The Use of Prior Knowledge in Reading

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http://psych.nyu.edu/pelli/highschool.html#2006
Abstract

The key step in reading is to recognize the word by combining visually acquired letter information with prior knowledge of the possible words, as determined by narrative context and vocabulary. How are these two kinds of information combined to identify a word? The purpose of this project was to determine the effect that vocabulary size has on word identification. Vocabularies of 4, 26 and 1708 words were created. All words were four letters long and presented serially, one after another, at the same location using the Rapid Serial Visual Presentation (RSVP) paradigm. It is known that words can be recognized letter by letter or holistically, by overall word shape. The holistic process was knocked out, sparing the letter-by-letter process, by presenting the words in the peripheral visual field surrounded by clutter. Reading rate fell as vocabulary increased. At maximum reading rate, the time per word was approximately proportional to the log of the vocabulary size. Since letter recognition is serial, this indicates that when the vocabulary was small, observers could identify the word by identifying just one letter. As the vocabulary increased, observers had to identify 2 or even 3 letters to identify the word. This shows that readers do not simply get all the letters and then identify the word. Instead they get one letter at a time until they get the word. With more prior knowledge, fewer letters are needed.
Introduction

Reading is representative of the combination of a person’s context and their letter recognition ability. Context can be defined as the use of other words in a sentence to determine what an object or target word is. It can also be defined as the use of previous knowledge of the text’s vocabulary in a person’s ability to read. It is difficult to estimate how much a person has read in their life and how many words they know, it is therefore impossible to quantitatively identify his or her vocabulary size.

Set sizes are the pool of random words that have the possibility of appearing on the screen during each trial. To control the vocabulary of the experiment, I created three lists of different lengths: 4, 26 and 1708 words. The words were randomly chosen from the complete list of 1708 four-letter words found by Kucera and Francis. The experiment allows a set size of four words to represent a person with a vocabulary of only four words. When running trials at this set size, the observer has only four words to choose from when performing the task. Comparatively, a set size that is 1708 words represents the largest vocabulary that a person can have (of four letter words). This causes a person to have many more choices to choose from. Therefore, a person with a smaller vocabulary size can use their vocabulary as more of a way to determine what a target word might be.

The observer read text presented serially, one word after another, in the same visual location. This is called Rapid Serial Visual Production, (Potter, 1984). With the aid of temporal flankers and spatial flankers, realistic reading is created. Spatial flankers are spurious letters near the target letter, with typically one appearing on each side of the target (Pelli, 2005). Temporal flankers in RSVP reading are words or letters that flash on
the computer monitor on a screen prior to the screen in which object word appears on the screen. These temporal flankers are a new idea that extends the idea of spatial flankers into time: spurious letters shown before and after the target (Pelli, 2005).

**Knocking out the holistic process**

Crowding is the difficulty in recognizing a letter flanked by another letter (Chung, Legge and Levi, 2000). In the normal periphery, neighboring letters with no overlap severely impair the identification of a signal letter (Korte, 1923; Ehlers, 1936; Bouma, 1970, Anstis, 1974; Flom, 1991). In order to knock out the holistic process in reading, and focus on the letter to by letter process, words were presented in the peripheral visual field surrounded by flankers (irrelevant letters) on all sides, as in a normal page of text (Martelli et al. 2005). By presenting the stimuli in the observer’s periphery, the use of the shape of the word in the identification process was eliminated. This allowed emphasis to be put on the letter-by-letter identification process. A part or feature based system is believed to be essential for word recognition. Therefore, when identifying a word, a person is serially processing each letter of the word to identify what it is (Gauthier & Tarr, 2002).

**Reading Rate**

Reading rate is the dependent measure within the experiment. It can be defined as the number of words read per minute. It will be controlled as duration (in milliseconds) that the each word is present on the computer monitor and can be represented by the
equation below.

\[ r = \frac{60 \text{ s}}{t} \]

(where ‘r’ is the reading rate in words per minute and ‘t’ is the duration in seconds.)

I will determine the effects of set size on threshold duration (for 80% correct) using words as stimuli. By controlling set size, the experiment quantitatively measures how a person’s reading rate with 4 words, differs from that with a set size of 26 and 1708 words.

It was also hypothesized that for a set size of four words, if one letter was completely identified, the whole word could be identified. This is true because there were no redundant letters within this set size. Furthermore, because word identification requires serial identification of letters, for a set size of 26, the duration that a word must be present on the screen for correct identification will double, because twice as many letters need to be serially identified. Finally, for the set size of 1708 words, at least three letters need to be serially identified because of the numerous repetition of letters, to identify a target word; the duration of text presentation will least triple.

**Observers**

Two observers were tested (JR and BJ). Both had normal, or corrected to normal vision and were seventeen years old.
Methods

Using Matlab software with Psychophysics Toolbox (Brainard, 1997; Pelli 1997) on an Apple Power Macintosh computer, the experiment was conducted using Rapid Serial Visual Presentation; RSVP (Potter, Kroll, Harris, 1980). While the program can be used to test RSVP reading in several different ways, the program was manipulated to add in a paradigm titled the ‘Partial Report.’ This paradigm allowed the observer to silently read the words as they were presented, and then identified which of four words on a response screen had not been presented in that trial.

Stimuli

All words used for this experiment were four letter words picked from the list of Kucera and Frances, 1967. The words were presented in the Helvetica font. The three set sizes used were four, twenty-six and 1708. The smaller set sizes were randomly chosen from the complete list of 1708 words. The largest set size was selected to see how the largest set size composed of four letter words would compare with the results from smaller set sizes of four and twenty-six words. The set size of four was selected to represents a minimal set size, while the set size of twenty-six words was chosen because this experiment can be replicated using single letters, with twenty-six words for each letter.

It is also important to mention that the size of the text was represented as1.25 times the letter spacing. Furthermore, the curves collected with vertical flankers above and below the text were at a line spacing of one. Therefore, the spacing between the word
and the spatial flanks abutting the word and the spacing between the word and the vertical flanks, above and below the word, were equivalent.

**Procedure**

While fixating on a point on the monitor, at a distance of fifty centimeters, a word was presented in the observer's periphery at ten degrees eccentricity of the lower visual field. Four words were presented per trial with spatial flanks (the ‘w’ and ‘t’ of screen 2 shown below in figure 1). One word was presented per screen and was systematically followed by the next word (or screen). After the four words were shown, the observer was shown a seventh screen that asked, “Which word was NOT shown?” (Screen 7)

**Text Presentation**

<table>
<thead>
<tr>
<th>Screen 1</th>
<th>Screen 2</th>
<th>Screen 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>j lkmn o k ytg w b xdf e h</td>
<td>o lrjk u w kate t t hgyk l</td>
<td>p lodg u s wove l l jhgd h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Screen 4</th>
<th>Screen 5</th>
<th>Screen 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>u optf j v soon q h refc x</td>
<td>t hfeq w g wove j e nbmv c</td>
<td>u iqaz x p ertg x b zswa m</td>
</tr>
</tbody>
</table>

Which word was NOT shown?

1. kate 2. soon 3. wove 4. chin

(Screen 7)

**Figure 1** - This figure represents what one trial within one run consists of. Within each run, two screens (1 and 6) would represent temporal flanks that create crowding within time.
When the word was identified correctly, the observer was rewarded with a beep before beginning the next trial. Each run consisted of 40 trials. During each run, the presentation rate was automatically adjusted by the software to find the observer’s threshold. When the observer did not correctly identify the missing word, no response was given from the computer the subsequent trial began. Each run for the set sizes of 4, 26 and 1708 consisted of forty trials. During each run, pressure was put on time limitations, temporal crowding, by having a constant spacing.

After each trial, the Matlab program configured the percent correct and standard deviation. All runs with large standard deviations (above 0.10), and runs in which the observer failed to fixate their eyes solely on the fixation point, were canceled and redone. Furthermore, all runs below 75% correct identification were discarded.

*Varying Speed (temporal crowding)*

When the spacing of the text remained constant, the program controlled the speed at which the words were presented on the screen. After each correct response, the program automatically decreased the duration of the presented words for the subsequent trial using the QUEST Staircase Algorithm (Watson and Pelli 1983; King-Smith, Grisby, Vingrys. Benes and Supowit, 1994). Decreasing the duration for word presentation created crowding *between* the words. Similarly, after each incorrect response, the duration was increased. In so doing, the program was set to maintain the threshold speed at which the QUEST algorithm provided an estimate of the observer’s threshold reading rate (i.e. for 80% correct). By measuring the temporal crowding, the maximum speed limit at which successive objects could be perceived was found. After the forty trials
were completed, the QUEST algorithm was used to formulate the average reading rate of words per minute based on the forty trials.

**Figure 2**- Within the target word ‘chin’ the spacing was measured as center-to-center spacing. The spacing between the letters within the words, and the end letters with their flakers was equal.

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**Text Presentation**

Spatial flankers were added above and below the text, and the text was shown solely in lower case letters. These spurious letters above and below forced the observer to focus on the word in entirety because no longer was a word decipherable by a single part of a letter, because the flankers above and below the target word prevented this from occurring (see figure 3). Spatial flankers above and below the test were added to keep the observer from being able to identify a word using only a distinctive ascending or descending letter. The vertical flankers also are important because they enable the RSVP program to be even more similar to reading real text from a novel, because that too has lines of words above and below the target text that produce crowding in the periphery.
Figure 3- The letters above and below and on each side of the target word are spatial flankers that are used to lessen the use of the shape of the word in identifying what the target word is. They are also used to determine the point of critical spacing where too much crowding exists.

Results

The hypothesis was proven true that it would take longer to process and correctly identify words at greater set sizes because more letters needed to be processed. This result was consistent across observers shown in figure 4. Figure 4 shows the threshold duration (for 80% correct).
Maximum Reading Rates

<table>
<thead>
<tr>
<th>Set size</th>
<th>Duration (ms) Observer 1</th>
<th>Duration (ms) Observer 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>100</td>
<td>133</td>
</tr>
<tr>
<td>26</td>
<td>204</td>
<td>275</td>
</tr>
<tr>
<td>1708</td>
<td>252</td>
<td>313</td>
</tr>
</tbody>
</table>

Figure 4. This data represents the threshold word duration (for 80% correct) as a function of set size.

The data shown in figure 4 represents the maximum reading rates of the observers for each set at the point of the most crowding between consecutive words (temporal crowding).

As shown in figure 4, it took twice as long to correctly identify words for the set size of 26, as it did for a 4-word set for both observer 1 (204 ms to 100 ms) and observer 2 (275 ms to 133 ms). As previously stated, a person identifies words by letters. Because there were no repetitions of letters in the set size of four words, a person could identify one letter of the target word and read what it was. Therefore, 100 ms and 133 ms are representative of the identification time necessary to read one letter for observer 1 and observer 2 respectively.

Thus, twice as many letters need to be identified for words from a 26-word set and two and a half times the number of letters need to be processed for the 1708-word set. For both observer 1 and 2, the ratios comparing the stimulus duration to the set size are respectively 2:1 and 2.1:1 respectively for the set size of 26 to the set size of 4.
Finally, ratios of 2.4:1 and 2.4:1 were found for comparing the 1708-word set to the 4-word set. These results support the theory that the letters must be processed serially, resulting in increased durations for increased set sizes. This is represented in figure 5 below.

**Figure 5.** Maximum reading rate (expressed as word duration) for both observers as a function of vocabulary size. The linear-regression lines show that duration grows roughly in proportion to the log set size.
Discussion

By installing irrelevant letters (flankers) surrounding the target word, the serial, letter-by-letter process, was successfully being measured within this experiment rather than the holistic method for identification of words. It was proven that the duration needed for a stimulus to be present on the screen was approximately proportional to the log of the vocabulary size. This shows that when reading, observers do not simply recognize all the letters of the word and then know the word. Rather, they identify one letter at a time until the entire word is recognized. As shown with small set sizes, not all letters need to be recognized for the entire word to be recognized. This was because as set size increases, the observer’s ability to use their context and vocabulary as an aid to decipher the target words decreased.

In the 4-word set, (wove, chin, soon, kate), a single letter was enough to identify the word. If the observer was correctly able to identify the first letter of the word, they could accurately identify what word they saw. Within the 26-word set, it was more difficult of a task. It was hypothesized that it would take longer to identify what the target word was because of more repeating letters and because of the greater pool of words to choose from. Within the set size of 26 random words, only seven of the words didn’t have a repeating first letter. Therefore, 19 words did not start with a unique letter (e.g. crew and clip.) Because of this, observers had to identify more letters of the word, to identify what it was. Hence, as vocabulary size increased to a 26-word set, two letters needed to be identified.

Finally, because of the numerous repetitions of letters and the larger pool of words, it was though that it would take even longer to identify the words from the set size
of 1708. With this large set size, an even greater number of letters must be identified to correctly identify the target word.

Conclusion

Reading slows as the number of possible words increases. This reveals the marvelous flexibility of the word identification process that identifies only as many letters as are needed to identify each word. The letters are identified by letter-by-letter decoding, which is generally supposed to be mechanical and autonomous, but the number of letters received, how long it is allowed to run, is sensitive to how much the observer already knows about the word.
Acknowledgements

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Bibliography


