Table 1. (Inhoff & Shindler) *The size of the saccade to the target (in character spaces) and ensuing target first fixations and gaze durations (in msec) as a function of the length and the orthographic informativeness of the preview*

	Matched length		Mismatched length	
	Letter preview	No preview	Letter preview	No preview
Saccade to word	8.8	9.0	8.4	8.2
First fixation duration	199	217	224	235
Gaze duration	271	307	311	347

condition. First fixations and gaze durations on the target did not yield the expected result, however. Instead, letter previews were equally useful in the matched and mismatched conditions, suggesting that parafoveal selection for processing in the mismatched condition encompassed more than the next parafoveally visible letter sequence.

The spatial segmentation of the parafoveal target preview also did not influence the usefulness of available orthographic information on that subset of trials in which the eyes landed at the previously visible first segment of the mismatched target preview (see Table 2). Readers thus obtained useful orthographic information from both segments of the mismatched parafoveal target preview, irrespective of the selection of a particular segment for subsequent fixation.[2]

Table 2. (Inhoff & Shindler) *The size of the saccade to the target (in character spaces) and ensuing target first fixations and gaze durations (in msec) as a function of the length and the orthographic informativeness of the preview for the subset of 760 trials in which the eyes landed at the first segment of the target preview*

	Matched length		Mismatched length	
	Letter preview	No preview	Letter preview	No preview
Saccade to word	8.3	7.9	8.5	7.5
First fixation duration	193	223	211	233
Gaze duration	291	337	317	369

Other results (Briihl & Inhoff 1995; Inhoff 1989a; 1989b; 1990; Lima & Inhoff 1985), argue against the possibility that acquisition of useful orthographic information from the parafoveal target preview was confined to beginning letters in the matched and mismatched conditions. In Lima and Inhoff (1985), preview of the target's beginning trigram yielded a benefit of approximately 20 msec in the gaze duration data, substantially less than in the current data, and preview of the full word yielded a benefit of approximately 40 msec, quite similar to the current data.

Together, these findings indicate that the spatial areas used for saccade targeting and for the acquisition of useful orthographic information need not coincide. This conception is in harmony with our view (Inhoff et al. 2000; Starr & Inhoff, in press) that more than one spatially distinct linguistic unit can be processed concurrently during a fixation.

NOTES

1. The blank target space in the mismatched length condition was replaced with an uninformative letter in the matched length condition to reveal the identical sequence of useful and non-useful parafoveal letters in both conditions.

2. This does not consider potential inaccuracies due to oculomotor error.

On keeping word order straight

Alan Kennedy

Department of Psychology, University of Dundee, Dundee, DD1 4HN, Scotland, United Kingdom. **a.kennedy@dundee.ac.uk**
www.dundee.ac.uk/psychology/akennedy

Abstract: E-Z Reader is a highly successful model of eye-movement control, employing the notion of a serial-sequential attentional spotlight switched from word to word. Evidence of parallel processing of words in text calls this notion into question. Modifications to the model to accommodate this evidence are possible but will not address the fundamental objection that reading should not be seen as "surrogate listening."

At least until the present version of E-Z Reader, there was a sharp theoretical distinction to be drawn between a model committed to the strict operation of a serial attentional switch and alternatives involving a degree of parallel processing, through the operation of an attentional gradient, for example. The primary testing ground for this theoretical divide was the existence, or otherwise, of parafoveal-on-foveal effects; that is, demonstrations that properties of word$_{n+1}$ (not yet fixated, but possibly attended) influence processing on word$_n$. As noted by Reichle et al., most early evidence on this question was negative (Carpenter & Just 1983; Henderson & Ferreira 1993), but the balance of evidence has now shifted, with a majority of recent studies supporting the proposition (Kennedy 1998; 2000b; Kennedy et al. 2002). The current version of E-Z Reader goes a long way towards accommodating these data by adding an early pre-attentive mechanism, able to survey the terrain of the upcoming text. In particular, orthographic parafoveal-on-foveal effects can now be accounted for without deserting the crucial claim that processing is to be characterised by default as involving a serial attentional switch. The modification to the model will no doubt have the effect of changing the focus of future empirical work from questions about *whether* such effects occur, to questions about their precise locus of operation. For example, sublexical effects exerted from initial letter familiarity or constraint might be characterised as less subversive than apparent lexical or supralexical effects. Nonetheless, it is difficult to avoid the conclusion that further erosion of the "seriality" assumption underlying E-Z Reader must occur. This is, indeed, foreshadowed in the target article by the concession that the SWIFT model of Engbert et al. (2002) "provides a viable alternative" to the E-Z Reader model.

The critical problem with the E-Z Reader model may not, in fact, be its adherence to "contentious" assumptions about the serial allocation of attention. It may rather be the set of tacit assumptions underlying that process and, in particular, the claim that words must be identified in turn because readers "need to keep word order straight" (Pollatsek & Rayner 1999). Although not made completely explicit in the target article, it is clear that this claim relates to the authors' belief that higher-level linguistic processes such as the computation of syntactic relationships can be understood *only* within the framework of a model where word-order can be preserved ("The serial allocation of attention is necessary because it preserves the temporal order of the words" [sect. 5.2.2, para. 5]). Given that reading is essentially a spatial activity, involving the deployment of eye movements over a visual object, the reference to *temporal* order is revealing: It suggests a commitment to the assumption that reading is, in fact, a form of surrogate listening. The clearest statement of this assumption, largely accepted but normally undeclared in the literature, is provided by Ferreira and Clifton (1986): "there is no reason to doubt that the

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syntactic processing strategies used by listeners and readers would be the same." This assumption has had a profound effect on theories of reading and has played a part in the evolution of models of eye-movement control that assign a significant role to an attentional spotlight, deployed sequentially across "word objects." It is, nonetheless, fallacious. Written text is normally continuously available as a spatially extended object on the page or screen, and, unlike the speech signal, can be inspected at will (Kennedy 2000a). This bestows unique advantages on the reader because, as noted by Reichle et al., re-inspection is typically deployed as a reprocessing option. The cost of incorrect initial structural analysis is far higher when processing speech, where no process equivalent to visual re-inspection is available (Watt & Murray 1996).

It should be noted, however, that the equivalence between *re-inspection* and *reanalysis* is itself in need of careful justification: It can be drawn only because readers compute and retain enough spatially coded information to make saccades to specific locations possible. This point needs to be stressed, because saccades made in the service of reanalysis are often very large and cannot be controlled accurately by physical identification of their correct landing site (Murray & Kennedy 1988). For readers of English, the relationship between initial landing position and launch site for progressive saccades is linear over the whole range of launch positions likely to be found in normal reading, with one character shift in launch position producing a corresponding shift of about a third of a character in landing position. However, the equivalent analysis of inter-word regressive saccades shows a virtually flat relationship between extent and accuracy. Landing position is close to the target word's centre, regardless of launch position, an outcome that strongly implies spatial control over saccades to "already-inspected" sites. The fact that readers know where previously inspected words lie (Radach & McConkie 1998) means that their temporal order of fixation need bear no relationship at all to their spatial succession. Indeed, the fact that the reader, unlike the listener, can afford to adopt a single "preferred" structural analysis rests on the fact that a repair process is readily available, underpinned by this spatially coded information (Kennedy et al. 2003; Kennedy & Murray 1987; Pynte et al. 1988).

The E-Z Reader model takes as a theoretical given the concept of *word object,* an idea which found its place in the literature because it neatly captured the idea of a visually-presented word functioning as a cognitive *event,* bounded by the time spent inspecting it (McConkie 1979). Processing could thus mimic the (temporal) sequence of events that would obtain if the word were heard rather than seen. It is hardly surprising, therefore, that the claim that text presented without inter-word spaces can be read quite well (Epelboim et al. 1993) should have been seen as peculiarly subversive and rejected with vigour (Rayner & Pollatsek 1996; see also Epelboim et al. 1996). What else but inter-word spaces could underpin the notion that the "primitive object level" in reading is the word (McConkie & Zola 1987)? Inter-word spaces are the visual equivalent of auditory segmentation, defining the boundary of attention. They allow the notion of an attentional spotlight, switched to each word in turn, to smuggle into any model of reading that employs it the plausible, but questionable, belief that reading is a form of surrogate listening. From this point of view, properties of a word in the parafovea *cannot* influence current foveal processing, because it is obviously not possible to hear the next word before it is uttered. The irony is, of course, that the serial-sequential nature of speech is precisely the property that a writing system avoids.

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How tight is the link between lexical processing and saccade programs?

Reinhold Kliegl[a] and Ralf Engbert[b]

[a]*Department of Psychology;* [b]*Department of Psychology and Center for Dynamics of Complex Systems, University of Potsdam, Potsdam, 14415, Germany.* **kliegl@rz.uni-potsdam.de**
www.psych.uni-potsdam.de/people/kliegl/
engbert@rz.uni-potsdam.de www.agnld.uni-potsdam.de/~ralf/

Abstract: We question the assumption of serial attention shifts and the assumption that saccade programs are initiated or canceled only after stage one of word identification. Evidence: (1) Fixation durations prior to skipped words are not consistently higher compared to those prior to nonskipped words. (2) Attentional modulation of microsaccade rate might occur after early visual processing. Saccades are probably triggered by attentional selection.

Two core assumptions of the E-Z Reader model are: (1) attention is shifted across the text in a strictly serial fashion from word$_n$ to word$_{n+1}$, and (2) eye-movement programs are initiated by completion of the first of two stages of word identification. The SWIFT model does not make these assumptions; its three core assumptions are: (1) eye-movement programs are initiated by an autonomous timer, (2) words within the perceptual span are processed in parallel at rates that depend on the distance from the current fixation, and (3) lexical processing difficulty of the fixated word delays the initiation of a saccade program (Engbert et al. 2002). We comment on implications of E-Z Reader's core assumptions in the light of new experimental results and speculations.

Lexical cancellation of saccade programs. E-Z Reader is strongly committed to the assumption of serial word-to-word shifts of attention. Together with the assumption that saccade programs are triggered by completion of a first stage of lexical processing, this implies longer fixation durations prior to skipped than prior to nonskipped words. The reason is that word skipping requires that a saccade targeting the next word is canceled and reprogrammed to the following word; saccade cancellation necessarily increases the fixation duration. E-Z Reader and our own previous model generate a large effect of this kind (58 msec in E-Z Reader 7; 75 msec in Engbert & Kliegl 2001). The empirical evidence, however, is not consistent with this assumption, with effects ranging from 38 to −26 msec (see Kliegl & Engbert [2003a] and Radach & Heller [2000] for references to six studies/twelve estimates with a median close to zero). We checked this effect in a recent corpus based on 32 young and 33 older adult readers of German sentences (Kliegl et al., in press). In both samples the critical fixations were shorter (−9 to −4 msec) in various analyses (e.g., contrasting saccades from word$_n$ to word$_{n+2}$ with saccades from word$_n$ to word$_{n+1}$; matching words that preceded a skip with the same words [read by different participants] when they preceded a saccade to the next word).[1] Obviously, this experimental variance needs to be explained, but given that E-Z Reader 7 overestimates even the maximum reported increase in fixation duration by 53%, the assumption of lexical-processing triggered saccade-cancellation does not appear to be well supported. Guidance by attentional gradients does not predict a specific increase of fixation durations prior to skipped words.

Lexical initiation of saccade programs. The SWIFT assumption of autonomous saccade generation was motivated by the considerable explanatory power of models assuming primary oculomotor control and by research demonstrating a close link between attentional selection and saccade program initiation (see Deubel et al. [2000] for an excellent review). Recently, covert attention shifts were shown to modulate microsaccade rate and orientation in spatial cueing paradigms (Engbert & Kliegl 2003; see also Hafed & Clark 2002). If attention modulates microsaccade rate and orientation in reading fixations, we can test the E-Z Reader assumption that saccade programs are triggered exclusively by the completion of the first stage of word identification (*L1*), which is

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