Reading and the split fovea

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Abstract: We argue that models of reading should be based on anatomical reality, namely, the fact that both eyes are used in reading; and the observation that the human fovea is precisely vertically split, and projects each half of a fixated word to the contralateral hemisphere.

Although E-Z Reader very effectively organizes a complex literature and has the advantages of an implemented model, we take issue with it for being grounded at a functional level of description. The best starting point for modeling reading and visual word recognition is with the anatomical givens. In a series of statistical and connectionist simulations, we have shown the productivity of incorporating the fact that the human fovea is precisely vertically split and initially projects each part of a fixated word to the contralateral hemisphere (Monaghan et al. 2003; Shillcock et al. 2000). When this anatomical fact is incorporated into a computational model of the reading of isolated words, a range of behaviors emerges – from those core behaviors captured by the different developments of Seidenberg and McClelland's (1989) triangle model (with various versions of its abstract orthographic input), through to behaviors that are either problematic for the triangle model (such as Coltheart & Rastle's [1994] demonstration of apparent serial processing in word naming), or are currently outside its scope (such as laterality effects in reading). We argue that the initial division of a fixated word between the two hemispheres goes on to condition the normal reading of that word; there is no early, seamless integration of the contents of the visual cortex in the two hemispheres, as implicitly assumed in most models of visual word recognition. Reichle et al.'s Figures 13 and 14 suggest a unidirectional, cascaded flow of information processing, from lower/peripheral levels to higher/central levels, consequently transcending the initial splitting of the word. However, recurrent connectivity is pervasive in the brain; the fixated word is precisely split between the two primary visual cortices, and it is this representation that provides the reader with the most authoritative record of what is on the retina.

Visual word recognition is central to the reading of text. We suggest that a model of eye-movement control in reading is best built on the same anatomical foundation, so that there is a degree of autonomous representation and processing of the information in the two hemifields. This approach is in contrast to Reichle et al.'s assumption of a single window onto the text. Evolution has devoted only the posterior part of the human corpus callosum to a direct connection with visual information, compared with the whole of the corpus callosum for lower primates. It is reasonable to infer that interhemispheric coordination in the human brain is mediated substantially by information that is not primarily visual. For reading, this assumption means that there is an option of allowing the autonomous processing of visual information in each hemisphere, with interhemispheric communication based on some of the output of that processing, such as partial semantic activation of words. It also means that some of the information driving eye movements might be best captured in terms of the visual information initially available to each hemisphere, and its immediate consequences.

Some of our current research into characterizing the control of eye movements is based on definitions of the information available to each hemisphere, operationalized in terms of the probability of identifying the word(s) present in the half of the foveal window on either side of the fixation point. We suggest that building up a computational model from these anatomical foundations will demonstrate that some of E-Z Reader's architectural distinctions and some of its parameters will emerge from the interaction of the divided architecture with the informational structure of the task.

The divided architecture of the split-fovea model allows attentional processing to be implemented in terms of quasi-autonomous, contralaterally oriented opponent processors located in the respective hemispheres. This approach has a long history in the modeling of normal and impaired attention (see, e.g., Cohen et al. 1994; Kinsbourne 1970; 1977).

A further anatomical given is the fact that most reading happens with two eyes. (The single eye in Reichle et al.'s Fig. 3 is labelled "Eyes.") The two eyes do not always seem to focus on exactly the same point in the text, with the disparity sometimes being nontrivial (e.g., 1–3 characters); furthermore, monocular occlusion slows reading down (Heller & Radach 1999). Perception is robust in the face of binocular disparity: Minimally different images are fused; more disparate images rival each other and one is suppressed. Both of these processes seem to occur similarly in each hemisphere (O'Shea & Corballis 2001), but there is also the possibility that binocular rivalry has at least a higher-level component; for example, it is possible for complementary checkerboard pictures to be resolved into single, coherent pictures when they are presented to different eyes (Ngo et al. 2000). Clearly, the resolution of the fact that the two eyes may often have different fixations is important to a model of reading, if speed of reading can be affected; there is every indication that the role of the two eyes can be incorporated into a model based on foveal splitting.

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The effects of frequency and predictability on eye fixations in reading: An evaluation of the E-Z Reader model

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Abstract: We tested whether the E-Z Reader model can be generalised to the French language. The simulation showed that the model can account for the frequency effect. The predictability effect is moreover accurate for word skipping, but not for fixation times. We think that this model is psychologically plausible for certain aspects of reading and we have used it to evaluate the performance of dyslexic readers.

The E-Z Reader 7 model was applied to data that were obtained in an eye-tracking experiment. The purpose of the study was twofold. Its first aim was to test whether the model can be generalised to the French language. The second objective was to test whether the model can satisfy to contextual constraint influencing reading, namely, predictability. Fifteen participants were requested to read a French text that contained 134 words varying in frequency and predictability (the latter factor was determined in a previous task by asking participants to guess $word_{n+1}$ when provided with the sentence up to $word_n$). As in Reichle et al., the words were divided into five frequency classes and eye movement was recorded. Furthermore, we ran a simulation to determine how well the model could predict the observed data (i.e., means duration and distributions of fixations). To be in agreement with E-Z Reader 7, the first and last words of each sentence were not included in the data analysis.

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