

Integrative and inferential Processes in sentence comprehension

Toshiaki Mori
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Abstract

Two experiments were carried out in order to investigate the integrative and inferential processes in sentence comprehension by using free association paradigm. Subjects learned sentences, each of which contained a free association word to a stimulus word. Following the acquisition phase of the sentences, the subjects were given a free association test, where they were asked to write down a response word to each stimulus word. The results indicated that in both experiments the percentage of target responses was markedly higher than the expected value of free association norm, and that the percentage of intrasentential responses was higher for Scrambled Order condition than for Regular Order condition in Experiment 1. Furthermore, it was indicated that the percentage of target responses was markedly higher than the expected value even if the stimulus word had not been contained in the acquisition lists, and the relative frequency with which target responses were elicited was higher for Inferred condition than for Noninferred condition. These results were discussed in terms of the spreading activation theory of semantic memory.

Key words: sentence comprehension, integration, inference, spreading activation.

Introduction

While the volume of literature on sentence comprehension has increased in the past two decades, the processes underlying sentence comprehension are so far only dimly understood. One of the problems to which a great deal of recent research effort has been directed is that of understanding how the meaning of sentence is represented in memory. It is now generally acknowledged that sentence comprehension is an active process in which integrative and inferential processes play an important role. When subjects are exposed to interrelated sentences, they do not encode and store the verbatim copy of original sentences but rather they integrate individual sentences into a complex memory representation. Furthermore, the subjects draw inferences on the basis of stored word knowledge, and the words in the sentences then serve to guide the subjects in retrieving relevant knowledge. Thus, what is stored in memory is a combination of the explicit information referenced in the sentences along with inferences drawn by the subjects.

Several experimental paradigms have been employed to examine the integrative and inferential processes in sentence comprehension. For example, Bransford and Franks (1971) provided the first experimental demonstration of knowledge integration through the use of the recognition memory paradigm. They found that positive recognition responses tend to be given to all test sentences that are semantically consistent with the holistic idea conveyed regardless of their actual prior occurrence. Another paradigm of studying

integrative and inferential processes that has been popular recently is cued recall paradigm. In this paradigm, the subjects read a list of sentences and then are given a list of cue words. The subjects' task is to recall the sentence that is suggested by each cue word. Using this paradigm, a number of studies have shown that a cue that represents information that could be inferred from a sentence serves as an effective retrieval cue (cf., Anderson & Ortony, 1975; Paris & Lindauer, 1976).

Although all of these previous studies hypothesized the dominant role of stored word knowledge in integrative and inferential processes, they provided little direct evidence about the nature and operation of such knowledge. In other words, little information is available on how the word knowledge is retrieved and used in sentence comprehension, and how the comprehension process affects the structure of word knowledge. To approach this question, it seems necessary to distinguish between episodic and semantic memory. According to the distinction proposed by Tulving (1972), episodic memory contains information that is coded both temporally and with reference to the memorizer, while semantic memory stores general world knowledge including knowledge of language. Thus, the principal purpose of the present study is to investigate the way in which episodic and semantic memory interact with each other in sentence comprehension.

In addition, a new paradigm for studying integrative and inferential processes in sentence comprehension was introduced, i.e., free association paradigm. A major advantage of this paradigm is that it can provide direct evidence about the issue of episodic-semantic distinction. In particular, this paradigm provides information pertinent to the spreading activation model of semantic memory, which has been widely advocated in recent memory research.

The logic of this paradigm is quite simple. Upon completion of the acquisition phase, the subjects are given a stimulus word and are asked to make a response to it. A relative frequency with which particular responses are given is taken as a measure of the activation level. For example, *chair* is a relatively common response to *table*, while *dish* is relatively rare in free association test. This implies that the association between *chair* and *table* is stronger than that between *dish* and *table* in semantic network. On the other hand, when the subjects are tested after they have comprehended the sentence like "A *dish* fell on the *table*", they may elicit *dish* more frequently than *chair* as the response to *table*. If that is the case, it seems reasonable to suppose that processing of the sentence activated the association between *dish* and *table* in semantic network.

In summary, the purpose of the present study was twofold: first, to investigate the integrative and inferential processes in sentence comprehension by using free association paradigm, and second, to evaluate the spreading activation theory for sentence comprehension.

Experiment 1

Experiment 1 was designed to investigate the integrative processes in sentence comprehension. The manipulation was made by varying the presentation order of interrelated sentences. In Regular Order condition, the sentences were presented in cohesive groups to form paragraphs, while in Scrambled Order condition the sentences were presented in a random order. Following this acquisition phase, the subjects were given a free association task. The relative frequency with which intersentential responses were elicited in this task was taken as the measure of integration. It was predicted that the relative frequency of these responses is higher for Regular Order condition than for Scrambled Order condition.

Method

Subjects. Sixty students at Hiroshima University served as subjects. They were tested in small groups randomly assigned to one of two conditions. Data were pooled to form two groups of 30 subjects each.

Materials. Forty-eight sentences were constructed in the following manner. First, a total of 48 words (nouns) were selected from the free association norm of Umemoto (1969). These words consisted of 12 stimulus words and three response words to each of 12 stimulus words. These response words were relatively

weakly associated to their stimulus words (the mean association value of 36 response words was 2.5 percent). Next, using these words, 12 independent paragraphs were constructed. Each paragraph was written so as to be coherent. Each sentence of paragraph contained one of three response words, and the stimulus word of these response words was contained in one of three sentences of the paragraph. The temporal position of the sentence in which the stimulus word was contained was counterbalanced across paragraphs. An example of the paragraphs is shown in Table 1. Finally, 12 paragraphs were divided into three sets, each set to be used in one trial of the three-trial experiment. From each paragraph set, eight different acquisition lists were constructed. In half the lists, the three sentences of each paragraph occurred in a regular sequence, while in the other half, the 12 sentences of 4 paragraphs occurred in a scrambled order.

Table 1
An example of the paragraphs used in Experiment 1

Sentence 1: Osanai korokara rekohdo (R1: records) ga watashino yuuitsuno yuuinde atta (Stereophonic <i>record</i> was my sole friend in my childhood).
Sentence 2: Sonotohji wagayadeha kurasshikku (R2: classics) igaiha yurusarete inakatta (In those days, I was permitted to listen to only <i>classical</i> music).
Sentence 3: Shikashi imadeha jazu (R3: jazz) nado arayuru shuruino ongaku (S1: music) ga wagayani afureteiru (My life is, however, filled with all kinds of <i>music</i> including <i>jazz</i> now).

Design and procedure. There were two independent groups of 30 subjects each, i.e., Regular Order group and Scrambled Order group. Each subject received all three 12-sentence lists, and the order of the lists was counterbalanced. The subjects in Regular Order group learned the interrelated sentences which were presented in regular sequences, while the subjects in Scrambled Order group learned the sentences presented in random orders. Prior to the start of the experiment, the subjects were given an answer booklet. The subjects were then instructed to read the general instructions typed on the first page of the booklet, informing them that they were participating in a study of memory for sentences.

On each trial, the subjects listened to a list of tape-recorded sentences. The list was presented twice in order to facilitate learning. Upon completion of this acquisition phase, the subjects were instructed to turn the page of the booklet. On the next page, 4 stimulus words were typed. The subjects were asked to write down the first response word which occurred to them regardless of whether it was contained in the acquisition list or not. The subjects were allowed 10 seconds for this free association test.

Immediately following the free association test, the subjects were given a cued recall test. The subjects were again instructed to turn the page of the booklet. On the next page were typed the 8 response words which were drawn from the sentences other than the sentences containing the stimulus words. The subjects were required to recall the sentences which contained these response words exactly as they appeared in learning, using these response words as retrieval cues. The subjects were also instructed that paraphrasing, partial recall, and guessing were acceptable. The subjects were allowed 5 minutes for this cued recall test.

Results

Free association. The subjects' free association responses were divided into two categories, i.e., target response and intrusion. When the elicited response was the response word which was contained in the acquisition sentences, this type of response was labelled as a target response. On the other hand, when the elicited response was not contained in the acquisition sentences, this type of response was labelled as a intrusion. Target responses were further divided into two categories, i.e., intersentential response and intrasentential response. Intrasentential response refers to the response word found in the same sentence containing the stimulus word. Intersentential response, on the other hand, refers to the response word found

in the sentences other than that containing the stimulus word.

The percentage distribution for three types of free association responses is shown in Table 2. As is apparent from Table 2, the percentages of target responses for Regular Order and Scrambled Order conditions were both markedly higher than the expected values of the free association norm of Umemoto (1969), $t = 23.35$, $df = 29$, $p < .001$ and $t = 20.34$, $df = 29$, $p < .001$, respectively. Another important aspect of the results was the distribution of intrasentential and intersentential responses. Out of 286 target responses, 148 (51.75%) responses were intrasentential responses for Scrambled Order condition. This percentage was statistically higher than chance level, $t = 4.69$, $df = 29$, $p < .001$. On the other hand, 99 (35.74%) target responses out of 277 target responses were the intrasentential responses for Regular Order condition. This percentage was not statistically different from chance level ($t = 1.69$, $df = 29$, $p < .05$).

Table 2
Mean percentage of target responses, intrasentential responses, and intersentential responses for Regular Order and Scrambled Order conditions

Conditions	Target Response	Intrasentential	Intersentential
Regular Order	76.94	27.50	49.44
Scrambled Order	79.44	41.11	38.33

Cued recall. The subjects' recall protocols were scored according to the number of phrases recalled. 24 sentences tested were composed of 125 phrases. In scoring, a lenient norm was employed. Responses that were scored as correct included both verbatim recall and recall that contained synonyms or paraphrases. The mean recall score was 98.83 (79.06%) in Regular Order condition and 73.79 (59.03%) in Scrambled Order condition. The subjects in Regular Order condition recalled more phrases than those in Scrambled Order condition ($t = 7.38$, $df = 58$, $p < .001$).

Experiment 2

Experiment 2 was designed to investigate the inferential processes in sentence comprehension. The paradigm employed was similar to that of Experiment 1. The primary differences were in acquisition lists. In Experiment 2, the stimulus words were not contained in the acquisition sentences, but could be inferred. The subjects learned interrelated sentences in a regular order, and were then administered a free association test. It was predicted that the inferred stimulus word would increase the frequency with which target responses were elicited.

Method

Subjects. Ninety-five students at Hiroshima University and 55 students at Hiroshima Shudo University served as subjects.

Materials. Eighteen acquisition sentences were constructed in the following manner. First, a total of 36 words (nouns) were selected from the free association norm of Umemoto (1969). These response words were relatively weakly associated to their stimulus words (the mean association value of 36 response words was 2.8 percent). Next, using these words, 12 independent paragraphs were constructed. Each paragraph contained 6 response words consisting of 3 response words to each of 2 different stimulus words. Using these 6 response words, a pair of paragraphs were constructed so that from one paragraph one stimulus word could be inferred and from the other paragraph the other stimulus word could be inferred. For example, using 3 response words to *kaigi* (meeting), i.e., *gichou* (chairman), *iken* (opinion), and *giron* (argument), and 3 response

words to senkyo (election), i.e., enzetsu (address), baishuu (bribe), and fusei (unfairness), 2 different paragraphs were constructed, one describing kaigi (meeting) and the other describing senkyo (election). In this way, 6 pairs of paragraphs were constructed. Each paragraph was written so as to be coherent. Finally, 2 different lists of 6 paragraphs were generated, each list involving one of each pair of paragraphs. Three sentences of each paragraph were presented in a regular order, and there were 3 random orders of 6 paragraphs for both acquisition lists.

Design and Procedure. The general procedure in Experiment 2 was the same as that in Experiment 1. The subjects listened to a list of tape-recorded sentences. The list was presented twice in order to facilitate learning. Immediately following the acquisition phase, the subjects were given a free association test. The subjects were asked to write down on a response sheet the first response word to each of 6 stimulus words. Six randomized orders were used in presenting the stimulus words, with a constraint that inferred and noninferred stimulus words had to be presented the same number of times for each paragraph. The subjects were allowed 15 seconds for this free association test.

Results

As in Experiment 1, the subjects' free association responses were divided into two categories, target responses and intrusion. The mean percentage score of target responses was 66.30 percent in Inferred condition and 46.67 percent in Noninferred condition. These scores were both markedly higher than the expected values of the free association norm of Umemoto (1969), $t = 25.20$, $df = 94$, $p < .001$; $t = 9.14$, $df = 94$, $p < .001$, respectively. A t test indicated that the relative frequency with which the target responses were elicited was higher for Inferred condition than for Noninferred condition, $t = 5.51$, $df = 94$, $p < .001$.

Discussion

The first concern of the present study was to investigate the way in which episodic and semantic memory interact with each other in sentence comprehension. The results indicated that the percentage of target responses were markedly higher than the expected value of free association norm. In the case of the sentences shown in Table 1, three response words (i.e., records, classics, and jazz) were relatively weakly associated to their stimulus word (i.e., music). The mean association value of these response words was no more than 2.5 percent. After the subjects comprehended the sentences, however, the relative frequency with which these response words were elicited as the responses to the stimulus word increased enormously, 77 percent in Regular Order condition and 80 percent in Scrambled Order condition. Similar results were obtained in Experiment 2.

The findings mentioned above provide sufficient ground for drawing the conclusion that the processing of sentences activated the association between stimulus word and response words in semantic memory. In other words, episodic memory can be described as an activated state of semantic network. These findings are in general agreement with those of Mori (1980) that the frequency with which target responses were elicited was markedly higher than the expected value of free association norm when adequate deep processing of word list occurred. Furthermore, the results in percentage distribution of intersentential and intrasentential responses should be noted. As shown in Table 2, the percentage of intrasentential responses was higher for Scrambled Order condition than for Regular Order condition. These results suggest that activation of associations between stimulus word and response words was strongly influenced by processes of semantic integration. It should be also noted that the percentage of target responses was markedly higher than the expected value even if the stimulus word had not been contained in the acquisition lists, and that the relative frequency with which target responses were elicited was higher for Inferred condition than for Noninferred condition (Experiment 2). These findings can be explained in terms of "encoding specificity" principle (Tulving & Thompson, 1973) where it has been strongly suggested that retrieval cues presented at recall will facilitate recall only if the to-be-remembered words were encoded with respect to these cues at the

time of input. In conclusion, it was indicated that free association paradigm employed in the present study has considerable potential with respect to the analysis of integrative and inferential processes in sentence comprehension.

Consider now the issue of whether free association paradigm is a valid method to evaluate the spreading activation theory for sentence comprehension. One method to evaluate this theory is priming paradigm (McKoon & Ratcliff, 1980a, 1980b; Ratcliff : McKoon, 1978). The measure used in this paradigm is the size of priming effect which can be defined as the facilitation of the response to a test item by a preceding item. For example, subjects were presented with sentences for study and then single word for recognition. Subjects were asked to decide whether a test word was included in one of the study sentences (Ratcliff : McKoon, 1978). Response time to a word which was immediately preceded in the test list by a word from the same sentence was faster than the response time to a word which was preceded by word from a different sentence. It was argued that the size of priming reflected the magnitude of spreading activation over adjacent part of semantic network. Thus, this paradigm appears to be useful for investigating the memory structure of paragraphs because it seems possible to index the distance between two words in terms of the size of the priming effect.

A major question that arises is what response time (RT) data reflect. Necessary premise for using priming effect as a measure of activation level is, of course, the assumption that RT is a function of activation level, that is, the assumption that shorter RSs represent greater amounts of activation. Although several recent studies evaluated the spreading activation theory using RT as a measure, it seems that RT might be influenced by random variation or other extraneous variables. Therefore, it seems necessary to test the validity of RT measure more closely under a variety of conditions, especially, the relationships between RT measure and other response measures should be examined. Thus, a relatively new methodology, i.e., free association paradigm was proposed in the present study. The results of the present study indicated that the percentage distribution of free association could be explained by spreading activation theory, also showing that integrative and inferential processes in sentence comprehension could be reflected by free association data. While the generality of this paradigm should be evaluated in future study, this paradigm would provide another useful tool for the investigation of sentence comprehension.

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