Trends in Cognitive Sciences

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Letter

Eye Movements and Comprehension Are Important to Reading

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In a recent opinion article, Snell and Grainger (S&G) [1] argued that the debate over serial versus parallel processing (SvP) in reading was due for a paradigm shift. S&G cover several SvP issues in language processing broadly, but in doing so have lost scope of the crux of this debate as it pertains to reading: can attention be allocated to simultaneously identify more than one distinct adjacent word (Box 1)? Adequately answering this question requires agreement on the definitions of attention and identify and the most appropriate measurements of those processes. Indeed, even advocates of serial attention allocation in reading agree that aspects of language processing are parallel (e.g., processing of letters across the visual field), so some of S&G's arguments are tangential. Although S&G raised several interesting and provocative questions, we find their answers unconvincing given the evidence they present. Furthermore, we caution against their recommendation to abandon decades of methodological and theoretical development in favor of focusing on artificial tasks that create very different processing demands from natural reading. Doing so discards important aspects of reading that define the process: endogenous control over attention and the goal of comprehending the text. Instead, we favor approaches that integrate theories and paradigms while maintaining a connection to and appreciation for the importance of ecological validity.

First, overwhelming evidence suggests that forcing people to hold fixation, rather than allowing them to move their eyes, changes the way they allocate attention to words. For example, without eye movements, participants name words or discriminate words from nonwords more slowly, even when the words are presented in central vision and eye movements would be unnecessary [2], and sensory neural responses associated with identifying upcoming words are reduced [3]. Furthermore, when paradigms experimentally prohibit the ability to reinspect the text via eye movements, comprehension suffers [4] and neural measures of word processing differ [5]. Because the allocation of overt attention, via eye movements, is critically engaged in the process of reading for understanding and is yoked to neuro-cognitive word identification processes, claims about attention in reading must acknowledge the interaction between attention and eye movement control.

Second, cognitive systems are incredibly flexible in accommodating task demands and goals. As a result, the answer to the SvP debate is not either-or, but depends upon the nature of the task and the goals of the language processor. For example, sensitivity to linguistic properties (e.g., how common or contextually congruent a word is) differs between reading for comprehension and skimming, zoning out, proofreading for spelling errors [6], and making explicit plausibility judgments [7]. Moreover, because different task demands make parallel models appear more serial (i.e., the spread of attention shrinks to appear more serial when reading becomes harder [8]), explicit tests of theories of parallel word recognition during natural reading require the task of reading for comprehension.

Given these arguments, we favor approaches that synthesize data across experimental scenarios and that abandon hard dichotomies for balanced theories that account for the flexibility of cognitive systems. The most productive way forward is to bridge traditionally siloed literatures [e.g., eye movements in natural reading and event related potentials (ERPs) in rapid serial visual presentation (RSVP) reading] via complementary experiments that identify areas of both convergence and divergence between paradigms

Box 1. The Crux of the SvP Debate in Reading

The critical SvP issue is whether identification of an upcoming word influences (not coincides with) fixation behavior on the previous word [i.e., lexical parafoveal-on-foveal (LPoF) effects] because even a serial model predicts that identification could happen for an upcoming word while the eyes are fixating the previous word, as long as that happens after identification of the fixated word. On this issue, the data favor a serial account because the only evidence for LPoF effects comes from corpus studies, and these apparent effects remain when gaze-contingent masks prevent visual processing of upcoming words [10], suggesting they are an epiphenomenon of co-relationships between words in sentences. Additionally, the following points S&G use to argue for parallel lexical processing are unconvincing:

- Orthographic neighborhoods. Just because word forms activate features or word candidates in parallel (i.e., 'hall' partially activates words like 'ball') en route to word identification, this does not imply that word identification simultaneously occurs across multiple words.
- Syntactic constraints. Syntax may be used to constrain word position for simplistic highly constrained sentences (e.g., 'The man can run'), but cannot scale up to more variable natural language (e.g., 'The girl saw a big beautiful fluffy white dog').
- S&G's rapid parallel visual presentation paradigm. The brief (200 ms) presentation of four words and uncertainty over which word is the target promotes the distribution of visual attention, unlike during natural reading. Visual processing could have been distributed during presentation and word identification could have occurred serially. Sixty milliseconds is sufficient for fixated visual information to enter sensory memory and for reading to proceed normally, even with postmasks, but more time is needed for information to be processed from upcoming words [11]. Moreover, unlike the N400 in multiword RSVP paradigms of reading for comprehension (e.g., [7]), the ERP effect they report has an anterior rather than central-posterior distribution and is syntactic rather than semantic. Even so, an N400 would not be evidence for parallel word identification because it does not require attention; it can be elicited during sleep, during the attentional blink, and even in patients in minimally conscious states [12].

(e.g., [3,5]). Only by understanding the degree to which findings generalize across paradigms and measures can we infer how they transfer to natural reading scenarios. Using newly developed methods of co-registration of electroencephalography with volitional eye movements during reading can reveal the neural attention mechanisms that are engaged in natural reading (e.g., [3]), but further efforts should be made to explicitly compare the effects of task goals and experimental paradigms (e.g., reading for comprehension versus making explicit judgments). Furthermore, future research should relate online neural and eye movement measures to offline measures of comprehension to determine how these fundamental processes change as a function of engagement in the task and to reveal important trial-to-trial dynamics of word processing.

In summary, although S&G raise interesting questions, we caution against 'dogmatizing' parallelism as a default that becomes masked by a serial behavior based on limited evidence from a set of contrived tasks. In contrast, we suggest that the needed paradigm shift in reading research is one that bridges domains and brings insight into the reading process in concert with decades of evidence we have already accumulated, not in spite of it. These new approaches may answer some yet-unasked questions. However, we anticipate they will reinforce long-standing conclusions that the brain can perform many processes in parallel (e.g., discriminating visual features of letters and objects), but just as attention is needed to bind multiple features of objects during visual search, some aspects of the natural reading process (e.g., word identification) must engage the serial allocation of attention (e.g., [9]).

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