Memory for redundant information*

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Ss learned a paragraph consisting of two four-term linear orderings. Such an ordering is comprised of six pairwise relations, three of which (the adjacent pairs) are essential to the establishment of the ordering and three of which (the remote pairs) are redundant. For one of the orderings only the three adjacent pairs were presented, for the other all six pairs were presented. Previous work indicated that, when Ss are asked to determine whether a test sentence is true (consistent with the ordering) or false (inconsistent with the ordering), proportion correct is higher on the remote pairs than on the adjacent pairs. The present experiment examined Ss' ability to determine whether a particular test sentence had actually been presented. For false sentences the above effect was replicated; for true sentences the effect was reversed. This result supports the argument that Ss store "semantic descriptions" rather than individual sentences.

Recently, considerable attention has been given to the question of what Ss actually store when trying to remember meaningful verbal material such as sentences and paragraphs. The oldest and simplest answer to this question is that Ss store an exact, though possibly faded, copy of the material that was actually presented. A somewhat more current answer is that Ss transform the individual sentences in the text into their linguistic deep structures (Chomsky, 1965) and store those deep structures (Miller, 1962; Mehler, 1963).

Several recent experiments have demonstrated that neither of these alternatives is adequate (Barclay, 1973; Bransford, Barclay, & Franks, 1972; Bransford & Franks, 1971). In all of these experiments, Ss were presented with a series of sentences and were then given a recognition test. Test sentences expressing information that was redundant with (i.e., could be deduced from) one or more of the acquisition sentences were consistently mistaken for "old" sentences. For example, when Ss were given the sentence, "Two robins were perched on top of their nest and a hawk flew over *them*," and were then tested for recognition of the sentence, "Two robins were perched on top of their nest and a hawk flew over *it*," they tended to report erroneously that the test sentence had been presented previously. It was concluded that, instead of storing individual sentences (either verbatim or in terms of their linguistic deep structure), Ss use the acquisition sentences to construct and store a "general semantic description" of the situation. Of course, a question immediately arises regarding the nature of this description. Potts (1972) attempted to answer this question for a particular type of information structure, the four-term linear ordering ($A > B > C > D$). Such an ordering is composed of six pairwise relations, three of

which (the adjacent pairs, $A > B$, $B > C$, and $C > D$) are essential to the establishment of the ordering and three of which (the remote pairs, $A > C$, $B > D$, and $A > D$) are redundant, in the sense that they can be deduced from some subset of the adjacent pairs. Potts found that performance was better on the remote pairs than on the adjacent pairs, even when the remote pairs were never presented. This result contradicts several alternative explanations regarding the form in which this information is stored, but it can be accounted for if one assumes that Ss use the presented information to construct the linear ordering of the four terms and then store that ordering.

In Potts' experiments, Ss were asked merely to indicate whether a test sentence was true (consistent with the ordering) or false (inconsistent with the ordering). Unlike the previous studies, Ss were not required to indicate whether a particular test sentence had actually been presented. The present experiment is designed to verify the previous recognition results, using the paradigm employed by Potts (1972).

If Ss do indeed store only the linear ordering of the four terms, then when Ss are required to determine if the test sentences had actually been presented, proportion correct should be higher on false sentences than on true sentences, and the truth value of the sentence should interact with the type of pair (adjacent or remote) represented by the sentence. Specifically, for false sentences proportion correct should be higher on the remote pairs than on the adjacent pairs. For true sentences this effect would be reversed. To understand these predictions, assume that an S had stored the ordering $A > B > C > D$. He could assume that the false sentence, $D > A$?, had not been presented, since it contradicted the ordering. Furthermore, the more accurate Ss are at determining the falsity of a false test sentence, the more accurately they can indicate that it had not been presented. Thus, for false sentences, Potts' finding that performance on remote pairs is superior to performance on adjacent pairs should be replicated. When presented with the true test sentence, $A > D$?, on the other hand, the S would have no basis for

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determining whether that sentence had actually been presented or whether he had deduced it from other information. Thus, performance on true sentences relating to remote pairs should be close to chance. Performance on the nonredundant adjacent pairs should not depend on whether the test sentence was true or false, since in either case Ss could know such information only if it had actually been presented.

It has been found that, though Ss' memory for the gist or meaning of a sentence is quite stable even after long retention intervals, the introduction of even a brief delay serves to almost completely eliminate Ss' memory for the syntactic structure of that sentence (Sachs, 1967). A second purpose of the present study is to examine the effects of such a delay on Ss' ability to determine whether a particular piece of information had actually been presented.

METHOD

Subjects

Ss were 62 Indiana University undergraduates who participated to fulfill a course requirement. Each participated in one 20-min session.

Procedure

Ss were tested in groups. The study and test materials were printed on separate sheets of paper that were stapled together to form a booklet. Each S was given one of these booklets prior to the beginning of the session. Ss were cautioned not to turn any pages in the booklet unless explicitly told to do so and never to look back to a previous page.

Prior to the beginning of the study period, Ss were told that they would be given a paragraph to study. They were also told that after studying the paragraph, they would be shown a series of sentences pertaining to that paragraph. Their task would be to indicate, on the basis of the information contained in the paragraph, whether each sentence was true or false.

The study period was divided into three parts, each 2 min in duration. During each of these parts, Ss either studied the critical paragraph or were given a filler task to perform. This task consisted of performing two arithmetic computations, one addition and one multiplication. One group of Ss ($N = 22$) performed arithmetic computations during Parts 1 and 2 of the study period and were given the paragraph to study during Part 3. This represents an immediate test condition. Another group of Ss ($N = 20$) was given the paragraph to study during Part 1 of the study period and performed arithmetic computations during Parts 2 and 3. This represents a delayed test condition. A third group of Ss ($N = 20$) was given the paragraph to study during Parts 1 and 3 of the study period and performed arithmetic computations during Part 2. Hence, Ss in this group were given extra time to study the paragraph before being given an immediate test on the material. The assignment to groups was random.

The materials for each of the three parts of the study period were printed on separate sheets of paper. The E timed each part, telling Ss when to turn the page and go on to the next part. Ss were allowed to take notes as they studied the paragraph. They were told to write their notes below the paragraph.

Following the study period, the E read a revised set of instructions. Ss were told they were not to respond on the basis of whether each sentence was true or false "but, rather, on the basis of whether the particular piece of information presented in the sentence had actually been presented in the paragraph. Thus,

you should respond 'YES' only if the specific piece of information expressed in the sentence had actually been presented in the paragraph. You should respond 'NO' to a sentence either if it is false or if it expresses information that could only be deduced from information actually presented." To clarify these instructions even further, Ss were given a paragraph containing explicit examples of information that was true and had actually been presented, information that was false and, hence, could not have been presented, and information that was true but had not been presented.

After having heard these revised instructions, Ss proceeded to respond to the test sentences. These test sentences were printed on two separate sheets of paper in the Ss' booklets. Ss were to respond to the sentences by marking "YES" or "NO" to each, "YES" if they felt the information in the test sentence had actually been presented in the paragraph, "NO" if they felt it had not. Ss were also told to mark beside each "YES-NO" answer their confidence in that answer on a 5-point scale. A 5 was used to indicate considerable confidence, a 1 to indicate a guess. This scale was printed at the top of each answer sheet.

Materials

The paragraph learned by all Ss consisted of two linear orderings of the form $A > B > C > D$. For an example of the actual paragraphs employed, see Potts (1972). One of the orderings in the paragraph was established by presenting only the adjacent pairs. These three pairs were presented in the chained order $A > B$, $B > C$, $C > D$. This presentation condition will be referred to as the "not presented" (NP) condition to indicate that the remote pairs were not presented. The other ordering was established by presenting all six pairs in the order $A > B$, $B > C$, $C > D$, $A > C$, $B > D$, $A > D$. This will be referred to as the "presented" (P) condition. The order of presentation of the two conditions was counterbalanced. For approximately half of the Ss the ordering representing the NP condition was presented first in the paragraph; for the other the ordering representing the P condition was presented first.

Note that for each relation either all three remote pairs were presented or none at all and that, when the remote pairs were presented, they were presented in a block following the three adjacent pairs. Of the many possible ways of inserting some redundant remote pairs into the paragraph, this method should serve to maximize the likelihood that Ss will be able to determine which remote pairs had actually been presented.

Ss were tested on all six pairs comprising each of the two orderings. This was accomplished by using a set of 24 test sentences, half of which were true and half of which were false. Of the 12 true sentences, 6 were statements of the six pairs presented in the P condition, 3 were statements of the three adjacent pairs presented in the NP condition, and 3 were statements of the three remote pairs in the NP condition. Though these last three sentences were true statements that could be deduced from the three adjacent pairs in the NP condition, they represented information that was never explicitly stated in the paragraph. Each of the 12 false sentences corresponded to one of the true sentences but had the order of the terms reversed. Accordingly, for every true sentence, $X > Y$, there was a corresponding false sentence, $Y > X$.

RESULTS

Though overall proportion correct was higher when Ss were given two chances to study the paragraph, manipulation of the delay between study and test was not effective. The effects of delay were probably minimized by the additional delay introduced to all groups by the reading of the revised instructions. Because of this additional delay, none of the three

groups received a truly immediate test. In what follows, therefore, only performance averaged over the three groups will be presented.

Statistical analyses were performed using two-tailed sign tests for matched samples. The proportions correct are presented in Table 1. Mean confidence scores are given in parentheses. It should be noted that a NO answer was correct to all false sentences and to true sentences referring to a remote pair in the NP condition; a YES answer was correct to all true sentences except those referring to a remote pair in the NP condition. The confidence scores reflect Ss' confidence in each answer regardless of whether or not that answer was correct.

Proportion correct on the adjacent pairs did not differ significantly between true and false sentences or as a function of condition ($Z < 1$ in both cases). For false sentences, proportion correct was higher on the remote pairs than on the adjacent pairs, while, for true sentences, the opposite was found. This interaction between type of pair and truth value of the test sentence was significant ($Z = 4.85$, $p < .001$). It should be noted that proportion correct for true sentences relating to the remote pairs was significantly lower than proportion correct for true sentences relating to the adjacent pairs in both conditions ($Z = 4.39$, $p < .001$ and $Z = 2.08$, $p = .04$ for the NP and P conditions, respectively). Since the remote pairs in the NP condition were not presented, a simple response bias toward saying, "Yes, that information was actually presented," could account for the low proportion correct on true sentences relating to those pairs. However, since the correct answer to all true sentences in the P condition was YES, such a response bias could not explain the fact that proportion correct was lower when these sentences described remote pairs than when they described adjacent pairs.

Ss' confidence scores also reflected the significant interaction of Type of Pair by Truth Value ($Z = 2.68$, $p = .007$). For false sentences, Ss were more confident of their answers to the remote pairs than they were of their answers to the adjacent pairs. For true sentences, this effect reversed itself, Ss being more confident of their answers to the adjacent pairs. While the confidence scores on the adjacent pairs still did not differ significantly as a function of condition ($Z < 1$), Ss were significantly more confident of their answers to false sentences relating to adjacent pairs than they were of their answers to true sentences relating to adjacent pairs ($Z = 2.31$, $p = .02$). It should be noted that Ss' confidence in their answers to true sentences relating to remote pairs was somewhat higher in the NP condition than in the P condition. Though this difference was not significant, the direction of the effect is surprising, in view of the fact that proportion correct on the remote pairs was so much lower in the NP condition.

DISCUSSION

The original predictions were confirmed. Overall

Table 1
Proportion Correct on Adjacent and Remote Pairs as a Function of Condition and the Truth Value of the Test Sentence*

Pairs Tested	True Test Sentences		False Test Sentences	
	Pairs Presented		Pairs Presented	
	Adjacent Only	Adjacent and Remote	Adjacent Only	Adjacent and Remote
Adjacent	.871 (4.34)	.882 (4.38)	.893 [†] (4.44)	.914 [†] (4.53)
Remote	.564 [†] (4.23)	.742 (4.10)	.941 [†] (4.55)	.941 [†] (4.61)

*Confidence scores are given in parentheses

[†]The correct answer is "No, that information was not presented."

proportion correct was higher for false sentences than for true sentences. Most of this difference was the result of differences in performance on the remote pairs; Ss were very accurate in indicating that false sentences relating to remote pairs had not been presented but were very inaccurate in determining whether true sentences relating to remote pairs had actually been presented. This result is in agreement with the results of Potts (1972), who observed that Ss are very good at determining the accuracy of test sentences relating to remote pairs, as well as with previous results which indicated that Ss have considerable trouble distinguishing between information that was actually presented and information that, though true, had not been presented. Hence, the present data support the contention that Ss use linguistic input to construct a "general semantic representation" of the material and then store that representation. These data give no reason to reject Potts's (1972) contention that for information of the type employed in the present experiment this general semantic representation corresponds to the linear ordering of the four terms. In the process of altering the form of the presented information, most of the information regarding what had actually been presented is lost.

It should be noted that, though Ss had considerable difficulty determining whether redundant information had actually been presented, they were not completely unable to make this discrimination. Thus, Ss must have retained some information above and beyond the simple ordering of the four terms. An estimate of the amount of this auxiliary information can be arrived at from the present data.

First, it is important to recognize that the fact that proportion correct was considerably higher on remote pairs in the P condition than in the NP condition does not necessarily reflect Ss' ability to recognize that the remote pairs in the P condition had actually been presented. If this were the case, then one would expect the overall confidence score to be higher for the remote pairs in the P condition than in the NP condition. The small difference that was obtained, it will be

remembered, was in the opposite direction. The higher proportion correct on remote pairs in the P condition is better explained by arguing that, when Ss do not know the answer, they guess but that their guesses show a bias toward saying, "Yes, that information was presented." Therefore, proportion correct should be higher on true sentences referring to remote pairs in the P condition, where YES was the correct answer, than on true sentences referring to remote pairs in the NP condition, where NO was the correct answer. Since this differential proportion correct represents only a response bias, one would expect that the average confidence scores in the two conditions should be approximately equal, as was found.

The appropriate estimate of amount of information to which Ss have access above and beyond the basic ordering of the four terms is represented by the degree to which the average performance on true sentences relating to remote pairs is above what could be expected by chance alone. Since guessing probability in the present experiment was .5, the number of wrong responses provides a reasonable estimate of the number of correct responses that were correct by guessing. Thus, an estimate of the proportion of the time that Ss knew whether the remote pairs had actually been presented can be arrived at by subtracting the proportion wrong from the proportion correct. In the present case, proportion correct on true sentences referring to remote pairs was .653 and, thus, the difference between proportion correct and proportion wrong is .306. The corresponding estimates for true sentences relating to adjacent pairs, false sentences relating to adjacent pairs,

and false sentences relating to remote pairs are .752, .806, and .882, respectively. Thus, though Ss apparently do retain some information above and beyond the actual ordering of the terms, the present data would indicate that the amount of this additional information is quite small. This is the case even though the redundant material in the present experiment was presented in a block, so as to maximize the likelihood that Ss would be able to recognize whether or not it had been presented.

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