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ABSTRACT

The purpose of this study was to determine if the Bransford and Franks linear effect is or is not a function of semantic integration. The subjects were 32 volunteers from two undergraduate psychology courses at the University of Georgia. Stimulus materials consisted of four meaningful (M) complex embedded English sentences and four meaningless (M-) sentences. The procedure was similar to that used by Bransford and Franks (1971). Subjects were randomly assigned to either the M or the M- condition. The two conditions were identical except for the type of sentence used. The experimental session was carried out in two phases, acquisition and recognition. Acquisition involved a test of short-term memory for each sentence. Recognition involved rating sentences on the basis of whether the subject had or had not experienced it during acquisition. Results showed a significant linear effect for the meaningless sentences. Furthermore, although the slope of the effect for meaningless sentences was flatter than that of the control, other data rules out a semantic integration explanation based on the availability of semantic information contained in sentence structure. The evidence would thus appear to support the view that structure and content are closely interrelated in language comprehension. (TS)

THE ABSTRACTION OF LINGUISTIC IDEAS IN "MEANINGLESS" SENTENCES

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ABSTRACT

It was proposed that the Bransford and Franks linear effect is unrelated to semantic processes and will, therefore, occur even when "meaningless" sentences (i.e., sentences containing nonsense instead of meaningful content words) are employed. Within the Bransford and Franks format, subjects were given either the meaningless sentences or control sentences. Results showed a significant linear effect for the meaningless sentences. Furthermore, although the slope of the effect for meaningless sentences was flatter than that of the control, other data ruled out a semantic integration explanation based on the availability of semantic information contained in sentence structure. A simple guessing strategy hypothesis was offered to account for the linear effect.

THE ABSTRACTION OF LINGUISTIC IDEAS IN "MEANINGLESS" SENTENCES[1]

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Bransford and Franks (1971, 1972) carried out a series of experiments on sentence recognition in which they found (a) that individuals were unable to distinguish between sentences which they had heard during an acquisition period and closely related sentences which they had not actually heard; and (b) that reported recognition of these sentences is a positive linear function of "sentence complexity", i.e., the number of simple ideas contained in them. (This linear function will hereafter be referred to as the "linear effect"). On the basis of these results, the authors argued that the comprehension of discourse can be characterized as the construction of unified semantic representations, and that recognition of new linguistic inputs is a function of the number of ideas in any unified semantic representation "exhausted" by such inputs...

Other studies, however, suggest that the Bransford and Franks results may have nothing to do with semantic processes at all. For example Reitman and Bower (1973) employed the Bransford and Franks paradigm using letter or number n-tuples instead of natural language materials and were still able to replicate the linear effect. Katz (1973) employed the paradigm using sentences similar to those found in the original study but instructed subjects to determine whether sentences presented during a recognition period meant exactly the same thing as sentences presented earlier (and not whether they had actually experienced such sentences, as in the original research). It was expected that instructions which stressed meaning would provide a more appropriate test of the Bransford and Franks hypothesis. Results showed, however, that under the new instructions the linear effect disappeared entirely. Taken together, the results of these later studies suggest that the linear effect may be unrelated to purely semantic processes since, on the one hand, the effect can occur without the use of natural language materials and, on the other, can be made to disappear even when such materials are retained under the most appropriate conditions. The purpose of the present study was to test directly whether or not the linear effect is based on sentence meaning. This was accomplished by comparing the sentence complexity curves of sentences that are meaningful with sentences that are virtually incomprehensible. Specifically, "recognition-confidence" ratings (a dependent measure defined in the Method section below), obtained using the standard Bransford and Franks paradigm, were compared for two types of sentences: (a) "meaningful" (M) sentences similar to those used in the original studies, and (b) "meaningless" ($\overline{M}$) sentences in which syntactic structure was retained but lexical meaning eliminated. The $\overline{M}$ sentences were constructed by replacing content words or word-stems in the M sentences with strings of nonsense syllables; structural features of the M sentences were not changed.

A comparison of the ratings for the M and $\overline{M}$ sentences should yield results which support either the semantic integration explanation offered by Bransford and Franks or another interpretation we shall call simply the "non-semantic" explanation to indicate that the underlying meanings of the sentences are not responsible for the linear effect. The non-semantic explanation would be supported if $\overline{M}$ sentences produce a linear effect whose slope is (a) significant and (b) equal to or greater than the slope of the M sentences since the $\overline{M}$ sentences are clearly deficient in the kind of information necessary (though, perhaps, not sufficient) for semantic integration. The semantic interpretation would receive support if the M sentences produced the linear effect while the $\overline{M}$ sentences did not. Under these circumstances it would be clear that semantic information is an essential factor since the M and $\overline{M}$ sentences differ only in this respect. There is a third outcome, however, which without further information would be inconclusive with respect to these two hypotheses. Both types of sentences could produce significant linear effects, but M sentences may show a reliably steeper slope than $\overline{M}$ sentences. In support of the non-semantic interpretation, it could be argued that differences in slopes merely reflect differences in sentence types which are of no special interest in the present study. What is important, according to this view, is whether $\overline{M}$ sentences produce a linear effect at all, especially in view of their virtual incomprehensibility. In support of the semantic integration hypothesis, it could be argued that the distinction between sentence structure and sentence content, implicitly assumed here, is unsupportable. Such is the position of proponents of "conceptual analysis" (e.g., von Glasersfeld, 1963;[3] 1972; Schank, 1972) and others who maintain that a sentence structure itself conveys relationships among conceptual entities and that such information is an important component of linguistic meaning. Thus it could be argued that the appearance of a linear effect in the $\overline{M}$ condition simply reflects the use of relational information available in the structure of the sentences; furthermore, a flatter slope in the $\overline{M}$ as compared to the M condition could be the result of greater difficulty in integrating when meaningful content words are not available. If we assume this to be the case, it would be necessary in the present study to incorporate some test of subjects' knowledge of the relationships among conceptual entities. This test was accomplished by using "noncases", a class of special sentences employed first by Bransford and Franks (1971,

1972) in which relationships among conceptual entities are changed so as to change the meaning of the complete semantic representations. The ability to detect noncases in a recognition period is, therefore, a measure of subjects' understanding of the relational aspect of meaning. Given the inconclusive third outcome, the non-semantic hypothesis would be supported if recognition-confidence ratings for noncases in the $\overline{M}$ condition did not differ from ratings for other sentences in that condition. Such a finding would demonstrate that subjects in the $\overline{M}$ condition were not making use of relational information. Alternatively, if subjects in the $\overline{M}$ condition were to detect noncases as different from sentences they experienced in acquisition, the finding would demonstrate that they were making use of such information. Therefore, the semantic integration hypothesis of Bransford and Franks would receive support, or, at any rate, not be refuted. In either case, the noncase data would resolve potentially equivocal results arising out of the possible use of semantic information contained in the structure of a sentence.

Method

Subjects

The Ss were 32 volunteers from two undergraduate psychology courses at the University of Georgia.

Materials

Stimulus materials consisted of four "meaningful" (M) complex embedded English sentences and four "meaningless" ($\overline{M}$) sentences. The M sentences are as follows: (a) The rock which rolled down the mountain crushed the tiny hut at the edge of the sea., (b) The barking dog chased the brown cat which jumped on the girl., (c) The ants in the kitchen ate the sweet jelly which was on the newspaper., (d) The thunder crashing through the valley shook the tinkling bells in the corner.

The $\overline{M}$ sentences were generated by substituting nonsense word-stems for meaningful stems in English sentence frames derived from the M sentences. The sentence frames retained information generally considered to be "structural", such as beginning and terminating symbols, bound morphemes, and function words[4]. For example, the sentence frame taken from (b) above was: The ____ing ____ ____ed the ____ ____ which ____ed ____ the ____. Each sentence frame was "filled" using a procedure similar to that employed by Forster (1966). First, a string of 400 bigrams was generated by applying a Monte Carlo sampling procedure to the table of English bigram frequencies found in Underwood and Schulz (1960). Pieces of the strings were then "cut" sequentially (beginning with the left most part of the string) to match, in length, the English word-stems which they were to replace in the sentence frames. For example, the first four English stems taken from sentence (a) were 4, 4, 4 and 8 letters in length respectively. Therefore, the bigram string was cut after the 4th, 8th, 12th, and 20th letters. All stems which sounded like or were English words, or which violated English orthographic rules, were rejected. The four $\overline{M}$ sentences constructed by this method are as follows: (a) The soto which tehoed inow the feexteva voneed the tioc len ic the froo ab the adex., (b) The fenting nior anpoed the oneap wint which elsted os the tive., (c) The vars ut the nojatap rame the erha iogan which sim ho the gevestinor., (d) The rotham droting raeg the tealam bant the ploking nonts oo the therft.

Each complex sentence for both sentence types was then analyzed into four simple declarative sentences. These latter sentences expressed in appropriate grammatical form a single semantic "idea". Two examples are given here. In the M category, The rock which rolled down the mountain crushed the tiny hut at the edge of the sea. was partitioned into The rock rolled down the mountain., The rock crushed the hut., The hut was tiny., and The hut was at the edge of the sea. In the $\bar{M}$ category, The soto which tehoed inow the feexteva voneed the tioc len ic the froo ab the adex. was partitioned into The len sim tioc., The soto tehoed inow the feexteva. The soto voneed the len., and The len sim ic the froo ab the adex. Wherever was and were were required for the construction of the simple declarative sentences in the M condition, the corresponding nonsense syllables sim and spol were used in the $\bar{M}$ condition.

After these simple declarative sentences, or ONES, had been constructed, they were recombined into new sentences expressing two ideas (TWOS), three ideas (THREES), or four ideas (FOURS). The FOURS, of course, were the original sentences. Three THREES, four TWOS, and four ONES were generated from each FOUR in this manner. These 12 sentences will be referred to as an "idea group". Sentences from the idea groups were used to construct acquisition and recognition lists for the M and $\bar{M}$ conditions described below. In addition, two M noncases and two $\bar{M}$ noncases were constructed. For M sentences, a noncase was defined as a THREE in which ideas from two separate idea groups were combined so as to create relationships among conceptual entities different from any in the original semantic representations. The M noncases are: (i) The ants in the kitchen shook the tinkling bells., and (j) The barking dog chased the brown cat at the edge of the sea.

$\bar{M}$ noncases were constructed in the same way as the original $\bar{M}$ sentences. Each meaningful stem in the M noncases was replaced by the same nonsense stem that replaced it when the $\bar{M}$ sentences were originally constructed.

The M̄ noncases are: (k) *The vars ut the nojatap bant the ploking nonts.*, and (l) *The fenting nior anpoed the oneap wint ic the froo ab the adex.*

The M and M̄ acquisition and recognition lists were constructed as follows: The acquisition lists contained 26 sentences each: two ONEs, two TWOs, and two THREEs selected randomly from each of the four idea groups, and two FOURs chosen from two of the four idea groups.[5] With the constraint that no two sentences from the same idea group appear consecutively, the 26 sentences in each list were randomized for presentation during acquisition.

The recognition lists were constructed as follows: Of the remaining sentences in each idea group not selected for acquisition, a single ONE, TWO, and THREE were randomly picked for recognition ("new" sentences). A single ONE, TWO, and THREE belonging to the same idea group were added from the acquisition list ("old" sentences). To these were added the FOUR ("old" if it appeared in acquisition, "new" if it did not). With the addition of the noncases, a total of 30 sentences appeared in each recognition list. Again, with the constraint that no two sentences from the same idea group appear consecutively, the sentences in each list were randomly ordered for presentation to *Ss* during recognition. The acquisition and recognition lists were typed on 3 x 5 index cards, one sentence to a card. Three decks of cards were made in this way, one for *E* and one for each of two *Ss*.

Procedure.

The procedure was similar to that used by Bransford and Franks (1971). Subjects were randomly assigned to either the M or the M̄ condition. The two conditions were identical except for the type of sentence used. The experimental session was carried out in two phases, acquisition and recognition.

A.   tion. Acquisition involved a test of short-term memory for each sentence. Subjects in groups of one or two were instructed to pick up the top card in the deck in front of them concurrently with E. As E read each card aloud, Ss were instructed to read along silently. After each card was read and placed face down in a separate pile, Ss counted out loud the number of fingers on E's right hand for 4-5 sec. Following the interpolated task, Ss were told to write down the sentence just presented to them. The procedure was repeated for each of the 26 sentences on the acquisition list. Appropriate counterbalancing was used to control for possible order effects in list presentation. When the list was completed, Ss rested for 2 min. During acquisition, no mention was made of any recognition test.

Recognition. During recognition, Ss were told that they would go through a second deck of sentences similar to the first. This time, however, they were to rate each sentence, after its presentation, on the basis of whether they had or had not experienced it during acquisition. For each sentence, Ss indicated whether they recognized it or not by first marking a yes-no scale and then a 5-point confidence scale ranging from "very low" to "very high" confidence. As before, counterbalancing was employed to control for order effects.

RESULTS

The dependent measure used in the present experiment was mean recognition-confidence score determined as follows: Each S's responses to the yes-no and confidence scales for each sentence were converted into a single rating. A plus (+) was assigned to a yes response and a minus (-) to a no response. The + or - was multiplied by S's numerical response to the confidence scale for that sentence. This resulted in an 11 point recognition confidence scale ranging from −5 to +5. Each of these ratings was then pooled for (a) FOURs, THREEs, TWOs, and ONEs, and (b) noncases.

Sentence Complexity

Results for sentence complexity appear in Figure 1. Initially, two multivariate analyses of variance (MANOVAs) were carried out so that the covariance among cells of the repeated measures could be taken into account.[6] In the first MANOVA, the eight repeated measures for each subject were treated as response variables while "meaningfulness" (M vs $\overline{M}$) was treated as the sole factor. With an F ratio derived from Hotelling's T^2, a significant overall effect was found for this factor, $F(8,23) = 2.96$, $p < .05$. A second MANOVA was also carried out using the levels of sentence complexity (FOURs, THREEs, TWOs, and ONEs) as response variables and meaningfulness and old vs. new as factors. A significant effect was again found for meaningfulness, $F(4,57) = 4.18$, $p<.01$. A univariate linear trend analysis was then performed to compare the slopes of the sentence complexity across the meaningfulness and new vs. old factors. Results were as follows:

1. A significant linear trend was found for sentence complexity, $F(1,30) = 80.06$, $p < .001$. This replicates Bransford and Franks (1971, 1972). To determine whether the $\overline{M}$ condition alone produced a significant linear trend, a simple effects test of the linear trend for sentence complexity in the $\overline{M}$ condition was carried out. The trend was significant, $F(1,15) = 38.17$, $p < .001$.

2. A significant main effect was found for new vs. old, $F(1,30) = 7.18$, $p < .05$. This unexpected finding differed from earlier results (Bransford and Franks, 1971, 1972; Katz, 1973). However, since the second MANOVA did not show a significant new vs. old difference, the finding will not be considered further.

3. A significant interaction was found between the linear trend for sentence complexity and meaningfulness, $F(1,30) = 8.83$, $p < .01$. As Figure 1 shows, the slope of the curve for sentence complexity in the M condition was somewhat steeper than that in the $\overline{M}$ condition.

Noncases

The mean ratings for noncases were -4.41 and 1.86 in the M and $\overline{M}$ conditions respectively. These values could be compared to the average of all levels of sentence complexity in their respective conditions. Considering the effect of sentence complexity, however, it would be more appropriate to compare the noncases to THREEs since both types of sentences contain three ideas. The means for noncases and THREEs (collapsed over new and old sentences) in the $\overline{M}$ condition were 1.86 and 2.25 respectively and they were not significantly different $t(15) = 0.59$, $p > .50$. The corresponding means in the M condition were -4.41 and 4.05. Their difference was highly significant $t(15) = 17.20$, $p < .001$. Thus, in the $\overline{M}$ condition, Ss were unable to detect differences between noncases and sentences which did not violate relationships contained in the complete semantic representations. In the M condition, however, Ss had no trouble detecting noncases as different from the THREEs, a finding which replicates the results of earlier studies.

DISCUSSION

The purpose of the present study was to determine if the Bransford and Franks linear effect is or is not a function of semantic integration. This was achieved by comparing meaningful (M) sentences with sentences whose content words or word-stems were composed of strings of nonsense syllables ($\overline{M}$ sentences). It was hypothesized that if the linear effect is based on semantic integration it should obtain for M sentences but not for $\overline{M}$

sentences. [illegible] [illegible]ect is unrelated to meaning, however, the M and $\overline{M}$ sentences should yield linear effects which are comparable. The results showed that both conditions produced a linear effect but that the slope of the sentence complexity curve in the M condition was the steeper of the two. As discussed in the introduction, this finding cannot by itself rule out either interpretation. While the significant linear effect in the $\overline{M}$ condition may have nothing to do with semantic information processing, it may also be the case that $\overline{M}$ sentences contain enough relational semantic in[illegible] their syntactic structures to make possible a weak integration. The use of noncases in the recognition lists made it possible to determine which of these two interpretations is correct. Since noncases violate relations in the complete semantic representations, subjects must be able to detect noncases if they are using the relational information to integrate. Results showed that $\overline{M}$ subjects could not do so. Thus, the significant linear effect found in the $\overline{M}$ conditi[illegible] cannot be attributed to semantic integration, either of the lexical or the relational sort. Furthermore, since [illegible] subjects easily detected noncases (and, therefore, were aware of relational changes among underlying conceptual entities) lexical meaning appears to be important, or even essential, to the processing of relational information in sentence structure. The evidence would thus appear to support the view that structure and content are closely interrelated in language comprehension.

If the linear effect is unrelated to meaning, what then is its cause? We propose that the effect is related to the method of presentation of stimulus materials. Consider again the standard procedure used in these experiments. Each complex four-idea sentence is analyzed into four simple declar sentences, each of which expresses a single semantic idea. The simple one-idea sentences are then recombined into other sentences containing two, three, or all four of the ideas. Subsets of the sentences generated in this way are then used in acquisition and recognition. The method assures the redundant, overlapping presentation of all the ideas in any four-idea sentence and, as a consequence, the integration of its semantic content. However, the method also appears to create a difficulty for subjects when they are later asked to recognize such sentences. Although completely familiar with the ideas, subjects appear confused about whether any particular sentence contains the same combination of ideas presented earlier. We offer the relatively simple hypothesis that the confusion forces subjects to adopt a guessing strategy in which they assign ratings, not according to what they have experienced (or integrated), but on the basis of the probability that a sentence having a particular number of "components" (i.e., ideas, phrases or anything Ss interpret as being manipulated combinatorially) could have occurred in acquisition. They do this, presumably, by estimating the total possible number (or "set size") of sentences of varying sentence complexity and then formulating a probability based on the inverse of that set size. The linear effect itself can thus be easily explained: Since the maximum set size is greatest for ONEs and least for FOURs, the probability estimates and hence recognition-confidence ratings would yield a reverse ordering, i.e., ratings would be greatest for FOURs and least for ONEs. The hypothesis not only predicts the linear effect but other related findings in which it is not obtained. (see, for example, Reitman and Bower, 1973, and Bransford and Franks, 1972). In each case the precise form of the sentence complexity curves can be predicted on the basis of the set sizes for ... ial numbers of ONEs, TWOs, THREEs, and FOURs created by the experimental conditions. The present authors are now conducting experiments to systematically test this hypothesis.

One other issue remains to be considered. Why, one may ask, did the $\overline{M}$ condition produce a flatter sentence complexity curve? It will be recalled that all subjects were required to write down each sentence a few seconds after its presentation during the acquisition period. Data on errors of omission and commission for their written responses revealed the following: The mean number of errors per sentence for subjects in the M condition were 1. and 0.3 for FOURs and THREEs respectively while errors for TWOs and ONEs were negligible. For $\overline{M}$ subjects, errors were 7.6, 6.3, 3.3 and 1.4 for FOURs, THREEs, TWOs, and ONEs respectively. Thus, compared to subjects in the M condition, $\overline{M}$ subjects had great difficulty retaining sentences in immediate memory. We suggest that the difficulty in retention is in turn the result of a difficulty in the initial processing during acquisition; i.e., subjects could not get the perceptual information "in" because they could not very easily "recognize" or "identify" the nonsense strings. If this difficulty is viewed as a distraction, subjects would be less likely to discover a strategy such as the one described above. The result would be greater uncertainty in assigning ratings and, hence, a migration of the ratings toward the center of the recognition-confidence scale. In other words, the sentence complexity curve would become flatter, which, in fact, is what the data in the $\overline{M}$ condition show. Interestingly enough, the error data do lend some support to the guessing strategy hypothesis itself because that hypothesis requires only that subjects adopt a fairly simple combinatory rule which can be applied during recognition. A rather superficial processing of acquisition sentences would enable at least some subjects to discover this rule. The error data, however, offer little support for a semantic integration hypothesis since a more exhaustive processing would be required.

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FOOTNOTES

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[3]von Glasersfeld, E. Operational Semantics: Analysis of meaning in terms of operations. 1963 Euratom Report 296.e. Copies of this report may be obtained from the author who is at the University of Georgia, Athens, Georgia 30602.

[4]The single exception to this procedure was the replacement of prepositions, nominally considered function words, with nonsense syllables.

[5]FOURs were excluded from the acquisition lists in past studies. Because H sentences are so difficult to understand, however, FOURs were used here simply to provide Ss with more integrative or relational information.

[6]The authors wish to thank Professor Rolf E. Bargmann for his assistance in the multivariate analyses.