Table 1 (Sparrow et al.). *Mean observed (obs) and predicted (pred) first-fixation (FFD), single-fixation (SFD), and gaze duration (GD), in milliseconds, for predictable and unpredictable words*

	FFDs		SFDs		GDs	
Predictability	Obs	pred	obs	pred	obs	pred
Low	226	213	232	212	280	240
High	207	209	212	209	235	223
Difference	19	4	20	3	45	17

in the pattern of results for fixation times (Table 1). E-Z Reader did not predict the effect of predictability on first fixation duration and single fixation. With respect to gaze duration, the effect predicted by E-Z Reader was comparable in size to the effect obtained in other studies (Rayner & Well 1996; Rayner et al. 2001), though it was lower than in our study.

A closer examination of the data indicated that the prediction of E-Z Reader was reversed for high frequency words: Fixation duration was longer for predictable than for unpredictable words (Table 2). For low-frequency words, the prediction of E-Z Reader appears to be larger for first and single fixations duration. However, the effect predicted by E-Z Reader on gaze duration was comparable to the effect obtained in our study.

This difference in the pattern of results for fixation duration versus word skipping can be accounted for by the different mechanisms that might be involved with regard to the decision about when and where to move the eye. With E-Z Reader, the time required to complete the first stage of lexical access (i.e., when to move the eye) is principally a function of word frequency and a free parameter (theta; see Equation 1 in the target article) reduces the extent to which the predictability of a word attenuates the lexical processing time. Our data suggests that, in normal reading, predictability can play a more important role during the first stage of lexical access (i.e., L_1).

Finally, the latest version of E-Z Reader appears to be psychologically plausible and gives an accurate account of various phenomena in reading. It is, however, incomplete, as it preferentially takes into account "low-level" aspects of the reading process. This model nonetheless provides a valuable analytical tool to examine some key assumptions about eye-movement and language processing. As an example, we used the model to simulate how individual differences would affect the pattern of eye movements in reading. For this purpose, we compared observed eye movements of dyslexic subjects with the E-Z Reader-predicted data. The observed and predicted values were very close for the duration of first fixation (224 msec and 213 msec respectively for dyslexic subjects and E-Z Reader). However, gaze duration was considerably longer for dyslexics (384 msec) than for E-Z Reader (256 msec). This pattern of results can suggest that later stages of lexical access were impaired in dyslexic subjects, but not the low-level aspect of reading process. Of course, further investigations are required to corroborate this conclusion.

Table 2 (Sparrow et al.). *Effect of predictability for low frequency (LF) and high frequency (HF) words (in msec.)*

	FFDs		SFDs		GDs	
	obs	pred	Obs	pred	obs	pred
LF	15	29	15	29	55	48
HF	22	−23	24	−23	35	−14

Where to look next? The missing landing position effect

Geoffrey Underwood

School of Psychology, University of Nottingham, Nottingham NG7 2RD, United Kingdom. **geoff.underwood@nottingham.ac.uk**

Abstract: The E-Z Reader 7 model is powerful but incomplete. When programming the saccade to the next word, we take into account the familiarity of the letter sequences at the beginning of that word. This landing position effect is well established, but is neglected in the model. A possible locus for the effect is suggested within the E-Z Reader framework.

The E-Z Reader model is clearly our most advanced model of eye-movement control in reading, and this version of the model is particularly welcome as a refinement of an already powerful description. The success with which the model accounts for variations in fixation durations and locations is impressive. The model is incomplete, however, and, like any model, it cannot be considered to be accurate unless it takes account of the full range of phenomena that can be observed. The starting point in the model-building enterprise is to know what it is that is being modeled – what are the phenomena to be taken into account? The E-Z Reader 7 model is impressive in its predictions about an extensive range of effects, but it fails to make predictions about the *landing position effect.* Although Reichle et al. are aware of this effect, their mention of it in the target article is restricted to Note 5. It is unclear whether this is because the authors do not regard it as an effect that requires explanation, or because they cannot see how the model could explain it.

There are two classes of *landing position effects* – the phenomena that reflect the output of the system that decides where we should look next when reading; and Reichle et al. account for the effects of (1) low-level visual factors, such as word length, comfortably. Another class of effects is (2) the influence of the distribution of information within the word that is to be fixated; and this is the effect that Reichle et al. appear to be sweeping under the carpet. Words like *awkward* and *coyote* can be described as having informative beginnings, because they start with uncommon trigrams. In contrast, the words *author* and *compact* start with trigrams that are shared with large numbers of other words. A number of published studies have demonstrated that the reader's eyes land slightly closer to the beginning of the word if the word starts with an uncommon trigram (Beauvillain & Doré 1998; Beauvillain et al. 1996; Everatt & Underwood 1992; Everatt et al. 1998; Hyönä 1995b; Hyönä et al. 1989; Inhoff et al. 1996; Underwood et al. 1990; Vonk et al. 2000). Oculomotor programming is influenced by the information in the word that is the target of the next saccade. This landing position effect has now been demonstrated with a number of different languages and is undoubtedly real, albeit small. Information within the word modulates the tendency to fixate slightly to the left of the centre of a word.

There is a question about the type of information that causes the modulation in the landing position. When we first reported the effect, we considered all options, including the possibility that it was lexical or morphemic information from the beginning of the word that was responsible (e.g. Hyönä et al. 1989; Underwood et al. 1990); but it is now clear that it is the orthographic content of the first few letters that is important. Note 5 of the target article acknowledges this debate but fails to incorporate the effect in the data set that the model should take into account. One reason for this might be that there is a question about the reliability of the effect. Indeed, there are reports of studies that have failed to find the effect for all of the words tested (Liversedge & Underwood 1998; Rayner & Morris 1992; Underwood et al. 1989). This in-

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consistency is possibly attributable to variations in our definitions of an informative or redundant beginning to a word (bigram/trigram frequency vs. predictability by a cloze task), or to variations in cognitive load imposed by the specific reading task, because we know that foveal load influences the effectiveness of parafoveal information (Henderson & Ferreira 1990), or to variations in the reading skill of the participants being tested (see Everatt et al. 1998). The inconsistency of an effect simply means that we have not yet determined the conditions in which it will appear. Not all words are skipped, and not all short words are skipped all of the time, but there is no suggestion that we should ignore this effect because it does not appear with total predictability. The same should hold for the landing position effect.

The conditions for an information-based landing position effect are that (i) oculomotor programming can be modulated by visually available information, and that (ii) orthographic information can be extracted from words currently in parafoveal vision. The evidence supporting both of these conditions is well established. First, landing positions are sensitive to word length, and some short words sometimes receive no fixation at all (target article, sect. 2.8.1). Second, the parafoveal preview effect has been demonstrated for orthographic information (sect. 2.6). The E-Z Reader model accounts very well for these demonstrations of modulation, and when they are viewed together they make plausible the modulation of the landing position by orthographic information.

The landing position effect is plausible on the basis of lability of oculomotor programming and on the basis of the parafoveal processing of orthographic information. It has been demonstrated in a number of experiments that have used a number of alphabetic languages. How then might the E-Z Reader model be developed to account for it? One possibility is that the first stage of word identification (L_1 in Fig. 3), which in earlier E-Z Reader models was described as performing a familiarity check, could identify predictable sequences of letters at the beginning of word$_{n+1}$. If a highly unfamiliar bigram or trigram started word$_{n+1}$, then a shorter saccade may be programmed. If a predictable sequence were detected, then the signal to the oculomotor system would be to start programming a saccade of increased amplitude. And if the word contained a predictable letter sequence and early visual processing had recognised that it was a short word, then the saccade would skip the word altogether. The model could incorporate this effect and make predictions that would help describe it further. The first task of all model-builders is to identify the essential evidence, and here the E-Z Reader model does not so much fall over as turn its back on the data.

The basic assumptions of E-Z Reader are not well-founded

Françoise Vitu

CNRS, Université René Descartes, Laboratoire de Psychologie Expérimentale, 92774 Boulogne-Billancourt, Cedex, France.
francoise.vitu@psycho.univ-paris5.fr
http://lpe.psycho.univ-paris5.fr/page%20perso/Vitu-Thibault/FEVitu.htm

Abstract: This commentary focuses on the two basic assumptions of the E-Z Reader model, discussing the possibility that adjacent words in reading may be processed in parallel rather than serially, and presenting evidence against a cognitive control of eye guidance in reading.

Like several recent models of eye guidance in reading, the E-Z Reader model provides a fairly good account of the variability of eye behavior that characterizes reading. From a psychological perspective, however, the performance of a computational model, or how well simulations fit behavioral observations, is not as critical as the reality of the mechanisms and the processes that lead to such performance. From that perspective, E-Z Reader may not be a serious candidate. In this commentary, I present several findings that challenge the two basic assumptions of the model, suggesting, first, that reading may not proceed through sequential attention shifts, and second, that ongoing processing is not the main driving force behind eye guidance.

The first basic assumption of E-Z Reader posits that for the temporal order of the words to be preserved in reading, adjacent words must be processed serially through covert shifts of attention from the fixated word to the parafoveal word(s). This assumption cannot, however, be asserted based on current empirical evidence. First, as noted by Schroyens et al. (1999), the negative influence of the foveal processing load on parafoveal preview benefit is in no way proof that processing of the parafoveal word starts only when the fixated word is identified. As the difficulty of the foveal word increases, a tendency for greater spillover effects in the visible compared to the masked preview condition can be observed, which suggests that the effect may simply originate from an interaction between processing associated with the foveal and parafoveal words. Furthermore, parafoveal preview benefit becomes greater rather than smaller as the fixation duration increases, thereby indicating that parafoveal processing lasts for the whole fixation time, rather than being limited to the delay that remains from the moment the fixated word is identified until the saccade is ready to go.

On the other hand, the fact noted by the authors, that processing of the foveal word remains unaffected in most instances by the lexical and semantic properties of the parafoveal word, does not necessarily mean that adjacent words are processed in sequence. In the framework of a pure parallel hypothesis that makes no recourse to the notion of attention, the presence of parafoveal-on-foveal effects is indeed not obligatory, but rather is conditional on the respective time course of processing associated with both foveal and parafoveal words (see Vitu et al., in press). As more letters from the parafoveal word fall into a region of lower visual acuity, parafoveal processing is relatively slow compared with that associated with the fixated word; and the likelihood that it influences processing associated with the fixated word may be relatively low, unless the word is very easy to process.

Parallel processing therefore remains a serious alternative to the sequential attention shift assumption, and, given that it relies strongly on visual acuity, it may as well preserve the temporal order of the words. Now, it remains an open question whether keeping word order straight is critical to reading. Indeed, several studies suggest that the eye-movement pattern does not always respect word order. This happens, for instance, when a word that is not yet identified is initially skipped. In that case, the word will be fixated only after the execution of a regressive saccade from one of the following words (Vitu & McConkie 2000; Vitu et al. 1998). These particularities of the eye-movement pattern, which are actually not accounted for by E-Z Reader, bring us to the second assumption.

The second basic assumption of E-Z Reader states that ongoing processing is the main driving force behind eye guidance. Ongoing processing would determine when the eyes move, and which word to send the eyes to, while visuomotor processes would produce systematic errors in sending the eyes to specific locations. Three major objections can be raised against this notion. First, the duration of individual fixations, although being correlated with the difficulty of processing associated with the encountered words, is also strongly influenced by the fixation position, with fixation duration being greatest when the eyes are at the center of words (Vitu et al. 2001). This phenomenon, which is opposed to Rayner et al.'s (1996) finding, is very robust since it was found in three different corpora of eye-movement data (based on a total of 153,855 fixations). Besides being interesting, it seriously questions the cognitive assumption, as it is about twice as large as the effect attributable to word frequency and as it cannot be interpreted in terms of ongoing processing. Because a word is most easily identified when the eyes initially fixate its middle, fixation duration should be shortest rather than longest at that position.

A second objection to the cognitive control hypothesis relates to the postulate that ongoing processing determines which word to