At what level is reading serial?

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Summary: We know that features are acquired in parallel, and words are acquired serially, but what about letters? We apply a serial test and find that letters are acquired in parallel. And what about sentences? We find that the effect of context on words is mediated through an effect on letters, which in turn reflects accrual of fewer features when we have more context.

When Susie reads a page of text aloud, the optical image arrives in parallel on her retina, but she emits the words serially. The question is: At what level of visual processing does the transition from parallel to serial occur? A. The feature level? B. The letter level? C. The word level? D. The sentence level?

A. Features are acquired in parallel.

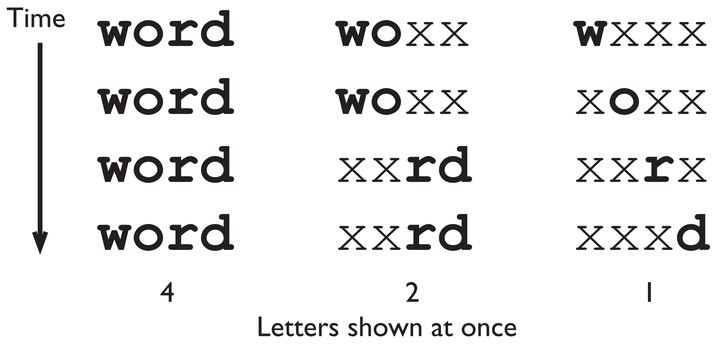
We know from probability summation that features are detected independently over time (Watson 1979). The number of features detected increases in proportion to duration.

B. Are letters acquired in parallel or serially?

If letters within a word are acquired serially, we should find no difference in reading rate if letters are shown one at a time. Taking away letters you're not using at that moment shouldn't hurt. We tested this prediction by reducing the number of letters shown simultaneously (Fig. 1) and find that, with serial letter presentation, reading rate for 4-letter words is reduced by about a factor of 4 (Fig. 2a). In other words, required *word* duration quadruples when we present the letters serially (Fig. 2b), but required *letter* duration is independent of how many letters are presented at once (Fig. 2c). Letters are acquired in parallel (independently).

Method:

Fig. 1



Using the Rapid Serial Visual Presentation (RSVP) paradigm developed by Molly Potter, we measured reading rates for 3 observers (NYU undergrads). On each trial, 6 words were presented. The observer read the words aloud while the experimenter recorded her errors. To hone in on 80% accuracy, the QUEST adaptive staircase program either increased or decreased the presentation rate on the next trial. Each run consisted of 15-20 trials, and each data point on this poster represents the average of 3 runs. We varied the number of letters presented simultaneously (Figs. 1,2), the number of letters in each word (Fig. 3), and the number of possible words (Figs. 4,5). Except in Fig. 3, all the words used were 4 letters long. The words were unordered, randomly selected from a list. Our longest list contained all 1700 4-letter words in the Kucera and Francis corpus. Our shorter lists (of 4 and 26 words) were randomly selected subsets.

Fig. 2a

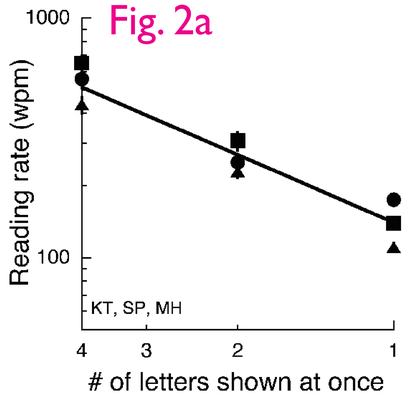


Fig. 2b

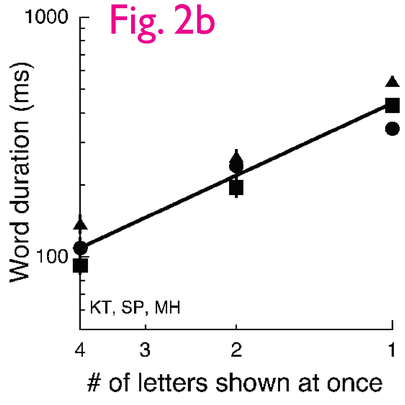
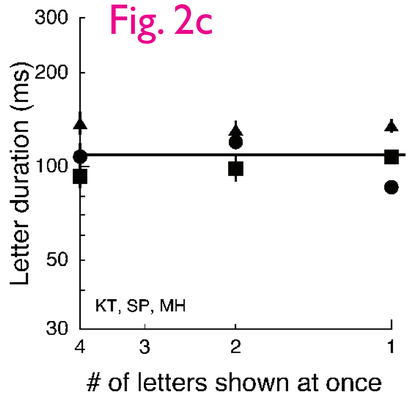


Fig. 2c



C. Words are acquired serially.

We know this because if you present whole words one at a time in the same location (RSVP), reading rate is not impaired. In fact, observers can read a little faster with RSVP than reading a printed page (Potter 1983).

D. Sentence context determines the number of features we need.

If words are acquired one at a time, why are we faster at reading ordered sentences than random lists? Of course, we make connections between words. That's what language is. In ordinary reading, we're able to guess the next word in the sentence about 25% of the time (Stanovich and Stanovich 1995). It is as though, as we read along in the sentence, the context reduces the list of possibilities for the next word from the thousands in our vocabulary to just 4.

We studied the effect of word list length (set size) on RSVP reading rate. When set size is constant, there is no effect of word length (Fig. 3). When word length is constant, threshold word duration is linear with log set size (Fig. 4). The greater the number of possibilities, the more time it takes to get the word. Could the set size effect originate at a lower level than the word? Yes. Threshold duration for letter identification shows the same effect of set size (letters) (Fig. 5).

When there are more possible words, there are also more possible letters in each position. When there are more possible letters, threshold duration goes up and so does the number features detected.

Fig. 3

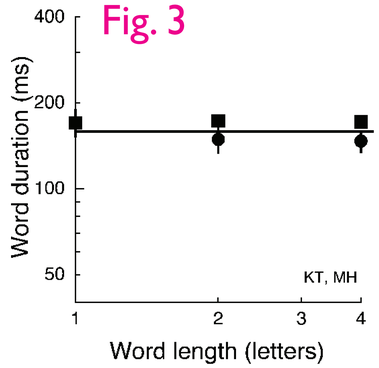


Fig. 4

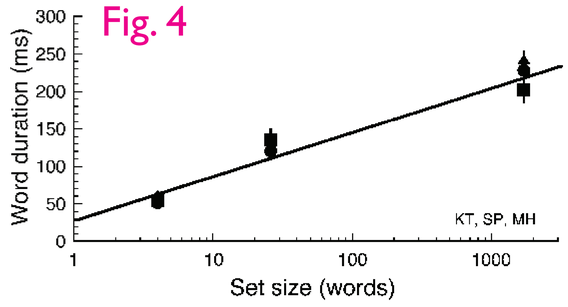
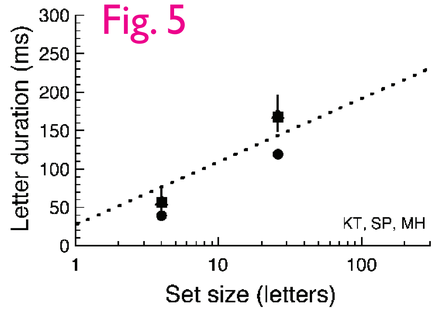


Fig. 5



Conclusion: Feature accrual seems to limit reading rate. When we have less information about what the next word might be, we detect more features to identify its letters. Detecting more features takes more time, which makes reading slower.

Tillman, K. A., Pelli, D. G., Martelli, M., Stott, J., & Rosenblatt, J. (2006). Is reading serial? *Journal of Vision, 6(6)*.
http://journalofvision.org/6/6/ http://psych.nyu.edu/pelli/posters.html