

Judging the Veracity of Ambiguous Sentences¹

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Eighty *Ss* saw a picture, heard a sentence, and judged the sentence true or false with respect to the picture. After five unambiguous sentences of a single syntactic structure, an ambiguous sentence was presented. Results for the ambiguous sentence revealed (a) that the ambiguity was most often perceived when both interpretations of the sentence were true with respect to the picture, (b) that response latencies were shortest when both interpretations were false, (c) that *Ss* who claimed to have seen the ambiguity before responding had longer latencies than those who claimed not to have seen the ambiguity, and (d) that these differences in processing were clear only in *Ss*' responses to their first ambiguous sentence. A model for the pragmatic and syntactic processes is considered.

Mehler and Carey (1967, 1968) presented sequences of sentences, all of the same syntactic type, to establish an expectation for that syntactic structure. When a subject (*S*) expects a particular structure and then receives a sentence possessing an unexpected structure, his difficulty in perceiving the sentence, or his increased reaction time in responding to the sentence, serve as an index of the importance of syntax in the processing of sentences. Using this technique, Mehler and Carey (1967) demonstrated that surface structure (Chomsky 1965) is important in perceiving sentences in noise. With the same technique, Mehler and Carey (1968) demonstrated that when *Ss* must judge sentences true or false with respect to pictures, unexpected surface structure results in a significant increment in reaction time. In the present paper, this method is employed to study the effect of a syntactic expectation on the processing of unexpectedly ambiguous sentences.

In some recent studies of ambiguity, *Ss* have

¹ This study was supported by N.I.H. Grant MH 14709 01 to Jacques Mehler; by ARPA Grant SD-187 and N.I.H. Grant 1 PO1 GM 16735 01 to Rockefeller University; and by N.I.H. Grant NB HD 08656 01 to Peter W. Carey.

been instructed to complete ambiguous sentences (MacKay, 1966) or to search for ambiguities (MacKay & Bever, 1967) while the experimenter (*E*) times his responses. Such experiments are interesting because they help to establish the relative order of difficulty in detecting ambiguities on the various linguistic levels. By inference, such studies of ambiguity can help to determine which linguistic levels are normally computed first, second, and third even in unambiguous sentences. As MacKay and Bever recognized, however, the usefulness of the ambiguity-completion and ambiguity-detection studies is limited by the fact that the explicit detection of ambiguity is an unnatural process. In some respects detection is the opposite of our normal treatment of ambiguous sentences. In everyday usage, many sentences that allow more than one structural description are understood unambiguously. Common sense suggests that syntactic, semantic, and pragmatic biases bring about the one-sided understanding of such (potential) ambiguities. In any particular situation the ambiguous sentence *He left the bathroom unwashed*,² for

² For these examples we are grateful to Dorothea Halpert.

example, will usually be understood in either the sense where the bathroom is unwashed or he is unwashed, but not in both senses. Similarly, the ambiguous sentence *They are the ones to help* will usually be understood as signifying either They are the ones who can help others, or They are the ones who need help, but not both. The theoretical possibility remains, however, that at some level of psychological performance, all possible readings are always computed by the listener. It may be the case that even when no misunderstanding or confusion results, all possible readings are computed, and that only afterwards do pragmatic and syntactic biases select a single reading for attention and recall. The present experiments allow a test of this exhaustive computation hypothesis.

Recent experiments on the lexical classes of verbs (Fodor & Garrett, 1967; Fodor, Garrett, & Bever, 1968) have provided evidence that might lead one to expect that the exhaustive computation hypothesis is correct. Fodor and Garrett did not study ambiguity per se but rather the related issue of the lexical complexity of verbs. They pointed out that verbs like *expect* are more complex than verbs like *borrow* because the former can take direct objects or whole clauses as complements, whereas the latter can take only direct objects. Fodor, Garrett, and Bever (1968) demonstrated that in psycholinguistic tasks such as paraphrasing or arranging verbal fragments into a meaningful sentence, complement verbs like *expect* were more difficult than pure transitives like *borrow*. Fodor and Garrett's (1967) discussion of this phenomenon contains clear implications for any consideration of the processing of ambiguous sentences:

It seems likely to us that the program *Ss* use to recover the grammatical structure of sentences has two primary components: on the one hand, it must consult a lexicon which classifies the verb in the sentence according to the base structure configurations it may enter. Second, *it must run through each such deep structure configuration*, asking whether

the surface material in the sentence can be analyzed as a transformed version of the deep structure [p. 295]. (Our emphasis.)

Thus, if *Ss* must run through each deep structure possibility for a verb like *expect*, we might think that *Ss* must also run through each deep structure possibility for the phrase *the ones to help* in the ambiguous sentence *They are the ones to help*. We might reason that just as we do not ordinarily recall having run through more than one analysis for *expect*, we need not recall the double processing of an ambiguous sentence.

Another possibility for the processing of ambiguous sentences is that under certain conditions, as yet unspecifiable, ambiguous sentences are treated exactly like unambiguous sentences. In more detail, it seems possible that under certain syntactic and pragmatic circumstances, only those semantic and syntactic relations pertaining to a single structural description will be perceived and processed. In such a case, there should be no difference at all between the processing of the ambiguous sentence and the processing of a non-ambiguous sentence with the same structure and equivalent lexical entries. This possibility, to be called the unitary perception hypothesis, is the opposite of the exhaustive computation hypothesis.

In studying the processing of ambiguous sentences, the technique whereby an expectation for a particular syntactic structure is created has the advantage of introducing in a controlled manner the sort of variable that seems to exist in the everyday situation; namely, the bias in favor of one particular reading. The technique therefore affords particularly appropriate conditions for evaluating the conflicting hypotheses. If evidence for one or the other hypotheses emerges under these conditions, we can be fairly certain that the evidence applies to more typical situations as well.

Some of the particular possibilities that the syntax-setting technique affords are the following:

1. Since one group of *Ss* may be set for

syntactic structure₁ of a particular ambiguous sentence, and another group may be set for syntactic structure₂ of the same sentence, the effect of ambiguity on the processing of a given sentence may be studied from both sides. Ordinarily, an ambiguous sentence has one interpretation that is computed with higher probability than the other, but the present technique allows some experimental control over these probabilities. A by-product of the technique is that we thereby obtain information on the absolute difficulty of computing syntactic structure₁ and syntactic structure₂ under conditions where the words used in the two structures do not differ.

2. In an ambiguous sentence such as *They are visiting sailors*, where in the progressive sense people are extending a visit to sailors, and in the adjectival sense sailors are extending a visit to someone else, four kinds of pictures can accompany the sentence. (a) Sailors visiting sailors makes both structural interpretations true (TT). (b) Women visiting women renders both interpretations false (FF). (c) Sailors visiting women renders the adjectival interpretation true and the progressive interpretation false (TF). (d) Women visiting sailors makes the adjectival interpretation false and the progressive interpretation true (FT). The four cases will be called the various truth conditions. The syntax-setting technique, coupled with these pictures, allows us to observe the effect of syntax, the effect of pragmatics, and the existence of possible interactions between them.

3. By asking Ss after the experiment whether they noticed the ambiguity when they were responding to the sentence, we may determine under which conditions Ss explicitly recall having noticed the ambiguity. If Ss who claim to have seen the ambiguity actually require more time to respond true or false than Ss who claim not to have seen the ambiguity, this would tentatively suggest that the former Ss did in fact compute multiple readings and that the latter did not. If subsequent analyses

showed no significant differences among latencies for the TT, TF, FT, and FF conditions for Ss who did not recall seeing the ambiguity, this would strengthen the claim that they had not in fact perceived more than one interpretation.

4. By presenting sentences only to a S's left ear or only to his right ear, possible quantitative and qualitative differences in processing ambiguous sentences may be observed. The suggestion (Kimura, 1967) that the right ear is more directly connected to the language areas implies that slight differences in reaction time may be observed for input to the respective ears. The syntactic findings of Bever, Kirk, and Lackner (1968) and Bever (1969) suggest that the right ear should differ from the left ear in its ability to process sentences of different syntactic structures.

EXPERIMENT I

Method

Materials. Four sets of sentences were used in the experiment; they are listed in Table 1. Every sentence began with *They are*, followed by a trisyllabic word ending in *-ing* and a plural, disyllabic noun. Set I contains five unambiguous sentences of progressive verb structure, followed by the ambiguous sentence *They are visiting sailors*. Set II contains five sentences of unambiguous adjective + noun construction, followed by the ambiguous sentence *They are lecturing doctors*. Set III contains the same progressive sentences as Set I, but this time they are followed by *They are lecturing doctors*. Set IV contains the five unambiguous adjectival sentences of Set II, followed by *They are visiting sailors*. Thus Ss receiving *They are visiting sailors* as their ambiguous sentence were biased toward its progressive sense (Set I) or toward its adjectival sense (Set IV). Subjects receiving the ambiguous sentence *They are lecturing doctors* were biased toward its progressive sense (Set III) or toward its adjectival sense (Set II).

All sentences were recorded by the same speaker in a normal intonation. The intonation of the ambiguous sentences was considered to be neutral with respect to its two possible interpretations. The same recording of an ambiguous sentence was used in each of the two sets in which the sentence occurred. Subjects heard sentences via stereophonic earphones at a uniform, comfortable sound pressure level.

For each of the unambiguous sentences, a 5 × 8-in. color picture was prepared that was appropriate (T),

TABLE 1
EXPERIMENTAL MATERIALS: SETS OF FIVE UNAMBIGUOUS SENTENCES FOLLOWED
BY ONE AMBIGUOUS SENTENCE

Set I	Set III
They are unearthing diamonds	They are unearthing diamonds
They are installing benches	They are installing benches
They are discussing paintings	They are discussing paintings
They are repainting ceilings	They are repainting ceilings
They are kidnapping babies	They are kidnapping babies
They are visiting sailors	They are lecturing doctors
Set II	Set IV
They are incoming signals	They are incoming signals
They are seagoing peoples	They are seagoing peoples
They are emerging nations	They are emerging nations
They are nourishing lunches	They are nourishing lunches
They are performing monkeys	They are performing monkeys
They are lecturing doctors	They are visiting sailors

and another picture was prepared that was inappropriate (F) for the sentence. A picture could be determined T or F only by reference to the last word of a sentence. For example, with *They are performing monkeys*, the T picture showed performing monkeys, and the F picture showed performing dogs. For each of the two ambiguous sentences, four pictures were prepared; these pictures formed the relations TT, TF, FT, and FF with the interpretations of the sentence. Pictures for the ambiguous sentences depicted two groups of people and could be determined T or F only after hearing the last word of the sentence.

Subjects. Eighty students from the Massachusetts Institute of Technology and Harvard University served as paid volunteers. All were right-handed native English speakers with no known hearing losses.

Design. Each *S* received one set of sentences, one quarter of the *Ss* being assigned to each set. Half of the *Ss* who heard any set received all six sentences in their left ear; the other *Ss* heard all six sentences in their right ear. Half of the *Ss* hearing the unambiguous sentences in any set received pictures such that the correct responses were F, T, T, F, T, in that order. The other ten *Ss* received the other pictures for the same sentences; the correct responses were therefore T, F, F, T, F. Of the 20 *Ss* receiving any set of sentences, five saw the TT picture for the ambiguous sentence; five saw the TF picture; five saw the FT picture; and five saw the FF picture. This assignment of *Ss* to conditions constituted a factorial design on sentence sets, ears, unambiguous picture sets, and truth conditions.

Procedure. In each trial a *S* had continuous visual access to the picture. Five seconds after a picture was presented, a *S* heard a tape-recorded sentence in one of his earphones. A click, recorded at the end of the sentence on a separate channel so that a *S* could not

hear it, activated a Hunter Klockcounter. A *S*'s vocal response of "right" if true, and "wrong" if false activated a voice switch that shut off the clock. The clock therefore indicated the latency of the vocal response from the end of the sentence. Before the first experimental trial, a *S* read a description of the task and practiced responding with two sentences that the *E* spoke to him 5 sec after the presentation of a practice picture.³

At the end of the experiment, a *S* proceeded to Experiment II. At the end of the second experiment, the *E* asked a *S* to paraphrase two sentences from each of the sets he had heard. The first sentence presented for a paraphrase was one of the unambiguous sentences; the second was the ambiguous sentence (which was not indicated as ambiguous). The paraphrase response for the ambiguous sentence was scored as a rendering of the adjectival structure or of the progressive structure. The paraphrase served to define the interpretation to which a *S* had responded during the experimental trial.⁴ A *S*

³ We are grateful to Miss Sue Alt and Mr. Henry Koopmans for testing the *Ss*, to Miss Joanna Blake for assistance in analysing the data, and to Mrs. Marilou Mehler for drawing the pictures.

⁴ It is conceivable that *Ss* could have seen and responded to the adjectival sense during the experimental trial, yet that they produced a paraphrase of the progressive sense at the end of the experiment. If this had occurred often, however, a large number of apparently erroneous responses would have been noted for the TF and FT cases. In fact, however, there were only 3 apparent errors for the 40 *Ss* receiving these conditions. We may therefore be fairly certain that *Ss*' paraphrases served to indicate the sense to which they had responded true or false during the experiment.

was then asked whether he had noticed the two senses of the ambiguous sentence "during the experiment and before he had responded." Subjects' answers defined the group who remembered perceiving the ambiguity and the group who did not remember perceiving the ambiguity.

Response analysis. The few latencies of over 5 sec (2 out of 480) were discarded, since they very likely indicated that a *S* had been distracted or was having other difficulties irrelevant to the experiment. The elimination of these few very long latencies had the desirable effect of rendering the distribution more Gaussian, and a series of planned *t* tests was carried out on means of usable latencies.⁵ Some data on unambiguous sentences were lost because a *S* spoke so softly that the voice switch failed to operate (11 out of 400), and *Ss* occasionally made incorrect responses (27 out of 400). For the ambiguous sentences there were no technical problems, but 6 of the 80 responses were incorrect. (A response to an ambiguous sentence was scored as incorrect by reference to the structure of a *S*'s paraphrase. Thus, for example, if his paraphrase indicated he had seen the adjectival sense, and the adjectival sense was true according to the picture, a false response would be scored as incorrect.)

Subjects always produced either a single true response or a single false response. The potential dilemma posed by an ambiguous sentence that had one true interpretation and one false interpretation was never a problem in practice.

Results

Unambiguous sentences. Analyses of the main effects revealed that *Ss* receiving adjectival sentences took considerably longer to respond true or false than *Ss* who received progressive sentences, $t(358) = 3.86, p < .001$. Table 2 shows that this difference occurred almost entirely for presentation to the right

⁵ No analysis of variance was attempted, because some treatment combinations yielded no data. For example, when *Ss* were set for a progressive structure and then received an ambiguous sentence with a false adjectival sense and a true progressive sense, no *S* responded to the false adjectival sense. The presence of empty cells in the data matrix, then, was an unavoidable consequence of the freedom of the design. In fact, it would have been impossible to study the effects of syntactic set on the processing of ambiguous sentences if *Ss* had been constrained in such a way as to yield an equal number of responses for every treatment combination. The use of *t* tests obviated the difficulties of the unequal or zero number of responses.

ear. The interaction of sentence type by ear was highly significant, $t(358) = 3.73, p < .001$. Between true and false latencies there were no significant differences, nor did the main effect of left versus right ear presentation approach significance.

TABLE 2

MEAN LATENCIES FOR THE INTERACTION OF EARS BY SENTENCE STRUCTURE FOR UNAMBIGUOUS SENTENCES

	Structures	
	Adjectival	Progressive
Experiment I		
Left Ear	.980	.955
Right Ear	1.285	.787
Experiment II		
Left Ear	1.274	.722
Right Ear	1.080	.911

Ambiguous sentences. Latencies for ambiguous sentences did not differ significantly between left and right ears, between true and false responses, or between responses to the adjectival versus the progressive sense, although latencies for adjectival responses were somewhat longer. The test sentence *They are lecturing doctors* did not differ significantly in latency from the test sentence *They are visiting sailors*. Subjects who claimed they saw the ambiguity before responding, however, had significantly longer latencies than *Ss* who said they did not, $t(72) = 2.40, p = .01$. Also, the interaction between detection of ambiguity and ears was significant, $t(72) = 3.55, p < .001$. The important term in the interaction was the latency for *Ss* who said they saw the ambiguity after right ear presentation. These² *Ss* took much longer to respond than any of the other *Ss*.

Subjects were categorized by their posttest paraphrase as having responded to the reading of the ambiguous sentence that had the same syntactic structure as their first five sentences (henceforth, "compatible" responses), or to the reading that did not have the same struc-

ture as their first five sentences (henceforth, "incompatible" responses). Latencies for compatible responses were significantly shorter than for incompatible responses, $t(72) = 2.69$, $p = .01$. Many more Ss, furthermore, made compatible responses than incompatible responses. Of the 74 usable responses, 61 were compatible responses, and 13 were incompatible responses. This distribution is significantly different from a chance distribution, $\chi^2(1) = 28.2$, $p < .001$.

The responses of the 61 Ss who responded compatibly deserve further analysis. These are the responses that allow us to test the hypothesis that both interpretations of an ambiguous sentence are always processed, even when a response to a single interpretation is made highly probable. Data for the 61 compatible responses are presented in Table 3; data for the 13 incompatible responses are presented in Table 4. Numerous significant differences were found for the data in Table 3; none were found in Table 4.

Do Ss who claim not to have seen the ambiguity of their sixth sentence nevertheless require more time to respond to it than to an equivalent unambiguous sentence? To answer this question, we may compare these Ss' latencies for compatible adjectival responses

with Ss' latencies for their fifth unambiguous adjectival sentence. The difference between the two mean latencies is so small as to suggest identity, $t(47) = .002$, $p > .95$.

Similarly, for these Ss' compatible progressive responses, there was virtually no difference from Ss' latencies for their fifth unambiguous progressive sentence, $t(60) = .27$, $p > .35$. The data therefore suggest that when the syntactic set was so strong that (a) it caused Ss to respond to the compatible sense of the ambiguous sentence, and (b) it caused them to be unaware of the other sense of the ambiguous sentence, the processing of the ambiguous sentence required no more time than the processing of an equivalent unambiguous sentence.

For subsequent analyses of the 61 compatible responses, a slightly different labelling convention for the truth conditions will be employed. The label "tt" will indicate that the sense responded to was true according to the picture and that the other sense was also true. The symbol "tf" will indicate that the sense responded to was true and that the other sense was false. The symbol "ff" will indicate that the sense responded to was false and that the other sense was also false. The symbol "ft" will indicate that the sense responded to was false and that the other sense was true.

TABLE 3
MEAN LATENCIES OF RESPONSES COMPATIBLE WITH THE SET

Condition	Did not see ambiguity		Saw ambiguity	
	Latency	No. of Ss	Latency	No. of Ss
Experiment I				
tt	.597	5	1.045	13
tf	.887	13	.856	3
ft	1.025	6	2.373	4
ff	.954	11	.764	6
Experiment II				
tt	.647	2	.574	8
tf	.692	7	.732	10
ft	1.312	3	.770	2
ff	.863	7	1.011	6

TABLE 4
MEAN LATENCIES OF RESPONSES INCOMPATIBLE WITH THE SET

Condition	Did not see ambiguity		Saw ambiguity	
	Latency	No. of Ss	Latency	No. of Ss
Experiment I				
tt	—	—	1.512	2
tf	1.283	3	2.775	3
ft	.674	2	2.794	1
ff	—	—	.669	2
Experiment II				
tt	1.821	2	.884	5
tf	1.096	4	1.220	10
ft	—	—	—	—
ff	1.019	7	1.253	1

When Ss responded to the compatible sense of an ambiguous sentence, how many of them claimed to have seen the ambiguity in each of the four conditions, tt, tf, ft, and ff? A chi-square test reveals that the distribution of Ss in these conditions is significantly nonrandom, $\chi^2(3) = 10.58, p = .02$. Table 3 shows that one general way of describing the distribution is to say that Ss tended to see the ambiguity when the second sense was true with respect to the picture (17 out of 28), but not to see the ambiguity when the second sense was false (9 out of 33).

Another question concerns differences in latency among the various truth conditions in Table 3. For Ss who claimed not to have seen the ambiguity, there were no significant differences among the four truth conditions. Among those who claimed they did see the ambiguity, however, there were several significant differences. The ff condition, first of all, required significantly less time than the tt condition, $t(17) = 1.75, p < .05$, and less time than the ft condition, $t(8) = 2.47, p = .02$. The tt condition required less time than the ft condition, $t(15) = 2.96, p < .005$.

Discussion

Unambiguous sentences. Mehler and Carey (1968) reported that Ss took more time to

decide whether adjectival sentences such as *They are performing monkeys* were true or false than to make equivalent judgments for progressive sentences such as *They are unearthing diamonds*. The present experiment replicated this finding with different sentences and different pictures. Together, the experiments constitute rather strong evidence that it is the linguistic structure that is critical in determining the latency, and not the inevitable difference between the pictures used, respectively, for the adjectival and progressive sentences. Furthermore, the finding that progressives are easier to judge true or false is in direct opposition to the prediction from Yngve's metric, which suggests that the surface structure of progressives is more complex and should therefore require more time to process (Martin & Roberts, 1966). On the other hand, the fact that progressives are easier is entirely consonant with the lesser complexity of progressive structures on the level of deep structure, as Rohrman (1968) has noted. Furthermore, the fact that progressives are easier argues that Ss were judging the truth or falsity of the entire sentence, and not simply the phrase formed by the last two words. If they had judged only the last two words, Rohrman (1968) would have predicted the opposite order of difficulty, since the deep structure of the phrase *unearthing*

diamonds is more complex than the deep structure of the phrase *performing monkeys*.

Bever, Kirk, and Lackner (1968) have observed that when *Ss* received shocks on one hand while listening to sentences in either the left or right ear, their GSR was larger and had a shorter latency for shocks occurring before a major clause break than for shocks occurring after a major clause break. This effect of syntactic structure on autonomic responses was much larger for sentences heard in the right ear than for sentences heard in the left ear. Similarly, Foss, Bever, and Silver (1968), in studying latencies of true-false judgments for pictures shown after an ambiguous sentence had been presented, found that latencies for expected and unexpected pictures showed the greater difference when the sentence had been heard in the right ear. In the present experiment, the difference in latency for progressive and adjectival sentences was much greater when the sentence had been heard in the right ear. The right ear may therefore be tentatively considered more sensitive to syntactic differences than the left ear. This sensitivity may be a consequence of the more direct connections of the right ear with the language areas of the left cerebral hemisphere (Kimura, 1967), but it is not yet possible to propose a detailed account of these phenomena.

Ambiguous sentences. Mehler and Carey (1968) reported that when *Ss* were set to receive an unambiguous adjectival sentence and instead received an unambiguous progressive sentence, or were set to receive a progressive sentence and received an adjectival sentence, their latencies were significantly lengthened. The present experiment observed that when *Ss* were set to receive an unambiguous adjectival or unambiguous progressive sentence and in fact received an ambiguous sentence, there was a difference between those who responded to the sense compatible with the set and those who responded to the incompatible sense. Those 61 *Ss* who responded to the compatible sense had significantly shorter latencies than the 13 who responded to the other sense. The

13 *Ss* with long latencies resemble the *Ss* from Mehler and Carey (1968) who received unambiguous sentences containing an unexpected structure. Already, then, we have evidence that *Ss* can treat ambiguous sentences as though they were unambiguous. This suggests that the exhaustive computation hypothesis derived from Fodor and Garrett (1967) is not correct.

The fact that *Ss* who claimed to have seen both interpretations had significantly longer latencies than *Ss* who claimed not to have seen them both suggests that *Ss*' introspections are accurate. The most parsimonious account for the difference in latencies is that those who claimed to have seen only one interpretation in fact did not perceive the other interpretation, and that those who claimed to have seen both interpretations in fact saw both of them (henceforth, the perception hypothesis). Additional support for the perception hypothesis was provided by Foss, Bever, and Silver (1968) who found that "the expected meaning of an ambiguous sentence had no slower VT [verification time, time to judge true or false] than an unambiguous sentence. Thus, ambiguity *per se* does not seem to interfere with understanding the meaning of a sentence [p. 306]." Their sentence applies exactly to the current data as well, since there was no hint of a significant difference between *Ss*' responses to their last unambiguous sentence and the compatible responses to an ambiguous sentence for those *Ss* who claimed not to have seen the ambiguity. Given the perception hypothesis, the present results allow us to add to the conclusion of Foss, Bever, and Silver the additional specification that when *Ss* do perceive the ambiguity in a sentence, even when not required or encouraged to do so, verification time is significantly increased.

The perception hypothesis, although parsimonious and compelling, is not the only plausible hypothesis that is consistent with the results. Before we regard the latency results conclusively accounted for, we must deal with the recall hypothesis. The recall hypothe

suggests that all *Ss* may have perceived all readings, but that some *Ss* used additional time to encode both readings for long-term memory, while others who responded more quickly forgot one of the interpretations. If such were the case, the results would be as observed; namely, the *Ss* who recalled seeing both interpretations would have the longer latencies.

The recall hypothesis has more difficulty in accounting for the rest of the data, however. If the real explanation were in terms of differential recall after identical perception, it would be extremely unlikely that the pattern of latencies for the *tt*, *tf*, *ft*, and *ff* conditions would differ for those who recalled the ambiguity versus those who did not recall the ambiguity. Specifically, it would be an astounding coincidence if statistical differences existed among these conditions for *Ss* recalling the ambiguity but not among *Ss* who failed to recall the ambiguity. In fact, however, this was precisely the pattern of the latency data. Thus the recall hypothesis will not work.

The lack of significant differences among the truth conditions for *Ss* claiming not to have seen the ambiguity really requires no additional explanation. Given that their latencies were not longer than responses to unambiguous sentences, there should be no effect of the truth or falsity of the unseen sense. And if the unseen sense has no effect on the response, then the four truth conditions reduce to the two conditions possible for unambiguous sentences; namely, true and false. Thus, just as there was no significant difference among true versus false responses to the unambiguous sentences, there was no significant difference among these true and false responses to ambiguous sentences.

Two related facts remain to be accounted for. First, the fact that there were significant differences in latencies among the four truth conditions for *Ss* claiming to have seen the ambiguity. Second, the fact that *Ss* tended to claim they saw the ambiguity when the second sense was true with respect to the picture and

to claim they did not see the ambiguity when the second sense was false with respect to the picture.

In accounting for these facts, we may begin by noting that when the sense a *S* was not set for was false by the picture, he was likely to claim he did not see the ambiguity, and he generally responded with a very short latency. Table 3 shows that for a few *Ss* who did claim to see the ambiguity when the second sense was false, their latencies were extremely short; so short, in fact, that they took slightly less time than *Ss* claiming not to have seen the ambiguity. This fact amounts to something of a paradox. Since in general *Ss* claiming to have seen both senses took significantly longer to respond than *Ss* claiming to have seen only one sense, how could it be that these few *Ss* show no differences, or even a difference in the other direction? The answer may well be that the technique for establishing whether a *S* saw the ambiguity or not is rather crude and admits a few false alarm responses. If some *Ss* claimed to have seen the ambiguity while responding, but really saw the ambiguity only later, the results would be as observed; in some cases both those claiming to have seen the ambiguity and those who did not see the ambiguity would have short latencies.

The probable explanation therefore goes as follows. The picture influenced the probability of detecting the ambiguity of the sentence. When the picture made the incompatible sense false, a *S* almost never saw that sense. The few *Ss* who claimed they saw the ambiguity under such conditions are exceptions to the rule that *Ss*' introspections are accurate; these few *Ss* probably saw the ambiguity just after they responded. Since they did not process both senses before responding, their latencies were not longer than those of *Ss* who claimed to have seen only one sense. As suggested above, the fact that many *Ss* claimed to see the ambiguity in these conditions, and the fact that their latencies were long suggest that they did, in fact, see both interpretations. Thus a true pragmatic relationship between a picture and

the second sense of an ambiguous sentence tends to cause that second sense to be seen. In other words, a true pragmatic relationship influences the probability of carrying out a particular syntactic derivation, and when the second syntactic derivation is carried out, additional time is required.

We must now account for the fact that in Table 3, ft responses required significantly more time than tt responses among those Ss seeing the ambiguity. The simplest possible explanation is that in the ft case, when one sense is true and the other false, the S experiences response competition. While this is probably true, it need not be the only reason for the slow responses. It may also be the case that in the ft condition the true sense is seen first, and that the shift from a true sense to a false sense requires a considerable amount of time. For the tt condition, no such shift from a true to a false sense would be required, and the latency would therefore be shorter.

The fact that Ss who claimed to have seen the ambiguity took longer to respond when they received the ambiguous sentence in their right ear is difficult to explain. If the connections of the right ear with the languages areas are more direct, one would certainly not expect responses after right ear presentation to require extra time. On the other hand, it may be the case that switching from one interpretation to another is more difficult after right ear presentation. If the syntactic effects are indeed more pronounced after right ear presentation, as suggested above, then switching from the expected interpretation and finding the other interpretation would be difficult. This hypothesis, however, is entirely *ad hoc*, and no explanation can claim to be conclusive at this time.

EXPERIMENT II

Method

Materials. The four sets of sentences from Experiment I were also used in Experiment II.

Subjects. The same eighty Ss were used in both experiments.

Design. Subjects receiving Set I in Experiment I received Set II in Experiment II, and vice versa. Subjects who received Set III in Experiment I received Set IV in Experiment II, and vice versa. In the first experiment, therefore, each S responded to five unambiguous sentences of a single syntactic type and then to a single ambiguous sentence. In the second experiment, he responded to five unambiguous sentences of the other syntactic type and then to a different ambiguous sentence. Thus in the second experiment, Ss responding to the ambiguous test sentence had already heard five sentences of the adjectival structure, five sentences of the progressive structure, and one ambiguous sentence with both structures. There is reason to expect, therefore, that the processing of the ambiguous sentence in Experiment II was different from the processing of the ambiguous sentence in Experiment I.

Procedure. Subjects judged sentences true or false according to the procedure of Experiment I.

Response analysis. Responses were analyzed as in Experiment I. Two responses out of 480 were longer than 5 sec, and they were discarded. For the unambiguous sentences, 7 out of 400 responses failed to register because of technical difficulties, and 24 of the 400 responses were incorrect. For ambiguous sentences there were no technical difficulties, but 6 of the 80 responses were incorrect. Incorrect responses were discarded.

Results

Unambiguous sentences. No significant differences in latency were observed between true and false responses, or between left and right ears. As in Experiment I, however, progressive sentences required less time than adjectival sentences, $t(357) = 5.29$, $p < .001$. Also, the interaction of sentence structure by ears was again significant, $t(357) = 3.01$, $p < .005$, but this time the interaction was in the opposite direction. Table 2 shows that the larger syntactic effect occurred in the left ear.

Ambiguous sentences. As in Experiment I, no significant differences were observed between true and false latencies, or between latencies for presentation to the left and right ears. Also as in Experiment I, the test sentence *They are visiting sailors* was not significantly different in mean latency from *They are lecturing doctors*. Responses that were compatible

with the structure of the pre-setting sentences were significantly faster than responses to the other sense of the ambiguous sentence, $t(72) = 2.34, p = .01$.

Unlike Experiment I, however, there was no significant difference between latencies for those who claimed to have seen the ambiguity versus those who claimed not to have seen it. When responses compatible with the set were examined according to the number of Ss in the various truth conditions (Table 3), no significant chi-square emerged. Also, no significant differences among latencies for the truth conditions were observed for either the group seeing the ambiguity or for the group that did not see the ambiguity. In three important comparisons on data in Table 3, then, differences were significant for Ss' first ambiguous sentence but not for their second ambiguous sentence. No significant differences appeared for the data in Table 4.

The latencies of compatible responses among Ss who claimed not to have seen the ambiguity were compared with the latencies for Ss' last unambiguous sentence. For adjectival responses, the latency for the ambiguous sentences was significantly shorter than the latency for the unambiguous sentence, $t(43) = 1.91, p = .04$. For progressive responses, the latency for the ambiguous sentence was significantly longer than for the unambiguous sentence, $t(48) = 1.92, p = .04$. These significant differences are in clear contrast to the lack of significant differences for corresponding comparisons in Experiment I.

Discussion

Unambiguous sentences. The data from Experiment II support the findings from Experiment I concerning the faster processing of unambiguous progressive structures. The fact that the significant interaction of structures by ears is in precisely the opposite direction from the first experiment, however, is difficult to explain. If we take the general position, though, that the right ear is more quickly sensitive to syntactic differences than the left ear, then it is

possible to interpret the interaction as the delayed manifestation of the syntactic phenomenon in the left ear. This line of reasoning leads to the expectation that after additional experience with the two syntactic structures, the differential syntactic sensitivity of the ears would no longer be an important factor, and the significance of the interaction would disappear.

Ambiguous sentences. Virtually all the evidence in Experiment I that supported the perception hypothesis and rejected the recall hypothesis was not replicated in Experiment II. In addition to the lack of significant differences in the expected places, significant differences appeared in unexpected places. For example, the fact that adjectival responses to ambiguous sentences were faster than adjectival responses to unambiguous sentences was certainly not predictable from the account of the data in Experiment I. To explain this fact, we may not appeal to a peculiarity of the particular unambiguous sentence used for comparison, since latencies tended to decline for each successive unambiguous sentence. Thus the latency for the fifth unambiguous sentence was shorter than for any of the previous sentences in the set. Similarly, in view of the finding in Experiment I that Ss who responded to the progressive sense of an ambiguous sentence without seeing the other sense had latencies that were nearly equal to latencies for unambiguous progressive sentences, it is difficult to understand how in Experiment II progressive responses to ambiguous sentences could be significantly slower than to progressive unambiguous sentences.

Although the specific explanation for each of the differences between Experiment I and Experiment II must remain obscure, the following general account may be offered. The main purpose of the experimental method employed in Experiment I was to bias the response to an ambiguous sentence toward a particular syntactic structure. The intent of Experiment II was to employ the same group of Ss to replicate the findings of the first

experiment. By the time a *S* received the ambiguous sentence in Experiment II, however, he had been exposed to five unambiguous sentences of each structure, plus one sentence containing both structures. Thus, the biasing effect in Experiment II could not have been as sharp as in Experiment I. The *Ss* in Experiment II could not help but process the ambiguous sentence in a different fashion from their first ambiguous sentence. Thus, if the method in Experiment I served to bias the response in a manner not unlike everyday situations, the method of Experiment II may well have created a very artificial and unnatural situation. We therefore prefer to regard Experiment II as an interesting lesson, with the following moral: If studies of performance with ambiguous sentences are to yield data representative of normal processing, each *S* can receive only one ambiguous sentence. After the first such sentence, the study of ambiguity becomes the study of contaminated data.

CONCLUSIONS

1. Subjects know what they are doing. When they claim to have seen an ambiguity before responding, their latencies suggest strongly that they did in fact carry out extra processing before responding.

2. Syntactic expectation can influence the processing of ambiguous sentences such that the ambiguity is not perceived and that reaction time is no different from an equivalent unambiguous sentence.

3. Pragmatic considerations—here, pictures—can influence response latency and the probability of detecting the ambiguity of a sentence.

4. Predicate nominative structures are more difficult to judge true or false than progressive verb structures, as their deep structures would suggest.

5. Prolonged experience with ambiguous sentences in an experiment can obliterate or distort effects that are clear in *Ss*' responses to their first ambiguous sentence.

6. Sentences presented to the right ear may be processed syntactically in a qualitatively different manner from sentences presented to the left ear.

REFERENCES

- BEVER, T. G. The nature of cerebral dominance in the speech behavior of the child and adult. To appear in Ingram and Huxley (Eds.), *Mechanisms of language development*. London: Academic Press, 1969.
- BEVER, T. G., KIRK, R., & LACKNER, J. An autonomic reflection of syntactic structure. *Neuropsychologia*, 1968, 6, 81-85.
- CHOMSKY, N. *Aspects of the theory of syntax*. Cambridge, Mass.: M.I.T. Press, 1965.
- FODOR, J., & GARRETT, M. Some syntactic determinants of sentential complexity. *Perception and Psychophysics*, 1967, 2, 289-296.
- FODOR, J., GARRETT, M., & BEVER, T. G. Some syntactic determinants of sentential complexity, II: Verb Structure. *Perception and Psychophysics*, 1968, 3, 453-461.
- FOSS, D. J., BEVER, T. G., & SILVER, M. The comprehension and verification of ambiguous sentences. *Perception and Psychophysics*, 1968, 4, 304-306.
- KIMURA, D. Functional asymmetry of the brain in dichotic listening. *Cortex*, 1967, 3, 163-178.
- MACKEY, D. G. To end ambiguous sentences. *Perception and Psychophysics*, 1966, 1, 426-436.
- MACKEY, D. G., & BEVER, T. G. In search of ambiguity. *Perception and Psychophysics*, 1967, 2, 193-200.
- MARTIN, E., & ROBERTS, K. H. Grammatical factors in sentence retention. *Journal of Verbal Learning and Verbal Behavior*, 1966, 5, 211-218.
- MEHLER, J., & CAREY, P. The role of surface and base structure in the perception of sentences. *Journal of Verbal Learning and Verbal Behavior*, 1967, 6, 335-338.
- MEHLER, J., & CAREY, P. The interaction of veracity and syntax in the processing of sentences. *Perception and Psychophysics*, 1968, 3, 109-111.
- ROHRMAN, N. L. The role of syntactic structure in the recall of English nominalizations. *Journal of Verbal Learning and Verbal Behavior*, 1968, 7, 904-912.

(Received November 6, 1969)