the following word; second, however, in cases where difficulty is detected in accessing the current word, the saccade may be replaced by a saccade targeted on the same word. The model would then posit two types of refixation, one driven only by low-level factors, the other guided by cognitive constraints.

Regressions and eye movements: Where and when

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Abstract: Reichle et al. argue that the mechanism that determines where to fixate the eyes is controlled mostly by low-level processes. Therefore, unlike other competing models (e.g., the SWIFT model), the E-Z Reader model cannot account for "global" regressions as a result of linguistic difficulties. We argue that the model needs to be extended to account for regressive saccades.

Two basic assumptions of the E-Z Reader model are that the mechanism responsible for *where* to fixate the eyes is controlled mostly by low-level processes, whereas the mechanism responsible for *when* to move the eyes is controlled mostly by cognitive processes. Although the model accounts for fixation durations, refixation/skipping probabilities, and initial landing positions in normal silent reading, it leaves regressive saccades unaccounted for. It is worth noting that a competing model, the SWIFT model (Engbert et al. 2002), can capture both short- (*local*) and long-range (*global*) regressions. Normal silent reading involves not only forward saccades, but also a number of regressions back to the previous word(s) when readers experience some difficulties with linguistic processing (or with oculomotor processes). Bear in mind that regressions represent around 14% of saccades for adults (and around 25% for children; Starr & Rayner 2001). The point we raise here is that, in regressions, the signal of where to send the eye does not seem to be controlled solely by oculomotor variables. Instead, cognitive processes can signal where to fixate the eyes next in order to resolve conflicting information from the text or to finish processing partially encoded information. We present two examples from recent research: one with sentences involving a target word with (or without) higher frequency *neighbors* (the neighborhood frequency effect; "local" regressions) and the other with sentences that include a mild garden path ("global" regressions).

Several eye movement experiments have shown that the number of regressions back to the target word in a sentence increases when the target word has higher frequency neighbors (see Perea & Pollatsek 1998; Pollatsek et al. 1999a). For example, in the sentence "The store didn't sell John's favourite [spice, sauce] any more," readers make more regressions back to the target word *spice* than to the target word *sauce.* (Note that *spice* has *space* or *spite* as higher frequency neighbors; *sauce* does not have any higher frequency neighbors.) Under these conditions, the target word may have been misidentified as the higher frequency candidate (*space* instead of *spice*) or, alternatively, the higher frequency neighbor could have slowed down the final stage of lexical processing (e.g., in an interactive activation system). This actually provokes an increased number of regressions back to the target word for words with higher frequency competitors. In the E-Z Reader model, the signal that word recognition is imminent (*L1* stage) causes the preparation of the saccadic movement on the word_{n+1} before lexical access (*L2* stage) is completed. A regressive saccade may occur when the *L2* stage is long and the reader is still processing the target word. In that case, the target of this saccade is the difficult-to-process word_n. Thus, the E-Z Reader model, despite not having a specific mechanism for regressive saccades, can predict the presence of these "local" regressions as a special type of refixation. It is important to note that the SWIFT model (Engbert et al. 2002), which borrows the two word identification stages from the E-Z Reader model, can also capture these local regressions as a result of incomplete lexical processing.

The E-Z Reader model can accommodate short, local regressive saccades as a special type of refixations. But what about global regressive saccades? Are they simply triggered by high-level processes blindly, in the sense that they do not indicate exactly which part of the sentence the eyes should be directed to? This does not seem to be the case. The pattern of regressive eye movements while reading mild garden-path sentences strongly suggests that readers perform an overt selective reanalysis process (see Meseguer et al. 2002). This process seems to direct the regressive saccade to specific points of the sentence in which relevant information can be picked up (see also, Kennedy et al. 2003). In other words, the reader's eye seems to be intelligently led to the critical part of the sentence. In the E-Z Reader model, only one word can be attended to at a time, and the model has no straightforward means to redirect the eye to the relevant area of the information in the sentence. (These regressive saccades are beyond the scope of the current implementation of the model.) One possible way to accommodate these regressions is to assume that readers have access to some form of spatially coded information (Kennedy 2001). Alternatively, in the framework of a "guidance by gradient" model (i.e., more than one word can be attended to at a time) like SWIFT, it is possible to send the eye back to the critical point of the sentence where the reader experienced some linguistic difficulties (global regressions; see Engbert et al. 2002, Fig. 7).

Therefore, one challenge of a sequential attention-shift model like the E-Z Reader is to specify in detail how regressions are made without violating the "when/where" principle. We agree with Reichle et al. that it may be difficult to make precise predictions in parsing experiments. However, inclusion of an explicit mechanism for regressions is not an obstacle. As stated above, the SWIFT model captures the presence of global regressive saccades by assuming that the gradient of attention is not confined to individual words, but rather, to a wider attentional window. We should also note that this issue may be linked to the fact that readers seem to extract information from more than a word at a time (see Inhoff et al. 2000). Whether these are critical limitations for attention-shift models (note that these models can be considered extreme cases of "guidance by gradient" ones) is a matter for future research.

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Attention, saccade programming, and the timing of eye-movement control

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Abstract: E-Z Reader achieves an impressive fit of empirical eye movement data by simulating core processes of reading in a computational approach that includes serial word processing, shifts of attention, and temporal overlap in the programming of saccades. However, when common assumptions for the time requirements of these processes are taken into account, severe constraints on the time line within which these elements can be combined become obvious. We argue that it appears difficult to accommodate these processes within a largely sequential modeling framework such as E-Z Reader.