DOCUMENT RESUME

ED 249 467 CS 007 793

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TITLE	A 'ord on Final Words.
PUB DATE	83
NOTE	19p.; Paper presented at the Annual Meeting of the Psychonomic Society (San Diego, CA, 1983).
PUB TYPE	Rep<rts - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Cognitive Measurement; *Cognitive Processes; *Encoding (Psychology); Higher Education; *Language Processing; Learning Strategies; *Modeling (Psychology); Reading Processes; Reading Rate; *Reading Research; Reading Strategies; Recall (Psychology); Sentences; *Sentence Structure; Word Recognition
IDENTIFIERS	*Prose Learning

ABSTRACT

Two experiments examined the cognitive resources used by readers in sentence modeling (summarizing the propositions in a sentence) as a function of reader task and of sentence complexity. It was predicted that encoding a sentence into memory for later recall would require more cognitive resources than reading a text to answer immediate questions, and that the modeling process would be more resource consuming, the greater the number of propositions. Undergraduate students acted as subjects for the experiments and word reading time was the dependent variable. In the first experiment, which involved both recall and question answering, 93 subjects read 15 passages, and in the second experiment, 58 subjects read 13 different passages. In both conditions, readers spent a longer time reading the final word than the remaining words in each sentence. Such sentence "wrap-up" was stronger in the recall than in the question answering condition. In both conditions, the final word processing increased with the amount of information in the sentence, and was diminished in sentences that contained a major clause. Similarly, the final word processing decreased with the serial position of the sentence in a passage. The results indicated that the readers used the end of a sentence, and to a lesser extent the end of a major clause, as an occasion to abstract the essential ideas of the sentence and to integrate them with the growing representation of the text. (HTH)

A WORD ON FINAL WORDS

Paper read at the Annual Meeting of the Psychonomic Society, San Diego, California, 1983

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Abstract

Undergraduate students read texts in a subject-paced reading experiment with word reading time as a dependent variable. Two task conditions were used, recall and question-answering. In both conditions, readers spent a longer time reading the final word than the remaining words of a sentence. Such sentence "wrap-up" was stronger in the Recall than in the Question-answering condition. In both conditions, the final-word processing increased with the amount of information in the sentence. It was diminished in sentences that contained a major clause. Similarly, the final-word processing decreased with the serial position of the sentence in a passage. These results indicate that the reader uses the end of a sentence, and to a lesser extent, the end of a major clause, as an occasion to abstract the essential ideas of the sentence and to integrate them with the growing representation of the text.

A Word on Final Words

Ten years ago Johnson-Laird (1974) formulated the fundamental problem in psycholinguistics as follows: What happens when we understand sentences? While there is no single answer to this question, theorists at least agree on two important aspects of sentence understanding. The first is that people segment the sentence into smaller units such as phrases and clauses. Second, people interpret the semantic relationship between the sentence predicate and its arguments (see Clark & Clark, 1977, p.44).

When the sentence appears in the context of a passage, as almost all written sentences do, people perform an additional operation. They establish relationships between the sentences. Importantly, in reading a text, the reader's goal is not so much understanding any individual sentence, but to understand the meaning of the passage as a whole. The meaning of the passage is represented in an abstract model of the text which is assumed to consist of propositions (Kintsch & van Dijk, 1978). The segmentation and semantic interpretation processes and a third process, sentence modeling, are components of creating this text model.

The process I am concerned with here is the sentence modeling process. It produces a propositional representation of the current sentence. This representation includes the propositions resulting from the semantic interpretation process. It also includes pointers to concepts introduced in previous sentences. The function of the sentence representation is to provide a set of propositions from which propositions can be abstracted for the growing text model. Text-level processes such as deletion, generalization, and integration (Kintsch & van Dijk, 1978) perform this abstraction process. Once certain propositions have been selected for the text model, the current sentence model has served its purpose. The reader can abandon it and move on to the next sentence. The notion of a sentence model is implicit in the text processing approaches of Jarvella (1979), Miller and Kintsch (1980), and Mitchell and Green (1978). These theorists assume, although in different terminologies, that the reader 'summarizes' or 'chunks' the information contained in a sentence. The sentence model simply provides the pool of propositions on which the summarization process works.

The purpose of this research was to study the resources used by the reader in sentence modeling as a function of reader task and of sentence complexity. If the task is to read the text in order to answer some easy questions, relatively few cognitive resources should be required. On the other hand, if the reader intends to recall the text, he or she is assumed to encode the sentence representation into long-term memory which should require more resources than question answering does. Similarly, the modeling process should be more resource consuming, the more complex the sentence is in terms of its number of propositions.

There is ample evidence that sentence reading times depend on the number of propositions of the sentences. Specifically, sentence reading times controlled for the number of words increase linearly with the number of propositions in the sentence (Graesser & Riha, 1984; Haberlandt, 1984; Kieras, 1981a; Kintsch & Keenan, 1973; Kintsch, W., Kozminsky, E., Streby, W. J., McKoon, G., & Keenan, J. M., 1975). However, since sentence reading time is a rather global processing measure, it does not reveal the location(s) at which the the propositional complexity exerts its influence. The proposition effect could become manifest in several different reading time patterns. Let me name three of these. First, it could be reflected in a continuous increase of the reading times of individual words, at least after several propositions have been introduced. Chang (1980) reported some data that support this hypothesis. Second, word reading times could increase with the introduction of each new proposition. Both of these hypotheses are based on the assumption that as the amount of information stored in short-term memory increases its capacity to process additional information should decrease. Third, as Kintsch & van Dijk (1978) hypothesized the proposition effect could manifest itself at syntactically defined locations such as clause and sentence boundaries.

I studied the sentence modeling process in a subject-paced reading situation by examining the relationship between word reading times and the task as well as the number of propositions in the sentence.

Method

Today I shall describe data from two experiments. In Experiment 1, which involved two task conditions, 93 subjects read 15 passages, and in Experiment 2, 58 subjects read a set of 13 different passages.

In reading research many factors are necessarily confounded. The approach I took was to identify these factors and control for them by multiple regression analysis.

The data I'll present here are word reading time results. Of the methods available for recording word reading times I used the "Moving Window" method (Just, Carpenter, & Woolley, 1982; Kennedy, 1983; Wilkinson, 1983). In this method, words of a text are presented on a video-terminal one at a time at successive locations from left to right on the terminal. The reader advances through a text by pressing a key which causes the current word to appear on the screen. Word reading times were defined as the interval between successive key presses.

Results

I computed regressions on word reading times with several predictor variables entered simultaneously. There were four classes of predictor variables, word-level, sentence-level, text-level, and layout variables. The word-level variables included the length of the word expressed in the number of characters, the occurrence frequency of the word in English (Kucera & Francis, 1967), and whether the word was a content or function word (see Clark & Clark, 1977, p. 22). Sentence-level factors included such variables as the beginning and the end of a sentence, and the end of a major clause. The words of a given sentence were also coded according to the number of propositions in the sentence (see Bovair & Kieras, 1981; Turner & Greene, 1977). I also included text-level factors, but I won't have time to discuss them today.

Table 1 contains results of a multiple regression analysis computed on data from the

Table 1

Regression results for two conditions from Experiment 1

	Assertions		Recall	
	coeff	t	coeff	t
Length	6	4.68	15	5.00
Frequency	-24	8.93	-35	5.64
First wd	71	9.91	109	6.59
Last wd	260	34.81	1079	62.36
Clause	30	2.19	109	3.38
Proposit	3	2.99	8	3.26
Ser pos	-3	7.06	-13	11.26
Familiarity	-13	6.98	-23	5.17
Beg of 1	35	4.71	46	2.66
End of 1	42	5.55	37	2.07

Table 2

Regression coefficients for last and control words

(Assertions Condition)

	final words		control words	
	coeff	t	coeff	t
Length		ns		ns
Frequency	-77	4.37	-41	4.88
Proposit	19	6.81		
Ser pos	-20	6.81		
Familiarity	-37	3.11	-15	2.55

Assertions and Recall conditions of Experiment 1. In the Assertions condition 55 people read passages with the goal of responding "Yes" or "No" to some assertions about each passage. In the Recall condition 48 people were asked to recall the passages as close to verbatim as possible.

Insert Table 1 about here

Two statistics are included in Table 1, the regression coefficient and the t-value associated with each predictor variable. Of interest to us here is the final word effect which is reflected by a regression coefficient of 260 msec in the Assertions condition. This means that final words in this condition take 260 msec longer to read than other words controlling for the remaining factors. The t-value indicates that this final word effect is highly significant. The raw word reading times reflect the final-word effect also. In the Assertions Condition mean word reading times for non-boundary words and final words were 483 and 776 msec, respectively. In the Recall condition the corresponding means were 605 and 1739 msec, respectively. So both raw word reading times and regression coefficients give evidence of special processing at the final word of sentences.

Now I shall describe this special processing more closely. I base this description on two regressions. One regression was computed on the reading times of sentence-final words and the other on the reading times of a set of control words. This set was comparable to the set of sentence-final words in terms of word length and frequency, and in terms of the proportion of content words. For the Assertions condition of Experiment 1, the regression results for last and control words are shown in Table 2.

Insert Table 2 about here

Table 2 shows that the pattern of factors contributing to the reading time variance in final compared to control words was different. Specifically, the number of propositions

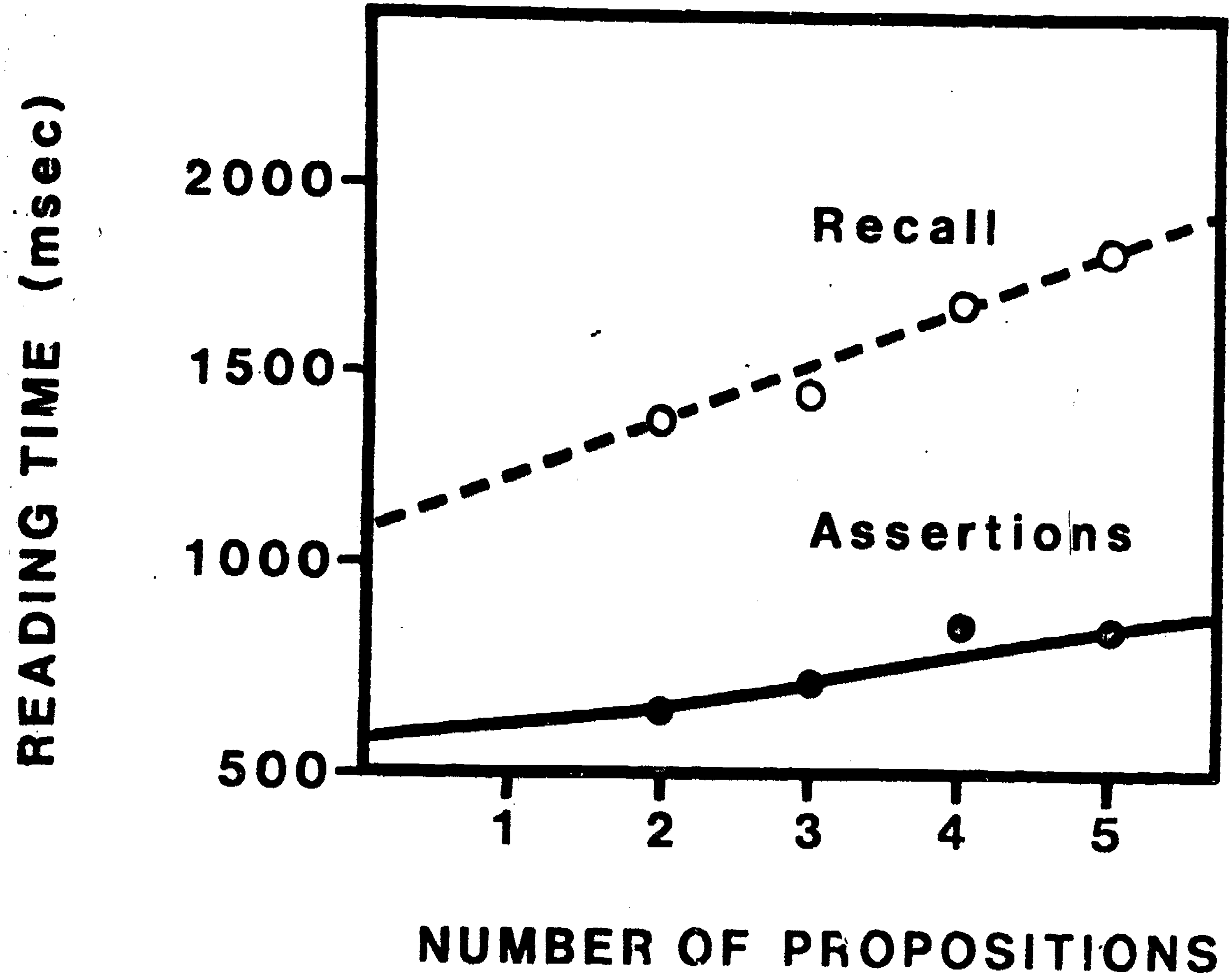

Figure 1. Reading times of sentence final words as a function of propositions and task.

per sentence had a significant effect on the reading times of final but not of control words. Similarly, there was an effect of serial position on final but not on control words. In my talk today I shall focus on the proposition effect.

The proposition effect was significant for both the Assertions and the Recall conditions of Experiment 1. However, as expected, it was more pronounced in the Recall condition. This interaction is illustrated in Figure 1. Figure 1 represents the proposition effect in the Assertions and Recall conditions. It depicts reading times of last words of sentences containing 2 through 5 propositions. I used this set of sentences because it provided a sufficiently large number of cases at each sentence length. The apparent interaction in Figure 1 was confirmed by a significant Proposition x Task interaction term ($t = 21.83$, $p < .001$) observed in a multiple regression. I computed this regression on last word reading times with serial position, passage familiarity, word length and word frequency as additional factors.

Insert Figure 1 about here

The fact that the proposition effect was present in final, but not in control words, supports the hypothesis that the reader creates the sentence representation at the sentence boundary rather than incrementally with each additional word. Unlike in Chang's (1980) study, there was no evidence of a continuous increase in word reading times with the serial position of words within a sentence.

The presence and the size of the final-word effect in the Recall condition raises the question whether or not, the level of a subject's recall is correlated with the extent of the person's final-word processing? If final-word processing does, in fact, mirror the sentence modeling process, a person who engages in such processing should encode the text effectively which in turn should support better recall. The answer to this question is yes. I correlated the mean recall of 9 passages with the standardized regression coefficient of

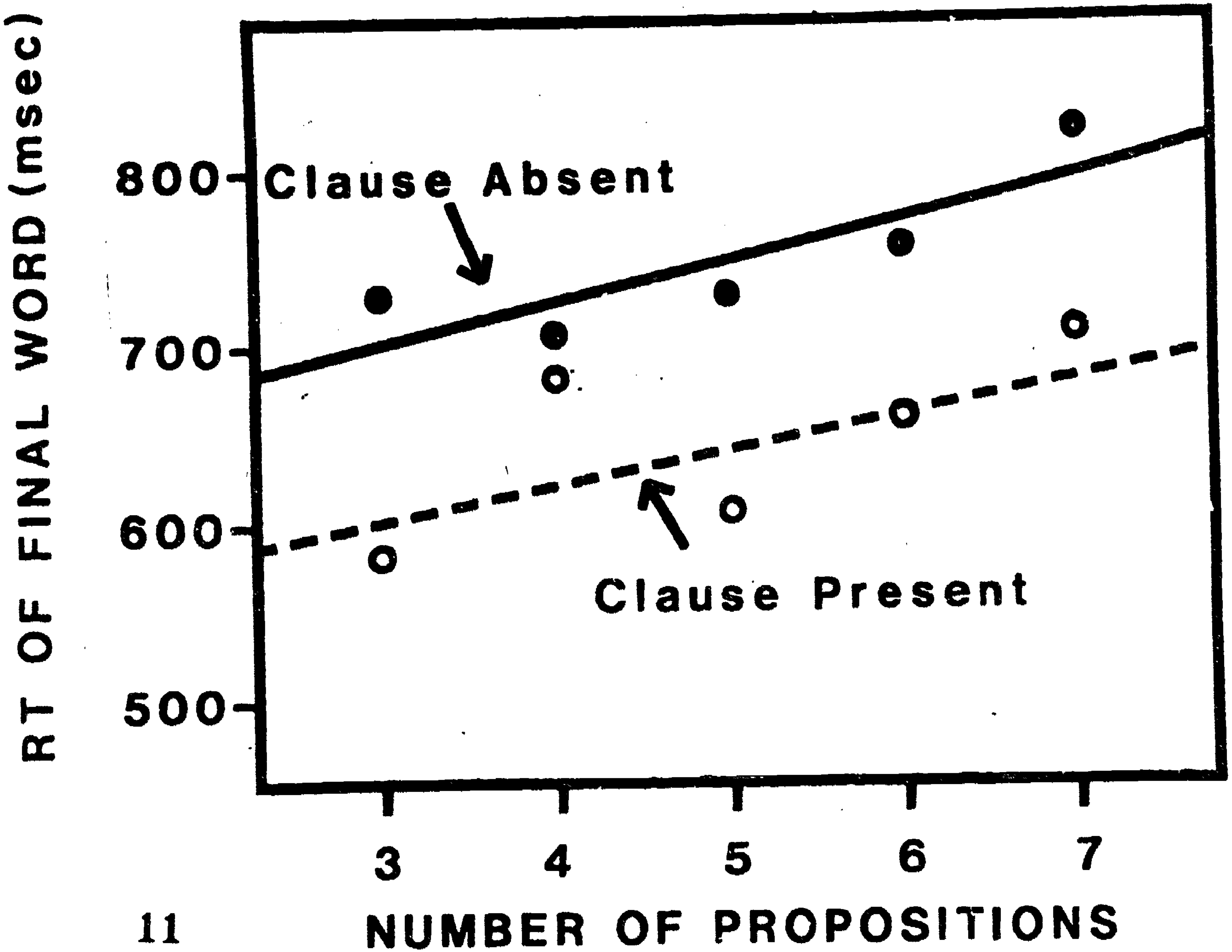

Figure 2. Reading times of sentence final words as a function of propositions and presence or absence of clause (Experiment 2).

final words for the 48 subjects who participated in the recall condition of Experiment 1. This correlation was $r = .55$, $p < .001$. This means that people who took longer to read sentence-final words recalled the passages better.

Of course, sentence-final words are not the only locations subjects use for encoding or sentence modeling. Other opportunities exist at at topic shifts, at episode and paragraph boundaries (e.g., Haberlandt, K., Berian, C., & Sandson, J., 1980), at physically marked locations such as the beginning and the end of a line, and at clause boundaries, as predicted by Kintsch & van Dijk (1978).

End-of-sentence and clausal processing: Regarding clausal processing, I evaluated the hypothesis that the presence of a clause in a sentence should provide the reader with an opportunity to generate the sentence model incrementally at the clause and at the sentence boundary. Consequently, reading times of final words should be shorter in sentences with a clause than in sentences without a clause. Analysis of data from Experiments 1 and 2 suggests that the clausal structure modified end-of-sentence processing as predicted. Specifically, final-word reading times were longer in sentences that did not contain a major clause than in sentences that did. This effect is shown for Experiment 2 in Figure 2 where mean word reading times of last words of a sentence are graphed as a function of the presence or absence of a clause and of the number of propositions from 3 through 7. The Figure indicates that for each sentence length, processing of the final word is shorter in sentences with a clause than in sentences without one.

Insert Figure 2 about here

The observation that end-of-sentence processing is less in sentences with a major clause supports the expectation that in those sentences the sentence modeling process is distributed over several locations in the sentence. As Figure 3 indicates one such location is the last word of a major clause (see also Fodor, J. A., Bever, T. G., & Garrett, M. F.,

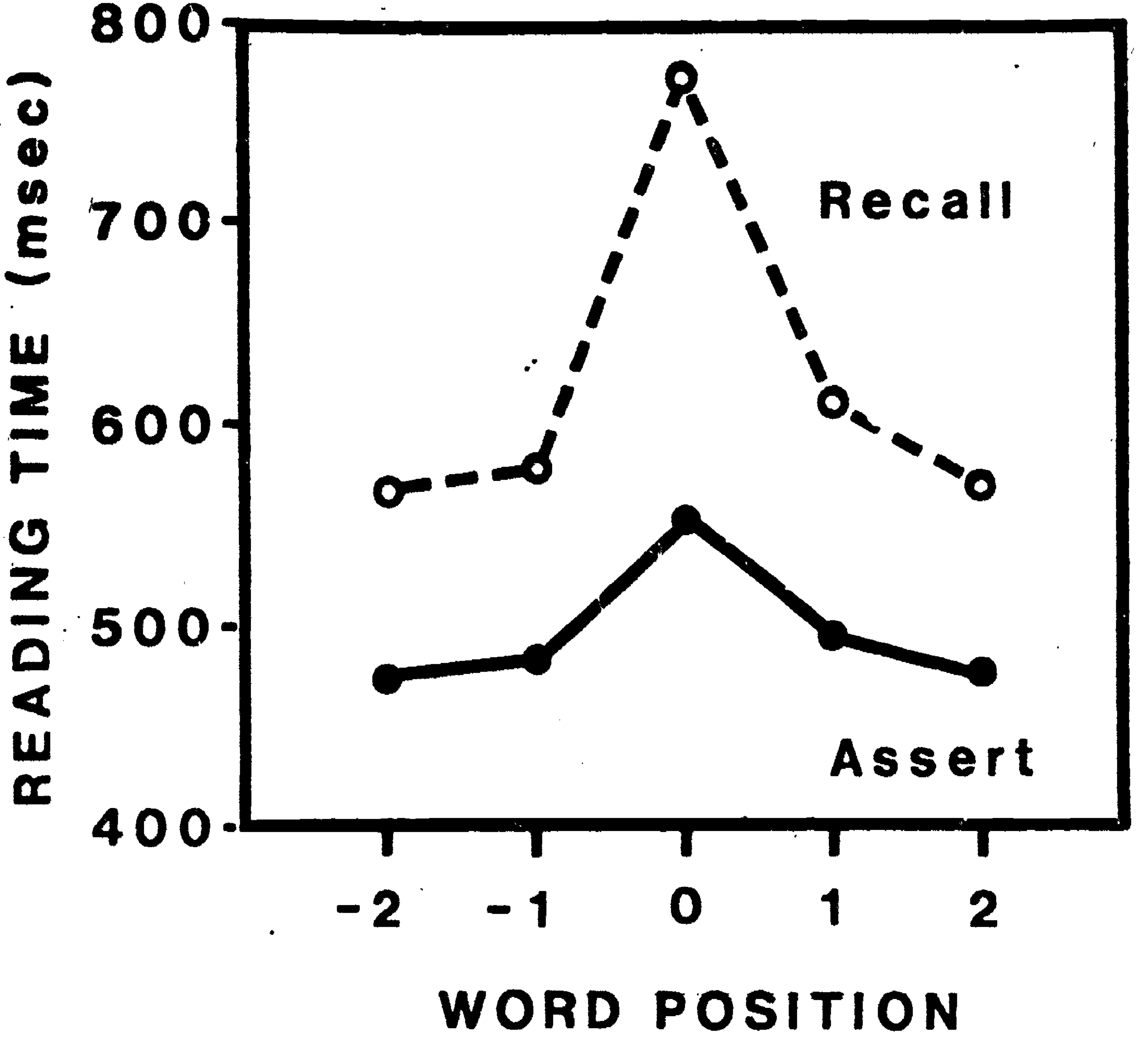

Figure 3. Mean reading times of last words (0) of major clauses and of surrounding words.

1974; Hurtig, 1978; Jarvella, 1971; Kaplan, 1975; Miller & Kintsch, 1980; Thibadeau, R., Just, M. A., & Carpenter, P. A., 1982). In Figure 3 mean word reading times are graphed for words at the clause boundary and for the two surrounding words.

Insert Figure 3 here

The solid and broken lines of Figure 3 depict the clausal effect for the Assertions and Recall conditions of Experiment 1, respectively. Since last words of clauses tend to be longer and less frequent than the surrounding words, this clausal effect is at least in part due to these lexical factors. However, even after partialing these factors, the clausal effect is statistically significant. The clausal effect is more pronounced in the Recall than in the Assertions condition, which is not surprising in view of long-term encoding processes required in recall (see Aaronson & Scarborough, 1976). Further analyses of the clausal effects in both conditions revealed that individual subjects differed considerably in the level of extra processing at clause boundaries. This was especially true in the Assertions condition where only 58% of the subjects evidenced a positive regression coefficient associated with clausal processing.

Conclusion and future directions:

I have presented results on special sentence-level processing at sentence and clause boundaries. These results support the hypothesis of a modeling operation that creates a propositional representation of the sentence. They do not, however, indicate that parsing and semantic interpretations are delayed.

The final-word effect has been obtained in using a variety of measures and methods, including gaze durations (Just & Carpenter, 1980), the moving window condition (Just & Carpenter, 1980), (Post, 1983), the pointing window condition (Dixon, 1983), and the stationary window condition (Aaronson & Scarborough, 1976). The effect is implicitly acknowledged by some researchers who use RSVP, e.g. Kutas & Hillyard (1983). However, the final-word effect is not universal. For example, Just, Carpenter, & Masson (1982) did not observe it in a gaze duration study. Similarly, many subjects, including some in my own studies, do <u>not</u> give evidence of prolonged end-of-sentence processing. It remains for future research to isolate the causes for the presence or absence of the final-word effect. Future research should also determine additional factors contributing to this effect. Such factors include the amount of new information and the the lexical complexity of the current sentence.

The proposition effect should also be investigated further. There was a significant proposition effect in the Recall and Assertions conditions of Experiment 1, but not in Experiment 2 in which I used an Assertions condition. This effect, then, should be further evaluated as a function of reader task and type of passage. Importantly, the effect should be examined in longer sentences than those I used to date. I could imagine that at a certain point final word reading times cease to increase with the number of propositions simply because there are too many.

Finally, there is an important question about the clausal effect I described. If part of the sentence representation is created at the clause boundary, as my results indicate, it must be determined how the partial representation is integrated with the rest of the sentence. Given all these questions you can see why my talk had to be entitled "A Word on Final Words," rather than "The Final Word on Final Words."

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