Left fusiform activity explains variability in fixation durations during natural reading: Evidence from co-registered MEG & eye-tracking

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Introduction: Eye movements during reading are influenced by the linguistic and cognitive demands of what is being read, indicating that brain networks controlling eye movements, and those controlling the recognition of words, must cooperate. Historically, however, neuroscientific studies of reading have tended to use rapid serial visual presentation (RSVP), thereby eliminating eye movements. This has resulted in a paucity of evidence concerning how brain activity gives rise to eye movement behavior during reading and makes it unclear if neurocognitive accounts of reading, informed by RSVP studies, generalize to the behavior of interest. Here, we used co-registered MEG and eye-tracking to examine the brain systems that support visual word recognition while participants freely read short stories with eye movements.

Methods: Thirty-two participants naturally read 216 short stories, each consisting of two sentences, while concurrent MEG and eye-tracking data were collected. Stories were annotated with the properties of each word (e.g., letter bigram frequency, lexical frequency, surprisal), enabling us to identify brain responses, time-locked to fixations, that were modulated by these properties. Responses were analyzed using linear deconvolution to disentangle overlapping activity and localized to the cortical surface using minimum norm estimation with high resolution anatomical MRIs. Linear mixed effects models and nested model comparisons were used to identify neural responses that correlated with each property of the fixated words and to identify brain responses that explained variability in the duration of fixations before they terminated, beyond what could be explained by psycholinguistic properties of the words alone. Finally, in a follow-up study, a separate sample of participants read the same short stories presented one-word-at-a-time in RSVP, allowing us to compare the influence of word properties on brain responses across the two reading modalities.

Results: We first replicated past results demonstrating that a progression of left occipitotemporal activity supports visual word recognition. We then examined where in this progression each of the properties of fixated words modulated responses. During natural reading, word length correlated with activity in primary visual cortex bilaterally (50-200 ms) while lexical frequency correlated with activity in the left fusiform gyrus (100-170 ms after fixation onset). In contrast, letter bigram frequency and lexical surprisal did not correlate with responses in the ventral visual word pathway. We next extracted responses from occipitotemporal areas and asked if activity at these stages correlated with how long the eyes lingered on the currently fixated word – possibly indicating that word processing at this stage influences oculomotor control. Consistent with the proposal that it houses a bottleneck on visual word recognition, the left fusiform gyrus showed this pattern, with longer fixations associated with more negative amplitudes, shortly after fixation onset. Finally, a comparison of natural reading versus RSVP revealed a stark contrast in how word frequency and surprisal correlated with brain activity across the two paradigms, with widespread correlations between these properties and brain activity observed only in the slower, one-word-at-a-time RSVP reading.