes to another word (e.g., Henderson & Ferreira 1990; Pollatsek & Rayner 1990); (4) Refixations may be linguistically guided movements targeting another region of the word (Hyönä & Pollatsek 1998; Pynte 1996). The E-Z Reader model allows for only the first two of these possibilities, although the model can account for some of the evidence of linguistic influence on refixation patterns indirectly. This is because the model supposes that dumb refixation decisions are less likely to win a race against linguistically based decisions to saccade to another word when the currently fixated word is (initially) easy to access.

Other evidence of linguistic influence on refixations is less easily reconciled with the E-Z Reader model. One example is evidence from Finnish that properties of a word's morphemes affect refixation location (Hyönä & Pollatsek 1998). The difficulties posed by this finding have been acknowledged in previous expositions of the model, but Reichle et al. (1999) suggest that a homologous adaptation of the current model, adopting the morpheme rather than the word-form as the fundamental lexical unit, might be capable of accommodating this result – in this case, linguistically guided word-form refixations would be reconstrued as linguistically guided intermorphemic saccades. A similar finding, not mentioned in any exposition of the E-Z Reader model, is Pynte's (1996) demonstration (using polymorphemic French words) that refixations may be preferentially directed to whichever region discriminates the word from similar words of higher frequency.

Incidental findings I obtained in a reading experiment using the boundary technique (Rayner 1975), pose further difficulties for the E-Z Reader model. In the experiment, participants read Dutch sentences for comprehension while their eye movements were monitored. Each sentence contained a monomorphemic target word primed by a parafoveal preview of varying orthographic similarity to the target word: The preview was either a higher frequency orthographic neighbor (HFN) of the target word, overlapping with the target at all letter positions but one (e.g., *spier-spies*), or an unrelated word preview, overlapping at zero letter positions (e.g., *jacht-spies*). To guard against the possibility that preview effects would be attributable to something other than the manipulated variable, the two preview groups were equated in terms of predictability from the preceding context, number of syllables and morphemes, word class, word frequency, summed bigram frequency, neighborhood size, number of higher frequency neighbors, familiarity, age of acquisition, imageability, polysemy, and (because the Dutch orthography is highly transparent) regularity. In addition, launch site distributions and the distributions of landing sites on the target word did not differ as a function of preview type. The primary aim of the experiment was to test predictions derived from the results of previous experiments, concerning the interaction of perceptual and lexical factors in visual word recognition. As expected, clear inhibitory effects of orthographic preview similarity were found in eye-movement measures such as gaze duration and total time on the target word, once well-known perceptual constraints were taken into account. The findings have been reported at a number of conferences (e.g., Pacht et al. 1999) and form the basis of a manuscript in preparation.

For present purposes, the most relevant findings concern the pattern of preview effects on the first fixation of refixated target words (FFR) and on target word refixation rates. Many studies have found that target word processing may benefit from the availability of a parafoveal preview sharing the first two or three of the target word's letters (for a review, see Rayner 1998). Consistent with these findings, I found that FFR was facilitated by the HFN preview, provided that the HFN preview and target word overlapped at the first 2–3 letter positions (255 msec vs. 273 msec, $F1(1,50) = 4.24$, $p < .05$, $F2(1,62) = 4.57$, $p < .05$). The E-Z Reader model accounts for this result (and other findings of preview benefit) by assuming the HFN preview facilitated the initial phase of target word lexical access (*L1*). By the same token, the model predicts planned refixations on the target word should have been canceled more often, given the HFN preview, resulting in fewer refixations in that preview condition. However, this was far from being the case: If anything, there was a tendency for target words to be refixated *more* often, given the HFN preview (16% vs. 14%, $Fs < 1$).

A plausible account of these findings is that the HFN preview initially facilitated target word access, by priming representations or form-neighborhoods shared by the target, but subsequently interfered with target word access by activating (or adding to the activation of) its own higher-frequency lexical representation. The initial facilitation elicited a relatively fast decision to move the eye, while later-emerging lexical competition elicited a decision to fixate the current word, which might be construed as the initial "where" decision, or as a supervening "where" decision to maintain fixation or to refixate. Two implications for models of eye-movement control in reading are that the execution of refixations may *follow* execution of linguistically guided saccades (or at least, "when" decisions), and that refixations may themselves be *proximally* (and not only indirectly) controlled by linguistic variables. Both of these implications are at variance with the assumptions of the E-Z Reader model.

In sum, while some refixations may be planned without reference to linguistic information, others appear amenable to direct linguistic influence. I will close by suggesting one way in which my findings might be reconciled with the E-Z Reader model. If refixations are defined not as consecutive fixations on a word but as consecutive fixations during which the current word is processed, then according to the E-Z Reader model some refixations are indeed proximally controlled by linguistic variables and follow execution of linguistically guided "when" decisions. Specifically, the immediate regressions, which the model assumes arise when an intended interword saccade is executed before the current word is fully accessed, may be viewed as refixations following on the heels of a prior but improperly executed attempt to refixate. That is, in such cases, the "intended interword saccade" is in fact intended as a refixation at the moment the movement is executed. This amounts to a proposal that in its labile phase, the interword saccade destined for word$_{n+1}$ may be modified in two ways. First, as the current model allows, in cases where *L1* is completed on word$_{n+1}$, the saccade may be replaced by a saccade targeted on