phological subcomponents of words influence the timing of fixations (Andrews et al., in press; Pollatsek et al. 2000) which imply that "units smaller than 'the set of letters between the spaces' can influence the decision of when to move the eyes" (target article, sect. 5.1.2).

Reichle et al. are clearly sensitive to most of the issues I have raised. They acknowledge that their implementation of the two stages of lexical processing is a simplification adopted more for empirical convenience than theoretical commitment and emphasize that the model is not intended to provide a "deep explanation of language processing" but simply "a viable framework" for thinking about how cognitive processes interact during reading. However, it is precisely because of the remarkable success of the relatively simple framework offered by E-Z Reader in accounting for a number of complex features of reading behavior that it seems worthwhile to implement a more sophisticated set of assumptions about the factors influencing lexical processing to provide further support for Reichle et al.'s claim that "the intrinsic nature of the language processing during reading hinges upon word identification" (sect. 4.5, last para.). Validating and refining the distinction between the two stages of lexical access will be crucial to such developments.

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How can selection-for-perception be decoupled from selection-for-action?

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Abstract: Evidence is presented for the notion that selection-for-perception and selection-for-action progress in parallel to become tightly coupled at the saccade target before the execution of the movement. Such a conception might be incorporated in the E-Z Reader model of eye-movement control in reading.

A key assumption of the Reichle et al. model of eye-movement control in reading is that covert attention and eye movements are decoupled. Although the saccadic system relies on a spatial selection mechanism to calculate the saccade endpoint in the next word, shifting of attention refers to the process of disengaging the mechanisms responsible for identification so that they can be shifted to the next word. This conception is based on classic theories of attention – as applied to linear stage models – that assume that it functions to filter certain objects in the environment (Broadbent 1971; Treisman 1969). Capacity limitations at the perceptual stage was Reichle et al.'s central concept, and they considered selection its functional consequence. As with classical linear stage theories, Reichle et al. emphasize dissociation between attention and intention, as perception and action are viewed as relatively distinct. This leads to the hypothesis that the selection for processing is decoupled from the selection of the target for the next saccade. Instead, we think that selection does not require an attentional control system separate from action-perception cycles. Selection-for-perception and selection-for-action accompany each other within a spatial selection window. The preparation of a motor action, however, binds the perceptual system to the movement target. Then, both selection processes are strictly spatially and temporally coupled. This claim may be incorporated in recent modelizations of overt eye movements (Findlay & Walker 1999; Henderson et al. 1999) and covert shift of attention (Itti & Koch 2000), which use the concept of a saliency map, a topographic map that codes the position and relative salience of potential saccade targets.

A growing body of behavioral evidence given in tasks other than reading shows that the preparation of a movement induces a concurrent shift of attention toward the same location (Deubel & Schneider 1996; Hoffman & Subramaniam 1995). The preparation of an eye movement toward an obligatory spatial location enhances the perceptual processing of the stimulus at locations toward which the motor program is directed. We recently described a similar coupling of saccade programming and shift of attention at the intended landing position into spatially extended letter strings (Doré-Mazars et al., in press). Fine-grained information about the time and the location of the attentional shift was obtained by measuring the detection of a letter change that occurred tachistoscopically at different SOAs after the presentation of the letter string and before the saccade execution. The letter change could occur at different positions within the letter string. Given the variability of the actual landing positions within the letter string, it was possible to examine whether actual landing positions are coupled with corresponding attentional shifts. A strict and selective spatial coupling of attention at the saccadic endpoint was found in the last 50 msec preceding the saccade execution. Then, detection capability was shown to be at its best when the letter change location coincided with the actual landing position to decrease at other landing positions. This shows that attention shifted at the saccade target at the expense of the others when the saccade was prepared to be executed. However, before the selection of one precise saccade target, a salient, orthographically illegal cluster at the beginning of the letter string attracted attention automatically, independent of the intended landing position. At this stage, different targets seem to be selected for action and perception. However, when the command to move to a precise target location is sent to the motor effectors, the target that occupies this location receives prioritized visual processing. At this stage, both selection-for-action and selection-for-perception processes are strictly spatially and temporally coupled.

Recent brain-imaging studies have shown that covert spatial attention and overt oculomotor shifts are tightly integrated at the neural level. A large overlapping network of regions including FEF (frontal eye field), IPS (intraparietal sulcus), and STS (superior temporal sulcus) was active during both tasks (Corbetta et al. 1998; Nobre 2000). These studies, however, do not reveal the temporal relationship between the robust, attention-related signals obtained in the frontoparietal network during tasks requiring sustained covert attention to spatial locations in the visual field and the extrastriate activations. ER-fMRI studies, however, suggest that the engagement of a top-down attentional control circuitry that is centered on the dorsal posterior parietal and frontal cortex is the source of the facilitation of attended input in extrastriate visual cortex (Corbetta & Shulman 2002; Corbetta et al. 2000). Recent studies using ERP measurement revealed that directing covert attention to the location of a stimulus results in an enhancement of the P1 and multiple N1 components evoked by that stimulus, compared with the nonattended condition (Hillyard & Anllo-Vento 1998). Spatial attention exerts a selective amplification of sensory information flow in the visual pathways, the early signal enhancement around 80 msec after stimulus onset being localized in extrastriate cortex (Heinze et al. 1994; Martinez et al. 2001; Woldorff et al. 1997) and the later one (100–130 msec) in ventral areas specialized for pattern and object recognition (Mangun et al. 1997). Whether this enhancement in the extrastriate areas is coupled in time with the programming of an eye movement in the frontoparietal network has not yet been studied in humans. There is however, electrophysiological evidence of an activation enhancement around 50 msec prior to the monkey making a saccade to a target in the frontal eye field neurons (Schall & Hanes 1993) and in infero-temporal cortex (Chelazzi et al. 1993).

In short, the Reichle et al. model will likely need modification to integrate the above evidence. The spatial selection window in reading may be defined as a region including several words (Inhoff et al. 2000; Kennedy et al. 2002) that can be processed in parallel with a bias towards higher salience for the fixated word. Dur-

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ing a given fixation, the point of maximum salience dynamically changes to be highest at the saccade word target before the saccade execution. In interactive activation models (McClelland & Rumelhart 1981), the processing systems (as lexical access) are controlled by the connections among different interconnected units (features, letters, and words) and are not capacity limited.

Please stop using word frequency data that are likely to be word length effects in disguise

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Abstract: Reichle et al. claim to successfully simulate a frequency effect of 60% on skipping rate in human data, whereas the original article reports an effect of only 4%. We suspect that the deviation is attributable to the length of the words in the different conditions, which implies that E-Z Reader is wrong in its conception of eye guidance between words.

A computational model is as good as the data it simulates. This is why Reichle et al. rightly pride themselves about the good fit of the model's outcome with human data. The human data predominantly come from a reading study, reported by Schilling et al. (1998), in which 30 college students read 48 sentences. According to Figure 6 in the target article, the observed frequency effects in this study were roughly 70 msec for gaze duration, 30 msec for first fixation duration, and a 60% for word skipping rate. What Reichle et al. did not mention is that the Schilling et al. study was originally designed to look at the word frequency effect under very controlled circumstances (i.e., with words that were matched on all other variables except for word frequency, and with sentence context that constrained the target words equally). Each participant saw a number of sentences with low frequency words (2 per million) and a number of sentences with high frequency words (141 per million). These frequencies probably coincide with the frequency classes 1 and 5 of Figure 6 in the target article. If we look at the data reported by Schilling et al. for these particular stimuli, we obtain a frequency effect of 67 msec for gaze duration and 35 msec for first fixation duration, but only 4% for skipping rate ("Subjects fixated on HF words 89% of the time and on LF words 93% of the time" – Schilling et al., p. 1,272). That is, for this particular subset of well-controlled stimulus words, in Schilling et al., the effects for gaze duration and first fixation duration agree well with the overall data used by Reichle et al., but this is not true for the skipping rate. How come E-Z Reader "correctly" simulates a 60% difference in skipping rate between low-frequency and high-frequency words, whereas in the human data there was only a 4% difference attributable to word frequency?

After a review of all previously published word skipping data, Brysbaert and Vitu (1998) concluded that the frequency effect on word skipping is 4% on average (i.e., exactly the effect reported by Schilling et al., as well), and that the effect was 9% for contextual predictability (i.e., very predictable words in a sentence are skipped, on average, 9% more often than unpredictable words). In addition, they observed a 60% difference attributable to word length: 2-letter words are skipped more than 60% of the time, whereas 10-letter words are virtually never skipped in first-pass reading. To us, these data strongly suggest that what Reichle et al. simulate in the lower part of Figure 6 is not so much a frequency effect on skipping rate but a word-length effect on skipping rate. The authors themselves are clearly aware of this problem, because in Rayner et al. (1998c, p. 256, footnote 3), they wrote:

> In our modelling, to minimize the number of parameters, we did not distinguish between frequency and word length effects. Thus "frequency effects" in our model are really a combination of frequency and word length effects because the two are highly correlated in our sample of text as in printed English in general.

For this reason, we were very surprised to see that in the present article they still refuse to report the data separately for word length and word frequency, even though the current model is supposed to have a mechanism to deal with the effects of the length of the parafoveal word (see Equation 1 of the target article). What we ask is that Reichle et al. give us a figure in which the word-skipping rates of the Schilling et al. corpus are shown as a function of word length and word frequency, together with the predictions of E-Z Reader. If these provide a good fit, we will rest our case. However, we strongly suspect that the model will largely overestimate the effect of frequency and underestimate the effect of word length. For this reason, until proven wrong, we still believe that E-Z Reader is fundamentally flawed in its conception of interword behaviour in general and word skipping in particular.

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Reading the scene: Application of E-Z Reader to object and scene perception

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Abstract: We discuss five basic principles of E-Z Reader in terms of their potential for models of eye-movement control in object and scene perception. We identify several obstacles which may hinder the extrapolation of the E-Z Reader principles to nonreading tasks, yet find that sufficient similarities remain to justify using E-Z Reader as a guide for modeling eye-movement control in object and scene perception.

Eye-tracking has provided vision science with a powerful tool to unobtrusively monitor on-line perceptual and cognitive processing. Unfortunately, eye movement records generate a host of overt measures which all may (or may not) reflect some aspect of covert processing, leading to much debate about which measure would be most appropriate (e.g., Inhoff & Radach 1998). The most promising solution to this debate is to consider multiple eye movement measures simultaneously (Henderson et al. 1999). However, to do this, an integrated model is required that specifies the relations between the various overt measures as well as their correspondence to covert processes. This is precisely what Reichle et al. have achieved with E-Z Reader.

As users of eye-tracking methodology in object and scene perception, we can be only envious of this situation, yet at the same time Reichle et al. inspire some optimism with their suggestion that the basic principles of E-Z Reader may apply to other visual information processing tasks (sect. 4.9). We would like to evaluate the grounds for such optimism by examining five basic principles of E-Z Reader to determine whether and how they can be applied to the study of eye-movement control in object and scene perception.

First, according to E-Z Reader, the main engine of eye movements in reading is serial word identification. This makes sense given (a) the importance of individual word order and meaning to understand the whole sentence, and (b) the ease with which individual words can be segregated from a sentence. In scene perception, neither of these conditions is fulfilled. It is quite possible

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