Skimming

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ABSTRACT

Reading consists of serial recognition of words by three mental processes: letter-by-letter decoding, word shape recognition, and use of sentence context clues. Each process makes a specific contribution to overall reading rate. In order to understand how skimming differs from ordinary reading, we measured and compared the contribution of each reading process in skimming and in normal reading. In normal reading, observers read regular text as it would appear in a novel. In skimming, observers read modified text in which half of the words were omitted. For both reading and skimming, we also manipulated the text to selectively disable each mental process. This allows us to isolate the contribution of each process to overall reading rate. Our results show that the sentence context process, which contributes about one-fifth of the normal reading rate, makes hardly any contribution to skimming.

INTRODUCTION

We live in the wake of a print explosion. Reading materials abound through the traditional form of books as well as the recent medium of the Internet. As soon as we are flooded with materials to read, we are flooded with materials on how to read them, fast and efficiently. As a result, speed-reading, or skimming, has become a new frontier in the research on reading psychology. Skimming is often casually referred to as a method of rapidly processing written text without much, if any, loss in comprehension. The idea that skimming can become a valuable tool in learning has motivated many conscientious people in the academic and business worlds to receive instruction in skilled reading. Although countless commercial speed-reading courses and programs on the Internet have swarmed the market since the 1950s, very little is understood about how speed-reading works, and its connections to normal reading.

Early research on speed-reading tends to focus on eye movements and the quantity and duration of the observer's fixations, or the concentration of both eyes, on printed text. One study in the 1960's recorded a reading rate of 10,000 words per minute (wpm) for an observer who made six fixations per page in a "vertically downwards on the left-hand page and upwards on the right" type of pattern, with a mean duration of 320 milliseconds per fixation. Taylor (1962) sampled a group of 41 graduates from a speed-reading course who averaged 2,200 wpm; these readers skipped some lines of text entirely but made multiple fixations on other lines. Finally, McLaughlin (1969) studied a skimmer, reading at 3,500 wpm, who made 14 fixations on a page of 260 words in a "rough zig-zag" pattern; the mean duration of fixation was about 250 milliseconds long.

These findings suggest that skimmers do not rely on the same left-to-right eye movement pattern that normal readers use, as well as that a significant amount of the text has been skipped in the speed-reading process. In general, these results allow us to make only broad and qualitative comparisons between reading and skimming.

In order to draw a quantitative distinction between reading and skimming, we propose a bottom-up approach to identifying the fundamental processes underlying skimming, and compare them to those underlying reading. It is known that reading is comprised of three distinct processes: letter-by-letter decoding (L), word shape recognition (W), and higher level contextual sentence processing (S). This model of reading (called the LWS model) supposes that there are three independent ways to recognize a word. Each process makes an independent additive contribution to reading rate. By distorting the text, either the L,W, or S process can be selectively knocked out, preserving the others. Because each knockout defines a process, the amount (in wpm) that each process contributes to overall reading rate can be determined.

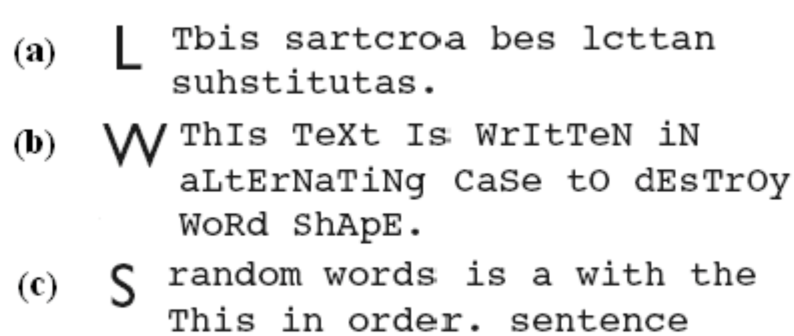


Figure 1. Knockout manipulations. (a) Substituting similar letters knocks out the Letter process (L), which identifies letters to form the word. **(b)** Alternating case knocks out the holistic Word process (W), which recognizes words by their shape. **(c)** Scrambling word order knocks out the Sentence process (S), which predicts the word based on context (Pelli et al., 2005).

Of the three, the Letter process contributes about 67% of the average adult's reading rate, the Word process only 12%, and the Sentence process 21% (Pelli et al., 2005).

How would the contributions of the distinct reading processes shift in skimming? In order to address this question it is paramount to confine skimming within the same parameters– L, W, and S– as normal reading. If skimmers were found to rely on completely different mechanisms (i.e. the ability to read multiple words at a time) in their task, the LWS model could not be accurately fitted to skimming. On the issue of whether skimmers read several words simultaneously, it has been found that the span of semantic processing, or the area of a page from which a reader encodes words while fixating on one given word, is fairly small. A study of fast readers who had developed their skill without formal training found that their span did not differ from that of slow readers (Jackson & McClelland, 1975). Further, speed-readers fail to answer a comprehension question correctly if they do not fixate on the clue words to the question while reading a text (Just & Carpenter, 1987). In addition to rejecting the conjecture that skimmers rely on broader semantic spans to read, it is found that the key differences between skimming and reading have little to do with subconscious cognitive processes but rather conscious sampling of which words to read in a text. Eye-tracking hardware have particularly aided this area of reading research. Eye-trackers project infrared light to the observer's eye, resulting in a reflectance point on the cornea and the illumination of the pupil. Given the reflectance point and the center point of the pupil, it is possible to map the observer's fixation patterns (Campbell & Maglio, 2001). Eye-fixation data on reading and skimming have shown that skimmers fixate about half as many words as normal readers do, and that the frequency of fixation is inversely proportional to the length of words

(Just & Carpenter, 1987). In other words, skimmers are more likely to fixate on longer words than shorter ones, but only on half of the words in the text. This phenomenon is implemented in our experiment, where all the one-letter, two-letter, and three-letter words have been deleted from the text until roughly 50% of the words remained.

We aim to compare reading and skimming using a bottom-up approach by applying our LWS model to each text condition. In our experiment, observers will be exposed to the normal text (for reading) and the modified text (for skimming) and their reading rates for each of the knockout manipulations will be measured to determine the contributions of the L, W, and S processes. Text will be presented in RSVP (Rapid Serial Visual Presentation), where each word is presented one at a time in succession at the same location on the screen. RSVP eliminates the need for saccadic eye movements, or fast changes in eye position in between fixations, which has been shown to improve reading rate (Rubin, 1992). By analyzing how L,W, and S contributions shift in skimming, it is possible to determine how skimmers “read” and what process(es) impair/enhance their reading experience.

METHODS

Participants

Three observers, JY, DL, and MK, participated in the experiment. The observers all had corrected-to-normal vision and were fluent in English. All were high school students.

Apparatus

All stimuli were rendered on an Apple Power Macintosh running MATLAB (Mathworks) in conjunction with the Psychophysics Toolbox extension (Brainard, 1997; Pelli, 1997). To achieve a 12-bit on-screen accuracy, and for accurate contrast control (Pelli & Zhang, 1991), a video attenuator was used to drive a green gun on an 18 Sony Multiscan G400 monitor. The display was set to 10 cd/m^2.

Stimuli & Design

Text was presented in the fovea, or the center of the visual field, using Rapid Serial Visual Presentation (RSVP). RSVP displays one word at a time, centered horizontally, at a specific location. The letter size, x-width of the lower-case letters, was 0.5º at a 200-cm testing distance. Center-to-center letter spacing was 1.25 times the letter size, or 0.62 º. To stimulate real reading, text was shown with spatial flankers, which are random single letters positioned one letter-space before and after each target word.

All texts were sampled from a Mary Higgins Clark fiction novel (average Flesch Kincaid grade level 7.5). All proper names were preserved to simulate actual reading. Punctuation was shown attached to its preceding word (*Said* with attached colon is shown as *said:*). Words with dashes were separated. All text was presented in Courier10 BT font.

There were 8 different text conditions for each subject. The same 8 text conditions were administered for normal reading and skimming, for a total of 16 reading rates per subject. To simulate reading, observers read from the normal text, in which all the words are preserved. To simulate skimming, observers read from the modified text, in which all words with three or fewer letters were discarded.

Text was shown in order or in scrambled word order. Regular text will be referred to as ordered, and scrambled sentences will be referred to as unordered. Plain text conditions refer to trials in which the case and letters of the original text were preserved. Alternating case text conditions refer to trials in which letters within a word are alternating upper and lower cases. Substitution text conditions refer to trials in which the letters are replaced with substitutes, as explained below. Substitution with alternating case conditions are trials in which letters alternate cases as well as being substituted.

LWS Model (words/min)	Ordered	Unordered
Plain	L+W+S	L+W
Alternating Case	L+S	L
Substituted	W+S	W
Alternating Case & Substituted	S	0

Table 1. Summary of the LWS Model. Reading rate predictions of the LWS model for combinations of text manipulations. The model has parameters, L, W, and S.

In the substituted text conditions, we replaced the original letter with a new letter that retains the basic shape of the letter, including its unique features (i.e. the ascender in “b” and the descender in “p”). The rule for choosing substitutes is that substituted letters must be indistinguishable from the original when viewed in the periphery. In the substitution condition, the L process is effectively knocked out while the W process is preserved. See Table 2 for a complete list of the substitutes.

Lowercase Letter	Substitute	Uppercase Letter	Substitute(s)
a	e	B	P, R
c	o	O	Q
o	c	X	K
b	h	C	G
n	r	I	L
g	q	B	F

Table 2. List of substitutes.

Procedure

In both the normal reading and skimming trials, two small black squares positioned vertically letter-height apart were presented in the center of a uniform green computer background, at eye level with the observer. The observer was asked to fixate between the two points, which sat directly above and below the middle of the target word. The points remained on the screen throughout a given trial. In these trials, the experimenter monitored the eyes of the observer to ensure that fixation was maintained. Trials in which the observer failed to maintain fixation were omitted from the reported results.

Each trial consisted of 7 words, and each run consisted of 12 trials. The experimenter clicked the mouse to begin the first seven-word trial. The text was displayed quickly, one word at a time, at the appropriate location on the screen, and the observer tried to read the words aloud with no time limit. After each trial, the experimenter counted the number of words read correctly. Credit was given regardless of the order in which the words were reported. The QUEST (Watson & Pelli, 1983) software uses an up-down staircase procedure to select a new rate for the next trial, honing in on 80% correct, which we call threshold. QUEST uses the presentation rate and number of words read correctly per trial to estimate a threshold reading rate for each text condition.

RESULTS

The reading rates, in words per minute (wpm) for each of the eight combinations of knockouts were measured for both the reading and skimming conditions. The observers are represented by the initials JY, DL, and MK.

Observers	JY		DL		MK	
Text Condition	Normal	Skim	Normal	Skim	Normal	Skim
Plain, O	354	275	469	367	545	284
Alt. Case, O	316	232	463	265	420	250
Substitution, O	37	19	39	14	15	11
Sub. Alt., O	16	13	45	13	13	8
Plain, U	251	260	373	335	335	292
Alt. Case, U	211	229	370	294	253	253
Substitution, U	17	48	38	20	11	9
Sub. Alt, U	13	29	40	34	10	10
RMS Error	**32**	**31**	**27**	**36**	**17**	**21**

Table 3. Reading rates for each knockout condition for the three observers. The knockout condition "Plain, O" denotes plain text with all words in correct order. "Plain, U" denotes plain text with words in randomized order, or unordered. "Sub. Alt" denotes where both substitution and alternating case were introduced to the text. "Normal" refers to normal text, used for the reading condition, whereas "Skim" refers to modified text, used for the skimming condition.

We fit the additive LWS model (Table 1) to the above reading rates to calculate the individual contributions of the three processes. The low RMS errors point to the excellent fit of our model.

Observers	JY		DL		MK	
Text Condition	Normal	Skim	Normal	Skim	Normal	Skim
L (letter process)	237	226	370	294	316	260
W (word process)	31	35	27	35	43	19
S (sentence process)	60	11	30	7	101	1

Table 4. The individual contributions of L, W, and S to the overall reading rates of the three observers.

It is important to note that, if we take into account all the words that were omitted (43% of the original) under the skimming condition, the reading rates for skimming should be significantly higher than the ones shown above. To be exact, each reading rate under the skimming condition should be multiplied by a factor of 100/(100-57), or approximately 1.75. These calculations are incorporated in Table 3, which shows the rates at which the skimmers would have read if we take into account the omitted words.

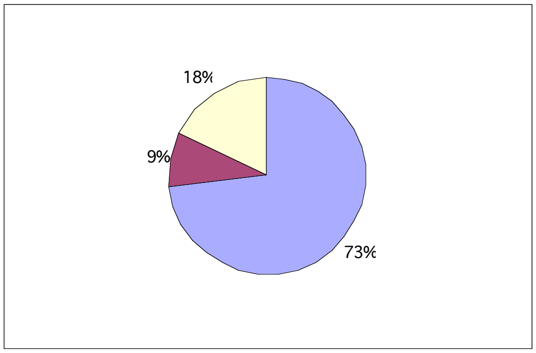
Observers	JY		DL		MK	
Text Condition	Normal	**Skim**	Normal	**Skim**	Normal	**Skim**
L (letter process)	237	**396**	370	**515**	316	**455**
W (word process)	31	**61**	27	**61**	43	**33**
S (sentence process)	60	**19**	30	**12**	101	**2**

Table 5. The actual reading rates under the skimming condition, or "skim rates," for the three observers (in bold).

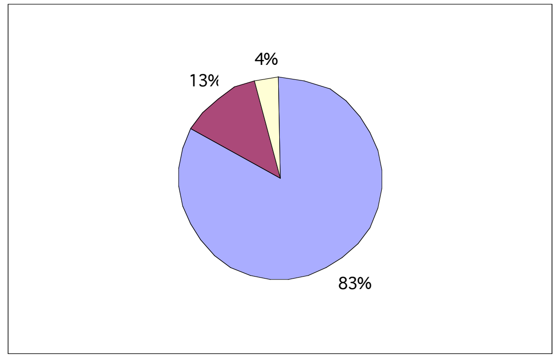
Fig. 2 presents graphical representations of how the contributions of each process shifts under the normal reading and the skimming conditions, for all three subjects. Consistent across all three observers, the contribution of the sentence (S) process to overall reading rate diminished the most under the skimming condition. In addition, the decline in the role of the S process seems to have created a greater reliance on the letter (L) process in reading. Reading rates for the word (W) process remain roughly the same in both text conditions for all three observers.

Observer: JY

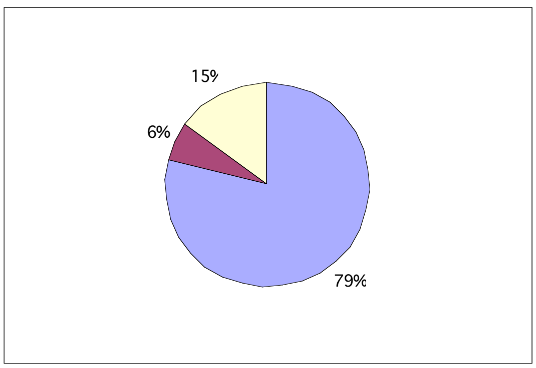
Normal

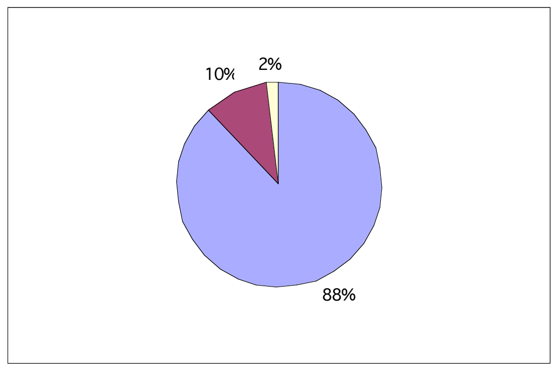


Skim

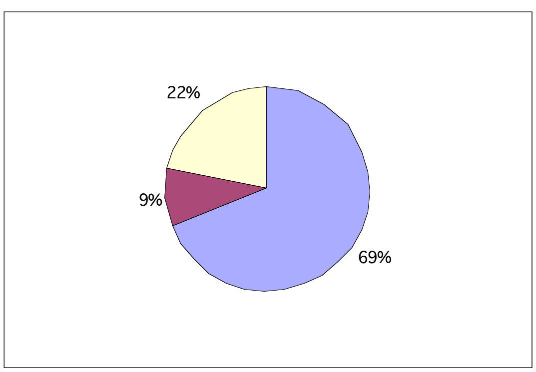


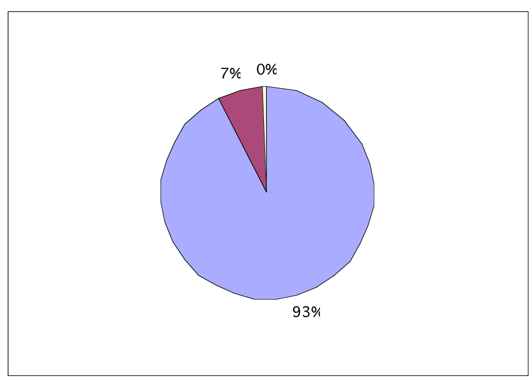
Observer: DL





Observer: MK





DISCUSSION

By determining reading rates achieved by various combinations of the three processes in reading and skimming, we found that (1) the L process contributes the most to both reading and skimming, 74% and 88%, respectively, and much more in skimming, (2) the W process contribution is similar in reading and skimming, contributing approximately 8% in reading and 10% in skimming, (3) the role of the S process is significantly greater in reading than in skimming, 18% compared to 2%.

The reading rates in both Table 1 and Table 2 under the skimming condition were calculated without taking into account all of the omitted words in the modified text. In order to report the speed at which the skimmers would have read, we must multiply each reading rate by a factor of 100/57, since 57% of the original words remained after the text had been modified. This calculation would yield an average of 457 words read per minute across the three observers in skimming. Their average rate for normal reading is still 282 wpm. As expected, the overall reading rates for skimming is much higher than the normal reading rates.

The S process, or context effect, is highly dependent on print exposure (Stanovich et al., 1995), or prior reading history. Contextual clues allow the observer to make inferences about the identity of a word before it is presented on the screen. One of the important methodologies we use in measuring the S process is to maintain a fixed accuracy criterion in measuring reading rates. We defined our reading threshold to be 80% correct word identification. Thus, at threshold, 80% of the words are identified. For ordered plain and alternated case text, we measured such threshold reading rate. However, the unexpectedly strong effect of our substitution manipulation, knocking out the L process while preserving the W process, makes the words almost impossible to read and thus threshold is rarely reached. Our threshold estimation procedure extrapolates from the low proportion correct to estimate threshold, but this extrapolation is based on data collected at a low proportion correct. Thus the words in the rest of the sentence, which provided context, are at well below 80%, and greatly impaired. When we apply letter substitution, the only information available is word shape and context. However, the W and S processes together cannot identify 80% of the words even at the slowest rate allowed by our program, which is 1 wpm. Even though the content threshold of 80% is not reached for all conditions with substitution manipulation, Quest uses the number correct to estimate a reading rate at which threshold should be 80% correct (Pelli et al., 2005).

Reading rate should be 0 wpm when all three process are knocked out. We find, however, that observers were still able to read at about 25 wpm. There are two explanations for this phenomenon. One, many of the letters lack good substitutes and are therefore best left alone. It is possible that these letters may have a valid contribution to the L process. Two, short words that are two or three letters long (i.e. the, to, in, etc), which appear in abundance in the text for the reading condition, can be guessed at even without context, word shape, or letters.

CONCLUSION

We investigated skimming by introducing our three-process reading model on a skimming condition. We found that the sentence process was most affected in skimming. While the role of sentence context decreased, the role of the letter process increased. This study suggests that skimmers perhaps rely on a trade-off between contextual clues and letter-by-letter decoding to gain a speed advantage.

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