# 6 Priming and On-Line Text Comprehension[1]

Gail McKoon and Roger Ratcliff
*Northwestern University*

There are a number of procedures that can be described as involving priming. What they have in common is an attempt to influence a subject's response to a test item by presenting some priming information immediately prior to the test item. Where the procedures differ is in the kind of priming information presented and the kind of response required to the target test item. The priming information is sometimes a single word, sometimes a whole sentence or paragraph; sometimes in the same modality as the target, sometimes not. The target can be a single word or a sentence. For a single word, the subject's task may be item recognition, perceptual identification, lexical decision, or naming the word aloud. For a sentence, the task is verification ('is the sentence true or false?'). In all of these tasks, the measurement of interest is the amount of facilitation or inhibition in response time to the target as a function of priming information.

The priming task we have found most useful for examining the processes of comprehension is item recognition. Subjects are required to respond 'yes' or 'no' according to whether a target word was or was not present in previously read textual information. We like this task for two reasons. First, it requires reference to information about the text, whereas in lexical decision or naming, a response can be made without reference to the text. Second, response times in item recognition are relatively long (around 600-700 msec) so that the effects of priming can be relatively large (as large as 100 msec). Such large effects ensure enough sensitivity

[1]Preparation of this chapter was supported by NIH grant HD16381 and by NSF grant BNS-8203061. We wish to thank David Kieras and Marcel Just for their useful comments on an earlier version of the chapter.

to examine differences in amount of priming as a function of various experimental conditions.

We have used priming in item recognition to investigate two different aspects of comprehension: these are the state of activation of concepts during comprehension and the organization of information in memory that results from comprehension. To measure activation, the priming information is the text being read and the target is a single word presented immediately after the text, with no delay between text and target. The idea behind this procedure is that, if the reader uses a concept in processing the text, then response time to that concept as a target will be affected.

To examine the representation of a text in memory, testing is delayed and a list of single words is presented for recognition. Measuring the relative distance between two concepts in the representation is accomplished by presenting the concepts in the test list; one, designated the target, immediately follows the other, designated the prime. The idea here is that, if the prime is close to the target in memory, then response time for the target will be affected.

These two different procedures will be described in more detail by presenting examples of experiments that use them. The first experiment examines the activation of the referent of an anaphor, and the second examines the representation in memory that results from anaphoric reference.

## EXPERIMENT 1: ACTIVATION OF CONCEPTS

Consider the text shown in Table 1 (from McKoon & Ratcliff, 1980b). In version 1, the final sentence begins with an anaphor, *the criminal*, so reading this sentence should produce activation of the referent, *burglar*. But reading the other version of the final sentence, where there is no anaphor, should not produce activation of *burglar*.

To measure this difference in the state of activation of *burglar*, and to examine the time course of this difference, subjects read texts like that shown in Table 1 (a more complete description of this research is given by Dell, McKoon, & Ratcliff, 1983). The texts were presented word-by-word across a CRT screen, with each word in a sentence turning on 250 msec after the previous one (about normal reading rate). By the end of the sentence, all of the words were displayed. Then the sentence disappeared and the next sentence was presented in the same way. By presenting texts this way, a test word could be presented at any point, after any word of the text. A test word was identified to the subject by presenting it all in capital letters; just before it was presented, any part of a sentence that was on the CRT screen disappeared. As soon as the subject responded to the test word ('yes' or 'no' according to whether it had appeared in the text being read), the test word disappeared from the screen and, after a subject-paced pause, presentation of the next text began.

As can be seen in Table 1, subjects read either the first or second version of the text. The test word was the referent of the anaphor in version 1 (*burglar*), another

TABLE 1
An Example of the Paragraphs
Used in the Experiments (1)

Referent of the anaphor: "burglar"
Word in the same proposition as the referent: "garage"
Control word: "bottles"

Sentence 1:
A burglar surveyed the garage set back from the street.

Sentence 2:
Several milk bottles were piled at the curb.

Sentence 3:
The banker and her husband were on vacation.

Sentence 4: (Version 1, anaphor):
The criminal slipped away from the streetlamp.
1 2 3 4 5 6

Sentence 4: (Version 2, no anaphor):
A cat slipped away from the streetlamp.
1 2 3 4 5 6

(1) The number subscripts represent test positions.

word in the same proposition as the referent (*garage*), or a word unrelated to the anaphor or referent from one of the two middle sentences (*bottles*). Across several experiments, the test word was presented in six different positions in the final sentence. The combined results of these experiments are presented in Table 2, which shows the amount of facilitation given to the test word by the final sentence that mentions the anaphor, relative to the amount given by the other final sentence. It can be seen that the anaphor gives rise to very rapid activation of its referent, that it gives rise to equally rapid activation of other concepts in the same proposition as the referent, and that activation of the referent but not the other concepts remains to the end of the sentence. Our interpretation of these results is that an anaphor causes very fast activation of propositions containing a referent and then continued activation of the concept selected as the referent. This continued activation of the referent may be necessary for the establishment in memory of connections between information mentioned in the text about the referent and information mentioned about the anaphor.

## EXPERIMENT 2: ORGANIZATION OF INFORMATION IN MEMORY

In version 1 of the text shown in Table 1, the final sentence mentions an anaphor for a concept from the first sentence. Thus, when this version of the text is read, information about the anaphor should be connected in memory to information about the referent. For example, the concept *streetlamp* should be connected to the concept *burglar*, because it was the burglar who slipped away from the streetlamp.

TABLE 2
Amount of Facilitation (in msec)
in Each Condition of Experiment 1

| | Test Position | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Test Word | | | | | | |
| Referent | -3 | 28 | 30 | 34 | 24 | 36 |
| Same prop. word | 1 | 30 | 35 | — | 3 | -6 |
| Control | — | — | 1 | — | 11 | 4 |

In the other version of the text, there is no anaphor in the final sentence, so *burglar* and *streetlamp* should not be connected.

To examine this difference in the way information is organized for the different versions, subjects read texts like the one in Table 1. There was a series of trials, and each trial consisted of a study phase and a test phase. In the study phase, two texts were presented, one at a time, for 8 sec each. Then the test phase began immediately. Single words were presented, one at a time, for recognition ('was the word in either of the texts presented in the study phase, yes or no?'). After 10 test words and a subject-paced pause, the next trial began.

One noun from the final sentence of each text, usually the object of the sentence, was designated a target. This word was placed in some randomly chosen position in the test list, except not in positions 1 or 2. The immediately preceding word in the test list, the prime, was the subject noun from the first sentence of the text (the referent of the anaphor in the final sentence of version 2). For the example shown in Table 1, the prime was *burglar* and the target was *streetlamp*. The amount of facilitation given by the prime to the target should differ, depending on which version of a text was read. If the final sentence mentioned an anaphor of the prime, then prime and target should be closely connected in memory and the amount of facilitation should be relatively large. If the final sentence did not mention the anaphor, facilitation should be less. In fact, these are the results that were obtained; response time for the target was 644 msec when version 1 was read and 686 msec when version 2 was read.

## AUTOMATIC AND STRATEGIC PROCESSES IN PRIMING

In order to fully understand results from experiments like those above about the activation of concepts and the organization of memory, it is necessary to understand the distinction between automatic and strategic processes and how this distinction applies to priming. Thus, this section of the chapter will be devoted to a discussion of these processes and experiments designed to investigate them.

There are currently two different notions of automaticity. One is that of Schneider and Shiffrin (1977) and it concerns the relationship between a stimulus and the response to that stimulus, and how that relationship can become automatic with practice. The other notion of automaticity, the one which will be used here for discussing priming, concerns the relationship between one concept and another, that is, whether one concept automatically activates another.

This notion of automaticity has been defined by Posner (1978) with respect to three criteria, which can be observed in priming experiments. The first concerns the probability that the subject will encounter a priming pair in which the two items of the pair are related in a way apparent to the subject (e.g. *A - a* or *bread-butter*). If this probability is varied (say, from almost all items in a test list being primed by a related item to almost none), then for an automatic process, the size of the priming effect will be unaffected. A strategic process, on the other hand, is sensitive to probability manipulations. Second, automatic processes have a very fast onset whereas strategic processes have a slower onset. Finally, the third criterion involves a cost-benefit analysis. Automatic processes give benefits but have no associated costs. In other words, a related prime would give facilitation to a target but an unrelated prime would not lead to inhibition. However, strategic processes do involve costs; a related prime gives facilitation as with an automatic process, but an unrelated prime results in inhibition.

Posner and Snyder (1975) developed this view with respect to letter matching and Stroop tasks, and a comprehensive discussion was presented by Posner (1978). We applied this view to the processes involved in item recognition, and in particular, the processes involved in recognition of concepts from texts, with three experiments (Ratcliff & McKoon, 1981).

All three experiments used a study-test procedure. In the study phase, a list of unrelated sentences was presented for study and in the test phase, which followed the study phase immediately, a list of single words was presented for recognition. For each word in the test list, a subject was required to respond 'yes' or 'no' according to whether that word had appeared in any of the sentences presented in the study phase. In the first experiment, the probability of a related priming pair was varied, where a related priming pair was two words from the same sentence presented sequentially in the test list. Results showed that varying probability in this way had no effect on the amount of facilitation given by the priming word to response time for the target word. Thus, the first criterion for automaticity is satisfied. In the second experiment, the time course of processing was examined. In this experiment, subjects responded to the target but did not make a response to the prime, in order that the time between presentation of the prime and presentation of the target could be varied. The prime was presented for a variable amount of time (the SOA), then it disappeared and the target was presented immediately. There were three kinds of priming pairs: related (prime and target words from the same sentence), unrelated (prime and target words from different sentences), and neutral (a string of random letters priming a word). Facilitation and inhibition were measured with respect to the neutral condition. It was found that for related pairs, facilitation occurred by 150 msec SOA, but that for unrelated pairs, inhibition did not occur until 450 msec SOA. These findings reflect the second and third criteria, that the automatic process producing facilitation is fast relative to a slower strategic process producing inhibition. The third experiment was designed to examine the time course of strategic processing in a task with specific instructions about strategic processing. In the study phase, subjects were presented with two unrelated sentences. Then in the test phase, there was only one priming pair, a prime (to which they did not respond) and a target. Subjects were told, truthfully, that on 75% of trials, the prime and target would not be from the same sentence so that when they saw a prime from one sentence, they should try to switch to recall the other sentence in preparation for the target. At 100 msec SOA, there was facilitation for related (same sentence) pairs, at 700 msec SOA there was inhibition for related pairs, but only at 1800 msec SOA was there facilitation for the unrelated (different sentence) pairs. These results show that, while strategic inhibition can occur by 700 msec, strategic facilitation probably requires at least 1000 msec. Other, less artificial strategic processes might take somewhat less time to produce facilitation, but, nevertheless, it is clear that strategic processes arise quite late in processing.

Taken together, these experiments demonstrate that, under properly controlled conditions, the priming effects observed in recognition of words from texts are automatic effects. Thus, when priming is used to examine the activation of concepts, under conditions where the SOA from the priming information in the text to the target is short, then any facilitation observed for the target can be assumed to be due to automatic processes. For example, in the data shown in Table 2, facilitation is observed for the target *burglar* when the SOA from presentation of the anaphor (*criminal*) to presentation of the target is only 250 msec; so activation of *burglar* by *criminal* is taken to be an automatic process.

Under appropriately controlled conditions, automatic processes are also responsible for effects observed when priming in word recognition is used to examine the organization of concepts in memory. Appropriate conditions are those in which the SOA from prime word to target word (in the test list) is relatively short. This can be accomplished in two ways. If the subject gives a recognition response to both the prime and the target words, then the SOA between them is the response time for the prime plus the time from that response until presentation of the target (150 msec in our experiments); assuming mean response time for primes at 700 msec, this gives a total SOA of about 850 msec. This SOA is almost certainly too short for both processing and responding to the prime AND strategically processing the relationship between the prime and target. Such strategic processing, by itself, would take on the order of 1000 msec according to the results of the experiment mentioned above. Thus, we argue that a procedure in which subjects give recognition responses to both primes and targets shows automatic facilitation effects. However, the SOA between prime and target can be more tightly controlled with the alternative procedure in which the subject does not make a response to the prime; the prime is simply presented for some experimenter - determined time, then it disappears from the CRT screen, and the target is presented. With this procedure, the SOA can be made as short as necessary so that any observed facilitation can be ascribed to automatic processing.

In summary, experimental evidence shows that priming in item recognition can be used to observe the effects of automatic processes, both the automatic processes of activation of concepts during comprehension and the automatic processes of activation of one concept by another concept in the memory representation of a text. The fact that priming can show automatic effects will be used in the next section of this chapter, where priming is compared to other procedures for investigating comprehension.

## PRIMING COMPARED WITH OTHER ON-LINE MEASURES

Priming in item recognition as a procedure for investigating comprehension can be compared both to other procedures for investigating comprehension and to other kinds of priming procedures. These will be discussed in order in this section.

The first dimension on which priming differs from other, more wholistic, measures such as reading time (for words, phrases, or sentences) or eye-movement time is level of analysis. With reading time and eye-movement time, all of the components of processing that increase processing time are measured simultaneously. But with priming, the emphasis is on measurement of components of processing that are not directly observable in reading times or eye movements, components such as the activation of concepts other than those explicitly mentioned in the text and the effect of activation on the memory representation of the text. While reading and eye-movement times can indicate when increased processing is required, they cannot indicate what the effect of that processing is. With respect to inference, for example, reading time may be longer because the subject searches for a to-be-inferred concept but does not find it. Or the concept may be found and activated but not connected to the new propositions as it should be. Even if the proper connections are made, they may not be stored in the long-term memory representation of the text. In general, these kinds of component processes may not be directly reflected in reading and eye-movement times.

Priming, on the other hand, is designed explicitly to measure component processes. For example, the inference that *the criminal* refers to a previously-mentioned burglar involves activating the to-be-inferred concept (*burglar*), connecting information mentioned about the criminal to information mentioned about the burglar, and storing these connections in memory. On the one hand, the activation process can be examined by presenting a test word for recognition, as was done in Experiment 1, and on the other hand, the connections among concepts in memory can be examined by measuring the amount of priming between words in a recognition test, as was done in Experiment 2. Thus, the two procedures allow the separation of two components of comprehension.

The second respect in which priming differs from other on-line procedures is that priming is not, strictly speaking, an on-line measure. What priming measures is the state of activation of concepts (or state of working memory, in some theoretical frameworks) at the point of interruption during reading or after a delay from the end of reading. Thus, rather than measuring the total time taken for reading, priming can measure the effects of on-line processes, effects that might be hidden in other measures. Specifically, presentation of a test word immediately after a text (or part of a text) is designed to measure the effect of comprehension of the text on the state of activation of the concept expressed by the test word. Similarly, presentation of a prime and target pair in a list of test words is designed to measure the connections between the two words that were established during comprehension. Because in both procedures it can be shown that obtained effects reflect automatic processes, it can be argued that the effects reflect comprehension, not strategies in which subjects engage at the time of test. Thus, priming is a way of investigating what happens in memory as a result of comprehension processes.

Priming in item recognition can be compared not only to other kinds of on-line procedures but also to other kinds of priming procedures. These include priming in lexical decision and word naming. For example, in experiments conducted by Swinney (1979), subjects listen to spoken text and at unexpected times are given a letter string for a lexical decision. In other experiments (cf. West & Stanovich, 1982), subjects read text and then are given a word to name aloud. If response time for a certain word is speeded, either in lexical decision or naming aloud, then it may be that a concept related to that word was activated by comprehension of the text. Thus these procedures may provide converging evidence on the activation of concepts during comprehension. However, recognition requires reference back to the text just processed, whereas lexical decision and word naming do not. Whether this difference leads to processing differences is a question which requires further research.

The final topic to be considered in a comparison of priming to other techniques is the limitations of priming. The use of priming techniques is not new, but the application to text processing is relatively undeveloped. The recognition priming technique that we have used has been presented in only about 10 published papers. To date, we have found that any problem that has arisen in the use of priming can be overcome, at the cost of some time and effort. We will list these problems and the solutions we have found.

One problem is to understand exactly what is being measured by the amount of priming between two concepts. Is it the distance between the concepts in the surface form of the text, in the meaning structure of the text, or in semantic memory (i. e. nothing to do with the text at all)? It is possible to address this problem by careful design of materials. For example, paragraphs whose surface and meaning representations are different (Ratcliff & McKoon, 1978; McKoon & Ratcliff, 1980a) show that priming reflects the meaning representation. That priming is not due entirely to semantic association can be shown in several ways: by varying the distance between the same two words in different versions of a text (McKoon & Ratcliff, 1980a) or by presenting the words in different sentences of a list of random sentences in order to measure any effects of semantic association (McKoon & Ratcliff, 1980a; 1980b; 1981).

A second problem is to be sure that priming is measuring the effects of comprehension and not strategies in which subjects engage at the time of test in order to improve their performance (or to speed the experiment to an early end). This problem was discussed earlier, and we argued that it is possible to examine the automatic and strategic components of priming and determine under what conditions priming is automatic, and thus determine when it reflects the effects of comprehension.

The last two problems are practical ones. First, a priming experiment is costly in subjects and materials. Optimally, there should be 8 to 10 observations per subject per condition. With the various control conditions and filler items to provide a balance of positive and negative test items and to keep the subject from perfectly predicting what the test items will be, the amount of work is not trivial. Although it is possible to use materials more than once in an experiment with the same subject, there are severe limitations on such repetitions (Dell, Ratcliff, & McKoon, 1981). Second, priming can only be used to investigate those components of processing which can be reflected in a single test item, either a single word or a single sentence (see McKoon & Ratcliff, 1980b, for the use of priming with sentences). So far, we have not found either of these practical problems as daunting as we would have expected, and we find that the gains in experimental results outweigh the costs in design.

## REFERENCES

Dell, G., McKoon, G., & Ratcliff, R. The activation of antecedent information during the processing of anaphoric reference in reading. *Journal of Verbal Learning and Verbal Behavior*, 1983, *22*, 121-132.

Dell, G., Ratcliff, R., & McKoon, G. Study and test repetition effects in item recognition priming. *American Journal of Psychology*, 1981, *94*, 497-511.

McKoon, G., & Ratcliff, R. Priming in item recognition: The organization of propositions in memory for text. *Journal of Verbal Learning and Verbal Behavior*, 1980, *19*, 369-386. (a)

McKoon, G., & Ratcliff, R. The comprehension processes and memory structures involved in anaphoric reference. *Journal of Verbal Learning and Verbal Behavior*, 1980, *19*, 668-682. (b)

McKoon, G., & Ratcliff, R. The comprehension processes and memory structures involved in instrumental inference. *Journal of Verbal Learning and Verbal Behavior*, 1981, *20*, 671-682.

Posner, M. *Chronometric explorations of mind*. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1978.

Posner, M., & Snyder, S. Attention and cognitive control. In R. L. Solso (Ed.), *Information Processing and Cognition*. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1975.

Ratcliff, R., & McKoon, G. Priming in item recognition: Evidence for the propositional structure of sentences. *Journal of Verbal Learning and Verbal Behavior*, 1978, *17*, 403-417.

Ratcliff, R., & McKoon, G. Automatic and strategic priming in recognition. *Journal of Verbal Learning and Verbal Behavior*, 1981, *20*, 204-215.

Schneider, W., & Shriffin, R. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 1977, *84*, 1-66.

Swinney, D. A. Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, 1979, *18*, 645-659.

West, R. F., & Stanovich, K. E. Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1982, *8*, 385-399.