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Theories of reading should predict reading speed

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Abstract

Reading speed matters in most real-world contexts, and it is a robust and easy aspect of reading to measure. Theories of reading should account for speed.

Frost notes that there is a vast range of languages and reading phenomena that one can measure and model. In order to not lose sight of the goal of a universal theory of reading in the thicket of language-specific phenomena, Frost proposes two criteria that such a theory must possess: first, universality across writing systems, and, second, linguistic plausibility. However, Frost's treatment ignores reading speed, which is the easiest aspect of reading to measure and has the greatest practical significance. Reading speed limits the rate at which information is processed by the reader. When impaired vision or dyslexia slows reading, the reader experiences a disability. The range of print sizes that maximize reading speed is highly correlated with the character sizes used in printed materials and affects typographic design quite generally (Legge & Bigelow 2011). In addition to Frost's two criteria for a universal theory of reading, we would like to propose a third criterion. Note that *visual span* is the number of characters that one can recognize without moving one's eyes. A theory of reading should assume or explain the observed proportionality between visual span and reading speed (Legge et al. 2007; Pelli & Tillman 2008; Pelli et al. 2007).

It has been known for a century that reading proceeds at about four fixations per second (Huey 1908/1968). This rate is preserved across the wide range of reading speeds encountered in low vision and peripheral reading (Legge 2007; Legge et al. 2001). This makes it natural to express reading speed as the product of fixation rate and visual span, the number of characters acquired in each fixation.

Woodworth (1938) asks,

> How much can be read in a single fixation? Hold the eyes fixed on the first letter in a line of print and discover how far into the line you can see the words distinctly, and what impression you get of words still farther to the right. You can perhaps see one long word or three short ones distinctly and beyond that you get some impression of the length of the next word or two, with perhaps a letter or two standing out. (Woodworth 1938, p. 721)

For ordinary text, reading is limited by spacing (crowding) not size (acuity) (Pelli et al. 2007). As text size increases, reading speed rises abruptly from zero to maximum speed.

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http://psych.nyu.edu/pelli/ http://vision.berkeley.edu/selab/ http://vision.psych.umn.edu/users/legge/

This classic reading-speed curve consists of a cliff and a plateau, which are characterized by two parameters: critical print size and maximum reading speed. Two ideas together provide an explanation of the whole curve: the Bouma law of crowding and Legge's conjecture that reading speed is proportional to visual span (Bouma 1970; Legge et al. 2001; Pelli et al. 2007).

Reading speed captures two essential properties of the early sensory part of reading: the recognition of written words and the processing of a rapid temporal sequence of stimuli. Thus, reading speed is more informative about a reader's reading ability than is simple word recognition.

Reading speed is closely linked to eye movements. The rate of eye movements is about four per second, with very little variation. Slower reading is associated with shorter eye movements. When reading slows because text is difficult to *see*, as in many forms of impaired vision, the main effect on eye movements is a reduction in the length of saccades, which may reflect a reduced visual span (Legge 2007, Ch. 3). When reading slows because the meaning of the text is difficult to *comprehend*, the time per fixation increases as well.

Reading speed receives distinct contributions from three reading processes: letter-by-letter decoding (i.e., recognition by parts), whole-word shape, and sentence context. Simple manipulations of text can knock out each reading process selectively, while sparing the others, revealing a triple dissociation. The independence is amazing. Each reading process always contributes the same number of words per minute, regardless of whether the other processes are operating (Pelli & Tillman 2007).

What about comprehension? Popular speed reading classes convince their clients to skim through text at arbitrarily high speeds, with commensurate loss of comprehension, so one might question whether silent reading speeds tell us much, unless comprehension is measured, to assess the speed–comprehension trade-off. In our experience, participants in reading experiments asked to read as quickly as possible with full comprehension read at stable speeds, and can readily produce a gist of what they read. Most of our work is done with short passages; for example, eight words presented quickly in the rapid serial visual presentation (RSVP) paradigm. That is, words are presented one at a time in a rapid sequence and are read aloud by the participant, with no time pressure on the verbal response. Masson (1983) made a thoughtful comparison of several measures of comprehension and reading speed. A new development is automatic generation of text that allows easy assessment of comprehension by asking the reader to classify each four-word sentence as true or false (Crossland et al. 2008).

Can anyone claim to explain reading without accounting for speed?

Postscript: Let us all cite Rawlinson (1976; 1999) for "reibadailty."

In the target article (sect. 1.1, para. 1), Frost reports "a text composed entirely of jumbled letters which was circulating over the Internet. This demonstration, labeled 'the Cambridge University effect' (reporting a fictitious study allegedly conducted at the University of Cambridge), was translated into dozens of languages and quickly became an urban legend." In fact, that infamous e-mail was based on Rawlinson's 1976 doctoral dissertation at Nottingham University, but fails to cite it, instead misattributing the research to various other universities. Michael Su, an undergrad working with Denis Pelli, tracked down the source, and Dr. Rawlinson provided a copy of his thesis and granted permission to post it on the Web (Rawlinson 1976).

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