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A FURTHER TEST OF THE UTILITY OF A TECHNIQUE FOR ASSESSING STRUCTURE OF LANGUAGE IN CHILDREN AND ADULTS. FINAL REPORT.

BY- SUCI, GEORGE J.

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DESCRIPTORS- *LANGUAGE RESEARCH, *SYNTAX, *SEMANTICS, COGNITIVE PROCESSES, EXPERIMENTS,

THIS DOCUMENT COMPRISES REPORTS ON TWO TECHNIQUES USED IN SIX EXPERIMENTS DESIGNED TO ASSESS THE SYNTACTIC AND SEMANTIC PROCESSING OF AUDITORY, LINGUISTIC INPUTS. PAST RESEARCH HAS DEVELOPED THE "PROBE-LATENCY TECHNIQUE," THE FIRST OF THE TWO TECHNIQUES USED IN THIS RESEARCH, FOR ASSESSING THE STRUCTURE OF LINGUISTIC INPUTS. RESULTS TO DATE INDICATE THAT THE PROBE-LATENCY STRUCTURE IS PRIMARILY A FUNCTION OF SYNTACTIC RELATIONS IN THE INPUT, AND IS RELATIVELY INDEPENDENT OF SEMANTIC CHARACTERISTICS OF THE STIMULUS MATERIAL. THE "QUESTION TECHNIQUE," THE SECOND OPERATIONAL METHOD USED, WAS DEVELOPED AS AN APPROACH TO SEMANTIC PROCESSING. THE RESULTS OF THIS STUDY (USING BOTH THESE TECHNIQUES) INDICATE THAT THE QUESTION TECHNIQUE HAS PROMISE AS AN APPROACH TO SEMANTIC PROCESSES. THE STUDY ALSO GIVES FURTHER CONFIRMATION TO THE INDEPENDENCE OF SEMANTIC FROM SYNTACTIC PROCESSES. (AUTHOR/AMM)

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Project Director: George J. Suci
Associate Professor
Cornell University

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The original proposal described the "probe-latency technique" which in its simplest form refers to the following: The subject is presented, auditorily, with a linguistic input. Immediately after presentation, one of the words in the input is repeated as a stimulus to which the subject is instructed to respond as fast as possible with the word which followed the input. For example, the subject may hear: "The big bear climbs tall trees---BEAR." The word "bear" is repeated as a stimulus to which the subject is to respond with "climbs" as fast as he can. The response latency, onset to onset, is measured with an oscillograph recording made from a tape recording of the input and the response. It is assumed that this response latency is a direct function of the relationship between the two words. This assumption has been tested against syntactic structure criteria with favorable results for both children and adults (Suci, Ammon and Gamlin, 1967). It was found that the latency by probe position curve was in the shape of an inverted V with the apex at the phrase boundary.

In this report the terms "structure" and "probe structure" will refer to the probe-latency curve unless otherwise specified. The objective of the proposed research was primarily to relate probe-structrue to two other variables. These were short-term memory capacity and meaningfulness of the stimulus material.

Work with short-term memory was temporarily delayed because of procedural difficulties. Instead the research began with an attempt to find a technique for assessing semantic

processing and to relate semantic factors to syntactic structure. As a follow-up to this research memory factors were studied in later studies and in a Ph.D. thesis by Peter Gamlin.

STUDY NO. 1#

The purpose of this study was to investigate variations in probe-structure as a function of a set of semantic factors and as a function of one non-semantic factor. Previously, research with semantic factors had been done only with adults; in this study fourth grade children were used. In summary it was found:

(1) The semantic factors failed to alter probe-latency structure; therefore, the earlier finding (Suci, et al, 1967) that syntactic and semantic factors are independent with adults may be generalized to a different subject population and to another measure of semantic processing. Although by the fourth grade syntax appears as a very powerful organizing factor in language processing, the ability to comprehend language may be independent of this organizing factor. The results of this study seem to support the hypothesis that although syntactic organization may be a necessary condition, it is not sufficient for successful semantic processing.

(2) Although semantic factors seemingly do not affect probe-latency structure, a non-semantic feature, a pause, does. When a brief pause is inserted at the phrase boundary of a simple input sentence it separates phrase units (probe latencies at

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A report of this study has been submitted for publication and a copy of the complete report is attached.

the phrase boundary become longer), but tightens word units within phrases (latencies between words within phrases become shorter).

(3) As a possible method for assessing semantic processing the "question technique" was developed. To test the validity of this technique as an assessment of semantic processing latencies of responses to questions were related to the meaningfulness of the stimulus material and to the comprehension level of the subject. Comprehension level was indexed by a standard test. It was expected that anomalous inputs would produce longer latencies than meaningful inputs. This expectation was borne out. It was also expected that a low-comprehension group of subjects (as assessed by the test) would show longer latencies than a high group regardless of the meaningfulness of the stimulus input. This expectation was not borne out in an unqualified manner. The high-comprehension group did better with the meaningful material but did less well than the low comprehension group with anomalous material.

(4) Both the high and the low comprehension groups show greater structure with pause in the input, but the associated change in semantic processing, as measured by the question technique, differs for the two groups. The low group improves its performance with meaningful input and the high group improves in its performance with the anomalous input.

(5) The pattern of differences between the latencies of the responses to the three questions was considered. The sentence used in this study is represented by the example: The sly hunter followed the black bear. One question concerned the first adjective-noun relation (e.g., Was the hunter sly?);

another aimed at the second adjective-noun relation (e.g., Was the bear black?); and a third was concerned with the subject-predicate relation (e.g., Did the hunter follow the bear?). For both high and low comprehension groups and with both meaningful and anomalous inputs the shortest latencies were produced by the third question (subject-predicate), the longest latencies were produced by the second question (second adjective-noun), and the first question (first adjective-noun) produced latencies between the other two.

STUDY NO. 2

No evidence was found in the first study that differences in semantic factors in individuals or in the stimulus items affected the structuring of the inputs. In this study a variation in syntactic structure is introduced in the stimulus material as an independent variable, semantic content is held constant and the dependent variable is the response latency to the type of questions used in the first study. The question asked is whether a syntactic factor, independently of semantic content, has impact on semantic processing.

More specifically the aim of this study is to learn if response latencies to a particular question could be affected by a syntactic change relevant to the question, and if this syntactic change would have an impact on response latencies to the other two questions. The syntactic construction used in the first study was modified by inserting an adjective clause as a substitute for the first adjective, e.g., "The hunter <u>who is sly</u> followed the black bears." in place of "The sly hunter followed the black bears." Presumably these are semantically

equivalent but syntactically different. The aim of the study is to learn if the response latencies to the question about the first adjective-noun relation will be especially modified by this change and if the other two response latencies will also show a change.

Method

About four months after the first study, the same fourth-grade subjects were presented with the modified sentence. Only meaningful sentences were used. Both the probe task and the question task were presented in one session, counterbalanced for order. In the probe task each of the six possible probe positions was probed six times and each question was presented eight times. The stimulus items were presented in two sets of 18 in the probe task and in two sets of 24 in the question task. A brief rest was given between sets. Each task was introduced with six practice items. The rest of the procedure was exactly as in the first study.

Results

Probe Analysis. The results of an analysis of variance are given in Table 1.* The shapes of the probe latency curves corresponded to phrase structure; that is, the curve was peaked at two positions: between the first noun and the modifying clause, and between the noun phrase and the verb phrase. The main effect of probe position was significant ($p<.001$). Probe position did not interact with comprehension level to a statistically significant extent, but as can be seen in Figure 1 the shape of the curve for the low comprehension

*All tables and figures are given in the Appendix.

subjects deviated from the phrase structure pattern described above. For the low comprehension group, the first peak was between the noun and verb phrases, as before.

Question Analysis: An analysis of variance, given in Table 2, of syntactic type (simple or clause), questions (the three used in the first study) and comprehension level (low and high, as in the first study) was done. The relationwhips obtained among these variables are illustrated in Figures 2 and 3. The difference between questions was significant ($p<.001$) and, as before, the first noun-adjective question responses were slower than the second noun-adjective question responses. The question regarding the subject-verb-object again produced the fastest responses. The latencies to the two syntactic types differed significantly ($p<.001$). The simple type produced slower responses than the type with the modifying clause. The difference between comprehension groups in latency was not significant although the low group was slower. The interactions between syntactic type and questions, between syntactic type and comprehension level, and between questions and comprehension level were not significant. The interactions with syntactic type were in the following directions: the responses to the questions about the noun-adjective relation were speeded up more than responses to the subject-verb-object relation by switching from the simple to the modified sentence, and the low comprehension group gained the most in response speed from the same switch.

Discussion

Varying syntactic structure apparently does have an impact on semantic processing, at least to the extent that this kind of processing is assessed by the question technique. The effect

of inserting a modifying clause in place of an adjective-noun sequence is to facilitate responses to questions regarding any part of the sentence. Such facilitation is not a function of the comprehension level of the subject to a statistically significant degree, although the direction of change was such that the low group profited most by the new structure. The facilitation is also not a differential function of the question being asked to a statistically significant degree, although the direction of the change was such that the responses to the adjective-noun questions were speeded up more by the new structure than responses to the other question.

It is apparent that the probe-latency technique continues to reliably reflect structural differences, and that as yet no significant impact of semantic factors on how input is structured has been found. In this study, the semantic factor was the comprehension level of the subjects and although the probe-structure curves for the two groups varied, no significant interaction between comprehension level and probe structure was found. It should be emphasized, however, that no other study has shown as large a difference in probe-structure curve as was found in this study. In all studies using response latencies with children, the individual differences have been very large. Such lack of homogeneity perhaps masks a small, but real difference in this study. The results, however, must be considered as supporting the notion that syntactic structuring may be independent of semantic processing.

However, the reverse, that semantic processing is affected by syntactic structure is also supported in this study. The questions were answered faster: presumably the semantic processes

were facilitated by a structural change. The expected result, however, that the clause insertion would affect latencies particularly to the question relevant to the clause, did not materialize; rather special facilitation for both adjective-noun relations were indicated. The results in this direction were just short of significance (obtained F=2.93; required F, at $p<.05$ =3.15). Again, the large individual differences may have masked a real difference.

STUDY NO. 3

This was a pilot study primarily aimed at testing the question procedure and some of the substantive results of the other two studies with adults. Would the latencies of responses to the three types of questions follow the same pattern as with children? Are responses to questions facilitated by the insertion of the clause, and do meaningful sentences produce faster question responses than anomalous questions?

Method

Eight female college students were subjects. A subject was given eight conditions in one session. The conditions were all combinations of meaningfulness (anomalous or meaningful) and syntactic-type (simple adjective or adjective clause) for both probe task and question task. The same stimulus material used with children was used here. A subject received either all of the probe conditions first or all of the question conditions first. The probe and question sets of conditions were balanced for order of presentation across subjects. All other conditions were balanced within these sets for order of presentation. All other procedures were the same as with children.

Results and Discussion

An analysis of variance showed that the probe-position effect did not materialize for the simple sentence (Table 3) but did for the sentence which contained a clause (Table 4). Although the probe curves for the simple sentence were shaped as expected (an inverted V with the apex at the phrase boundary), the obtained variations in latencies were not significant. The probe structure curves are shown in Figures 4 and 5. This finding corresponds to previous results with adults. (See Suci, et al, 1967). Adults impose minimal structure on a short, simple sentence. This implies that the simple sentence can be "handled" as one complete unit by adults, whereas children must break the same input into smaller units.

The probe curves did not vary as a function of the meaningfulness of the input; i.e., again, semantic and syntactic factors remained independent. Statistically, the response latencies to questions were a function neither of syntactic type nor of the meaningfulness of the input, although the latter finding was in the same direction as in Study No. 2, with children (Table 5). This seriously limited the general validity of the question technique and led to a replication study with adults using more subjects.

Further motivation for repeating the study was given by another finding which did not correspond to a result with children. The pattern of differences between questions found in the previous studies with children did not materialize for the simple anomalous sentence with adults. It had been consistently found that the question regarding the first adjective-noun pair in the sentence produced a quicker response than the

question regarding the second adjective-noun pair. In other words, the later pair produced the slower response. In this study, this finding was reversed (although not statistically significantly); i.e., the later pair produced the faster response. The pattern of latencies to the question is shown in Figure 6. Since the pattern of response latencies to questions was potentially relevant to an understanding of the mechanisms involved in the comprehension process, a replication of this finding to statistically reliable degree was important.

STUDY NO. 4

This was a repeat of Study No. 3, using 16 subjects instead of eight. The design, stimulus materials and procedures are identical to the previous study; however, since the main aim was to test the validity of the question technique only the question task was assessed. The probe technique was not used in this study.

Results and Discussion

The analysis of variance given in Table 6 shows that the meaningfulness main effect is significant ($p < .01$). The anomalies produced slower responses than did the meaningful sentences. This was the expected result if the questions validly assess some aspect of semantic processing. The difference between this result and the corresponding negative finding in the pilot study may be attributed to subject population. Not only were there more subjects, but the caliber of subject was obviously superior. For the pilot study, subjects were obtained during a final examination week. They

were reluctant and in a hurry. For this study highly motivated freshmen volunteered. Their superior performance was visible in fewer errors and in much shorter latencies.

But the finding in the pilot study that the pattern of latencies was reversed for the first two questions was replicated in this study. This is illustrated in Figure 7 which shows inverted-V patterns for all but the simple, anomalous sentence. The interaction between syntactic type, meaningfulness and question (as illustrated in Figure 7) is not significant, but the syntactic type by question interaction is significant ($p < .05$). Apparently the effect of meaningfulness is not very strong; the main impact comes from the syntactic type. Adults tend to give a slower response to questions about the early portion of a simple sentence than to questions about the later portion. This effect has not been found with children. Perhaps this indicates that the sentence inputs are processed differently by the two age groups and that more specific attention should now be given to process variables.

A TENTATIVE PROCESSING MODEL

Results from the four studies described above seem to suggest a tentative model of how linguistic input is processed. The relevant findings may be summarized as follows: (1) Structure as measured by the probe technique is independent of semantic factors. This implies that a mechanism exists which can organize linguistic input in terms of syntactic factors and which can ignore semantic content. (2) Semantic processing, on the other hand, does not appear independent of structural factors. When structure is changed by the insertion of a pause, or a clause, semantic processes seem affected. This

implies a step-wise mechanism such that the semantic analysis of the input does not begin until after the input is syntactically structured. Incidentally, this finding has a practical implication: how an input is comprehended can be somewhat controlled by manipulation of structural factors and some of these factors can begin to be specified by the methods used in this research. (3) To the extent that semantic processing is assessed by the question technique, the patterns of latencies to the questions suggest that the retrieval of information from different portions of the input requires different amounts of time. This implies that a decay effect may be operative over time--i.e., that memory factors are involved.

This interpretation is not out of line with aspects of processing models suggested by others. Lindsay (1963) for example, suggests that at least two programs would be necessary in a machine which understands language: a "sentence-parsing" program which corresponds to determining the phrase structure, and a "semantic-analysis" program dealing with the meaning of the parsed input. Miller and Chomsky (1963) similarly suggest a perceptual device for language reception consisting of two basic components, M_1 and M_2, where M_1 contains a short-term memory and performs a "preliminary analysis"- - a syntactic analysis - - on the input. The task for M_2 - - which contains a long-term memory - - is to determine the "deeper structrue" of the input using the information from the output of M_1. That two such systems do, in fact, psychologically exist and are psychologically independent is supported by the research reported in this proposal. Neisser (1967) discusses two kinds of memory--echoic memory, which lasts only a few seconds, and

active verbal memory, in which the information from the briefly held echoic input is stored in recorded form. Although Neisser does not say this, it seems possible that syntactic structuring occurs during the time duration of echoic memory and that semantic analysis follows as a recoding of this initial process.

It does not seem unreasonable to assume that the input is first processed syntactically (Lindsay argues that this is left-to-right as the input comes in), into units which are independent of their semantic content. Each element (word) of the input regardless of semantic content is held in short-term memory until syntactic processing indicates that a syntactic unit is complete. The system is thus free of the burden of supplying meaningful content to each element as it rapidly comes in. The entire unit is then semantically processed--i.e., changed into a form which permits the kind of grammatical relations and transformations discussed in Study No. 1.

As it stands this tentative processing model is simple and crude. It is not readily amenable to test. However, it does serve as a guide to research and, as such, it indicates that the role of memory in processing should be investigated.

STUDY NO. 5

One aspect of memory is the effect of storage capacity on the way input is structured as structure is measured by the probe latency technique. In the original proposal it was suggested that as the limits of capacity are reached, either because the input is long or because the capacity is limited, the input will more likely be broken into smaller units. In

other words, a lower capacity or a longer input will produce a more structured organization. In a thesis, as yet not completed, by Peter Gamlin the memory capacity of ninth grade students was assessed with standard measures of digit span and also with the length of sentence which could be recalled errorlessly. Dividing the subject population into two groups, one with high capacity and one with low capacity, Gamlin found that the low capacity group had a much greater break at the phrase boundary of an input, as measured by the probe method. As predicted, a given input was much more highly structured by a low capacity group.

Another aspect of memory is the temporal effects on the inputs. As implied by the model, a short span memory may exist which handles only the syntactic structuring, independent of the semantic factors. This short span memory may hold the material only a few seconds, just long enough to structure the input for semantic processing. If this is so, one would expect differential impacts of short time delays between input and task stimulus (e.g. between sentence end and probe word) on (a) the probe structure latencies and the question latencies, and (b) on the three different questions. Probe structure latencies, since presumably they assess the state of the input during the initial, brief holding period should fade more over time than the questions which presumably assess a later (semantic) step in the processing.

On the other hand each of the three questions should behave differently. If the semantic processing proceeds left-to-right, with each syntactic unit being semantically coded as it is formed, the early portion of the sentence should be available before

the later portion. But if a brief time delay is allowed between input termination and the question, this difference should disappear since more time is allowed for the semantic processing of the later portion. In other words, with minimal delay, the first question, corresponding to the early portion of input, should be answered faster than the second question, but this difference between question latencies should decrease with a longer delay. Study No. 5 was designed to test these notions.

Method

Sixteen high school juniors were subjects. The stimulus sentences were the meaningful sentences used before. The probe and question tasks were balanced with respect to order and content as before. For both probe and question tasks two delays between sentence ending and task stimulus were used: approximately one-third of a second or approximately one second. The delays were balanced with respect to order of presentation. The stimulus items were presented in sets of 20 (for probe) and 15 (for question). Each set represented a combination of all conditions.

Results

The probe latencies did become longer with a longer delay, but not significantly (see Table 7). The probe structure curves corresponding to the two delays were almost parallel--i.e., all portions of the input decayed to the same degree (see Figure 8). The results with the questions showed that with increased delay there was no change in the latencies of questions 1 and 3 (see Table 8). Question 2, however, shifted in the opposite direction from that predicted (see Figure 9). That

is, the latencies to question 2 became longer with increased delay. This shift in the interaction between questions and amount of delay was statistically significant ($p < .01$).

Discussion

This unpredicted result with the question is difficult to explain even after the fact. It seems wise in the light of such a clearly negative result to postpone ad hoc explanations until the result is or is not replicated.

STUDY NO. 6

The aim of this study was to assess the validity of the finding in Study 5 with a new and different population of subjects, and to further assess the validity of the question technique as an operational index of semantic processing. The study used the same materials as for Study 5, but, in addition, a semantic variation was introduced by adding anomalous sentences to the stimulus materials. Thus the study may be represented by a 2x2 design: time delay (short-long) by meaningfulness of sentences (anomalous-meaningful). The rationale for including the anomalies is as follows: Memory decay functions should be a function not only of time but also of the meaningfulness of the input. An anomaly should decay more per unit time than a meaningful sentence. Further, if sentences are processed left to right, requiring a memory factor (that is requiring holding the earlier portion until a later portion arrives), the impact of time delay on different portions of the sentence should be different. If the questions are valid, they should reflect these differences; that is, the latencies should be longer for anomalies (as before), but they should be even longer with a longer time delay, and the three questions should produce different patterns of latencies under all conditions.

Method

The procedures and stimulus materials were as before. The probe task, the questions task, meaningfulness and time delays were balanced for order across subjects and across two different sessions held about two days apart. Subjects were fifth graders, the same subjects who were fourth graders in Study No. 2. Only high comprehenders were used in order to minimize errors and to maximize homogeneity.

Results and Discussion

The analysis of these data could only partially be completed (due to machine failure). The data for the question task were transcribed and means were found for all conditions, but the results could not be statistically assessed at this time. And the data for the probe task could not be transcribed. The means for the three questions were as follows:

	Q_1	Q_2	Q_3
meaningful--short delay	9.09	9.97	5.87
meaningful--long delay	8.97	11.28	5.47
anomalous--short delay	13.19	11.81	7.72
anomalous--long delay	12.97	12.53	10.06

The descriptive data clearly support the predictions. The earlier finding of Study No. 5 was replicated with meaningful material, and the differential impacts of time delay materialized. Given that these findings are statistically reliable, the validity of the question technique is given further support, and the potency of the technique as a possible lever toward describing the processes in language understanding is enhanced.

FURTHER WORK

The analysis of STUDY NO. 6 will be completed and the results interpreted. Future work will probably concentrate on the further development of the question technique as a tool for operationalizing

linguistic processing. This will be done primarily, at least at first, in relation to short-term memory factors. It seems that a first step now is another attempt at describing a processing model.

Lindsay, R. K. Inferential memory as the basis of machines which understand natural language. In Feigenbaum, E. A. and Feldman, J. Computers and Thought. New York: McGraw-Hill, 1963.

Miller, G. A. and Chomsky, N. Finitary models of language users. In Luce, D. R., R. R. and Galanter, E. Handbook of Mathematical Psychology. Vol. II. New York: Wiley, 1963.

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Figure 1

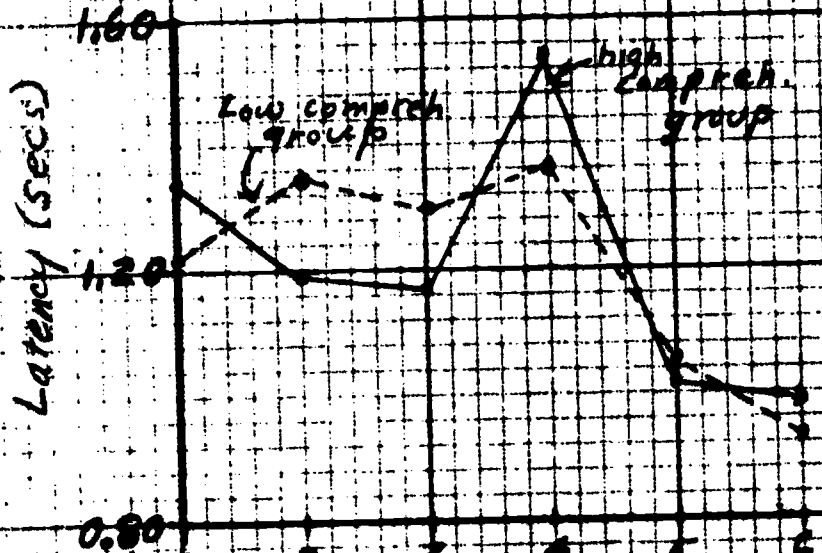

Figure 2

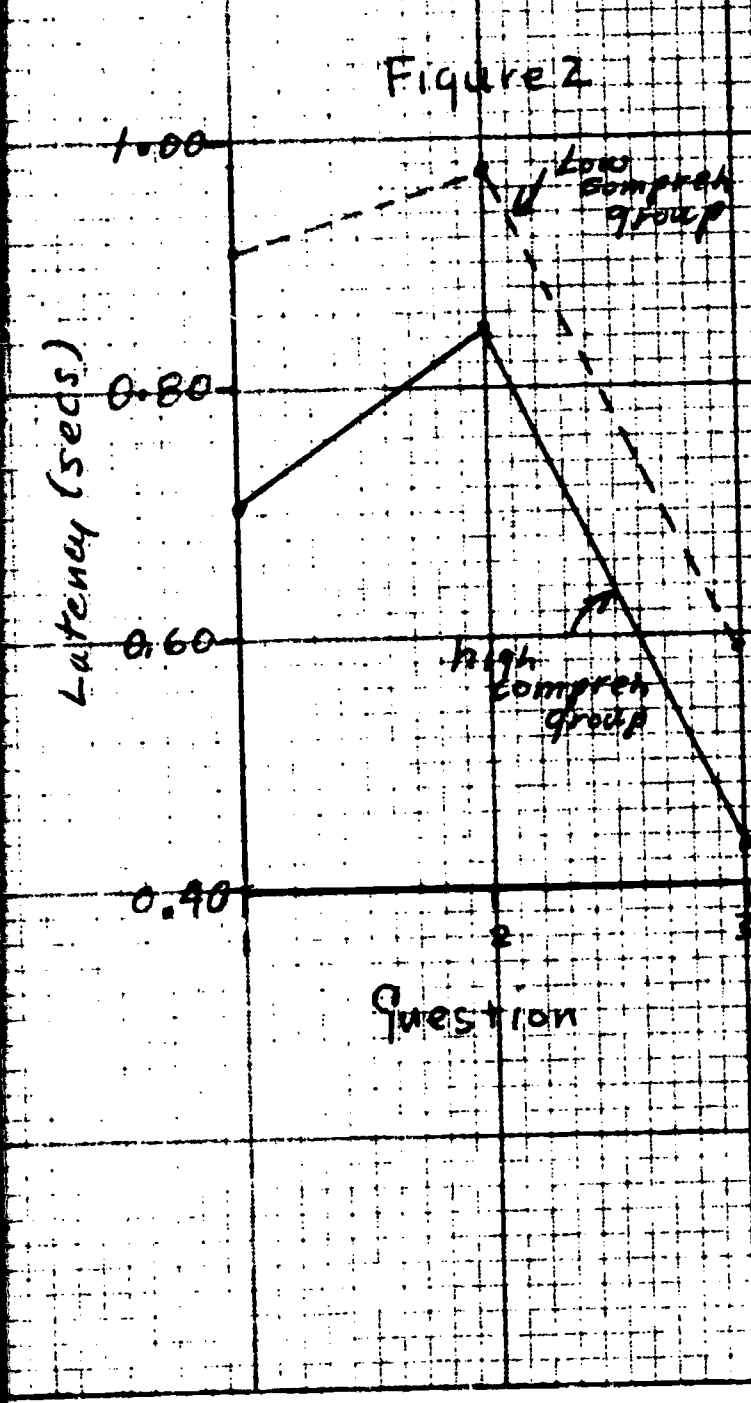

Figure 3

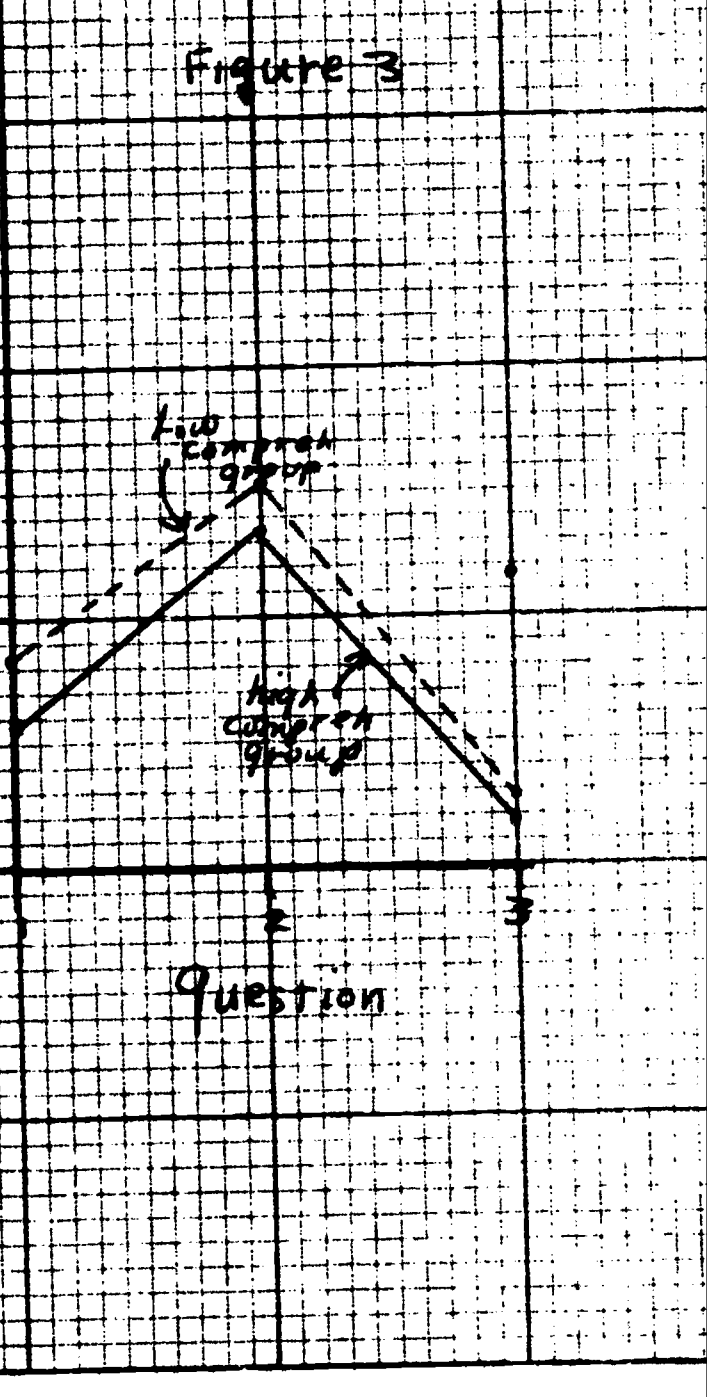

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Figure 5

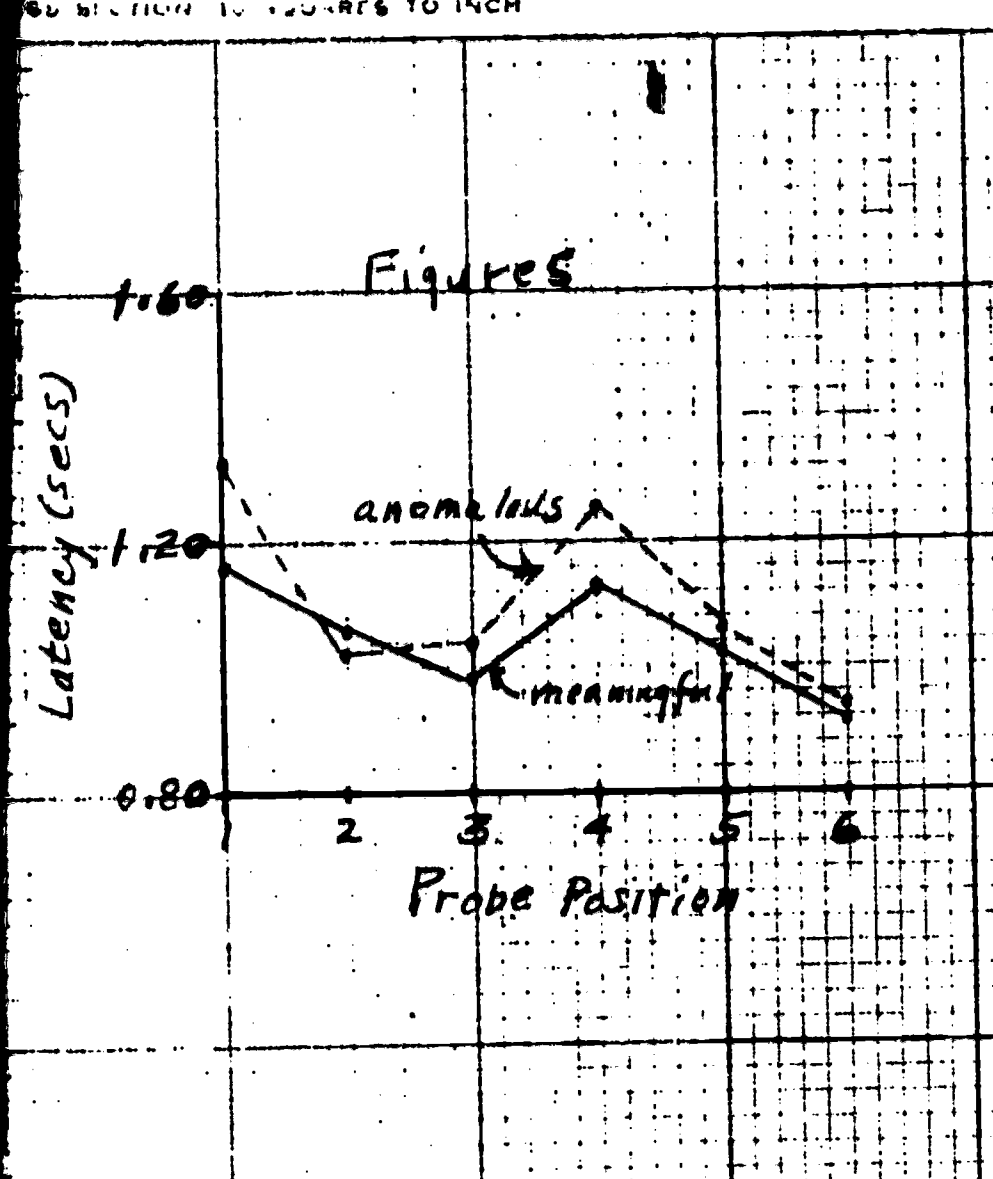


Figure 4

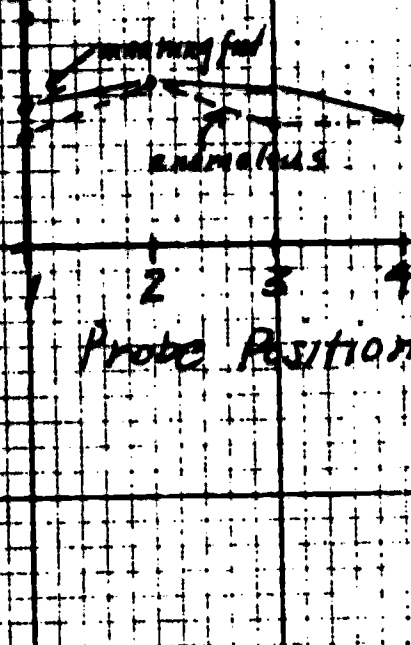


Figure 6

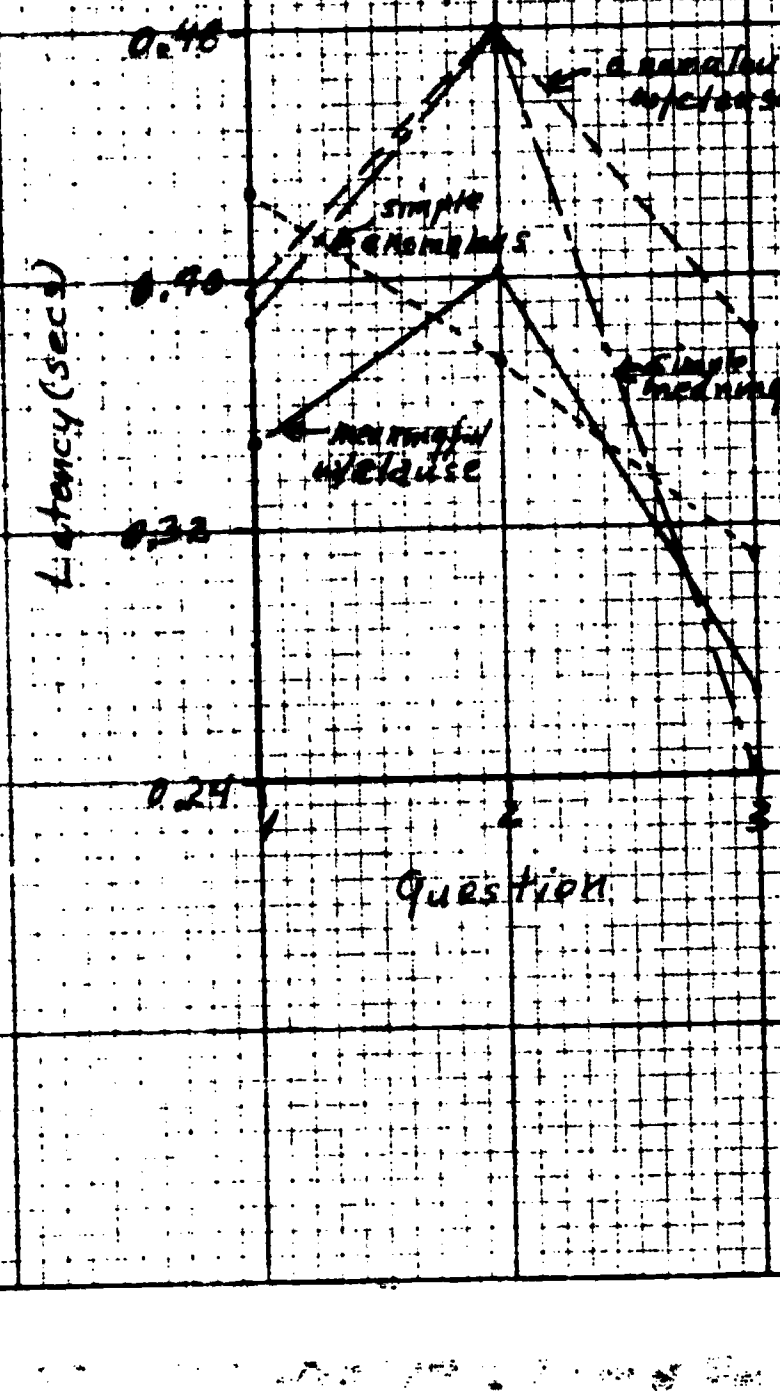


Figure 7

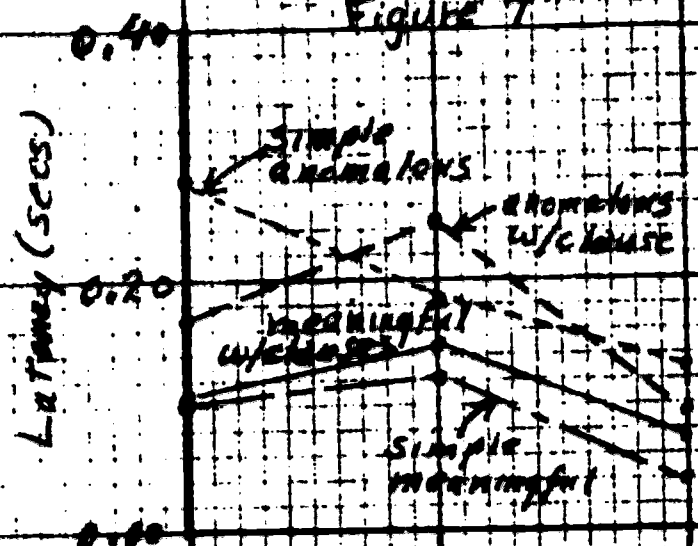


Figure 8

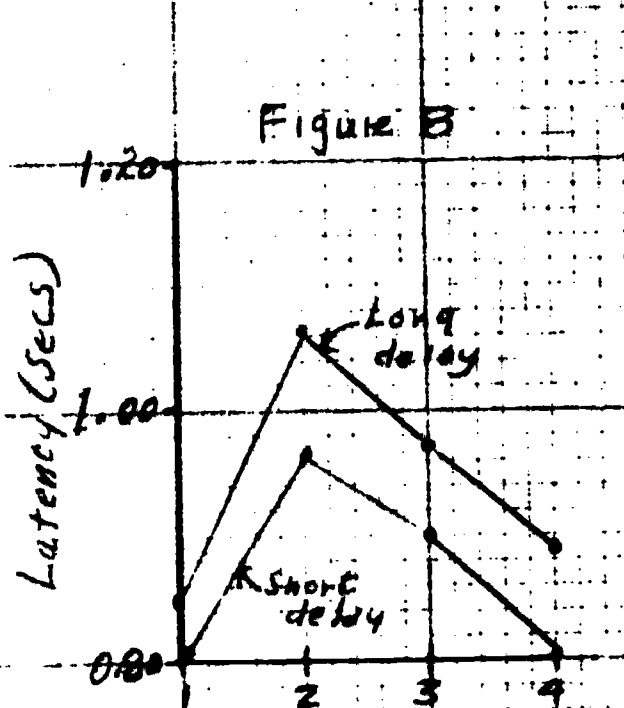
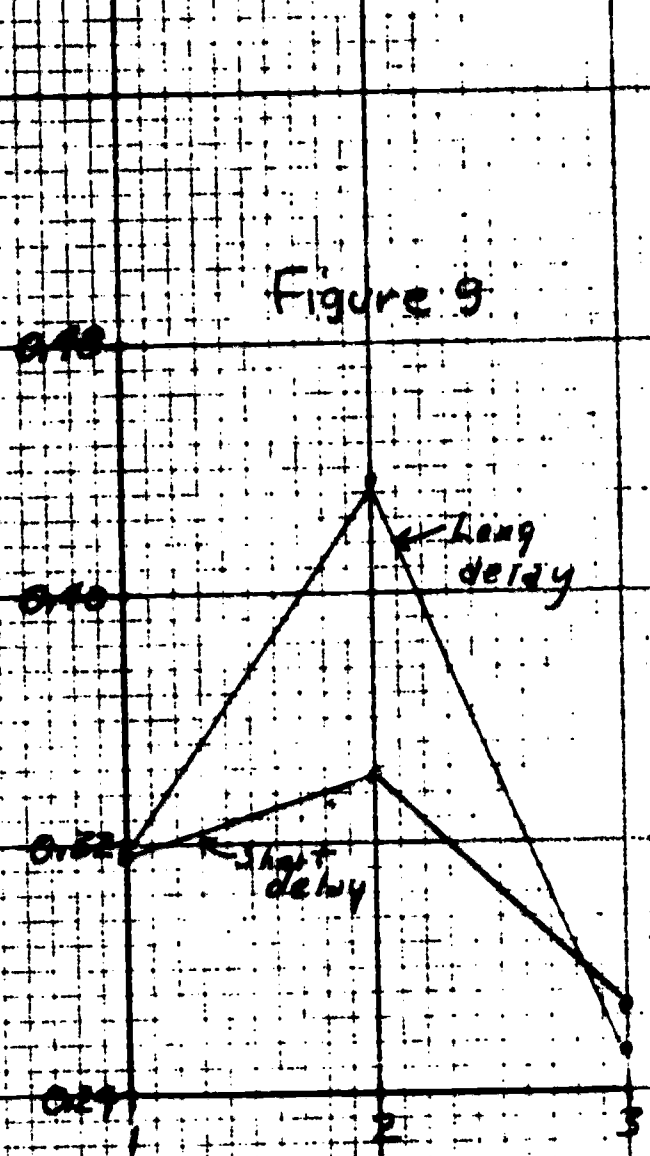


Figure 9



STUDY NO. 2

Table 1

Source	df	MS	F
p, probe	5	1178.57	15.49**
u, comprehension level	1	137.41	---
s:u, subject within level	30	251.52	---
pu	5	64.50	---
ps:u	150	76.08	---
Total	191		

Table 2

Source	df	MS	F
t, syntactic type	1	994.63	23.32**
q, question	2	1087.42	32.91**
u, comprehension level	1	327.13	2.61
s:u, subjects within level	30	104.73	---
tq	2	118.76	2.93
tu	1	115.63	2.71
ts:u	30	42.66	---
qu	2	10.38	---
qs:u	60	33.04	---
tqu	2	2.26	---
tqs:u	60	40.46	---
Total	191		

* $p < .05$

** $p < .01$

STUDY NO. 3

Table 3

Source	df	MS	F
m, meaningfulness	1	6.56	---
p, probe	3	8.01	---
s, subject	7	130.25	---
mp	3	3.45	---
ms	7	12.36	---
ps	21	18.56	---
mps	21	5.14	---
Total	63		

Table 4

Source	df	MS	F
m, meaningfulness	1	64.19	---
p, probe	5	160.58	4.42**
s, subject	7	193.05	---
mp	5	15.33	---
ma	7	124.30	---
ps	35	36.33	---
mps	35	28.83	---
Total	95		

Table 5

Source	df	MS	F
m, meaningfulness	1	23.01	1.46
q, question	2	91.53	10.82**
t, syntactic type	1	0.84	---
s, subjects	7	116.31	---
mq	2	15.49	1.20
mt	1	21.10	1.06
ms	7	15.79	---
qt	2	8.22	---
qs	14	8.46	---
ts	7	47.33	---
mqt	2	10.00	---
mqs	14	12.96	---
mts	7	19.97	---
qts	14	12.17	---
mqts	14	11.22	---
Total	95		

* $p < .05$

** $p < .01$

STUDY NO. 4

Table 6

Source	df	MS	F
q, question	2	92.82	8.53**
m, meaningfulness	1	248.66	17.91**
t, syntactic type	1	0.29	---
s, subjects	15	65.18	---
qm	2	10.13	1.08
qt	2	25.63	3.39*
qs	30	10.88	---
mt	1	19.06	1.91
ms	15	13.89	---
ts	15	7.96	---
qmt	2	19.04	1.85
qts	30	7.55	---
mts	15	9.98	---
qms	30	9.41	---
qmts	30	10.32	---
Total	191		

* $p < .05$

** $p < .01$

STUDY NO. 5

Table 7

Source	df	MS	F
t, syntactic type	1	107.86	3.54
p, probe	3	156.85	12.39**
s, subjects	15	81.66	---
tp	3	2.41	---
ts	15	30.44	---
ps	45	12.66	---
tps	45	8.45	---
Total	127		

Table 8

Source	df	MS	F
t, syntactic type	1	7.32	1.00
q, question	2	93.97	13.48**
s, subject	15	21.95	---
tq	2	20.64	5.40**
ts	15	6.91	---
qs	30	6.97	---
tqs	30	3.82	---
Total	95		

* $p < .05$
** $p < .01$

Relations Between Semantic and Syntactic Factors in the Structuring of Language*

George J. Suci

Cornell University

Abstract

Past research has developed the "probe-latency technique" for assessing the structure of linguistic inputs. Results to date indicate that the probe-latency structure is primarily a function of syntactic relations in the input and is relatively independent of semantic characteristics of the stimulus material. The "question technique", a second operational method, was developed as an approach to semantic processing. A study using both techniques is described in detail. The results of this study indicate that the question technique has promise as an approach to semantic processes. The study also gives further confirmation to the independence of semantic from syntactic processes.

* The author gratefully acknowledges the assistance of Peter Gamlin, Elaine Gruenfeld and Ann Savishinsky throughout this study. The research reported herein was performed pursuant to a contract with the United States Department of Health, Education, and Welfare, Office of Education.

In an attempt to approach empirically the processes involved in language comprehension it became apparent that it was necessary to develop techniques for assessing how a linguistic input is structured by the individual. The probe-latency technique was developed and seemed to validly assess at least some syntactic aspects of structure (Suci, G. J., Ammon, P. and Gamlin, P., 1967). In its simplest form the probe-latency technique refers to the following: The subject is presented, auditorily, with a linguistic input. This input is followed by one of the words in the input which is repeated as a stimulus. The subject is instructed to respond as quickly as possible with the work which followed the repeated work in the input. For example, the subject might hear: "The big bear climbs tall trees -- BEAR". The word "bear" is a stimulus to which the subject is to respond "climbs" as fast as he can. The response latency, onset to onset, is measured with an oscillograph recording made from a tape recording of the input and the response. It is assumed that this response latency is a direct function of the relationship between the two words. The probe-latency structure of an utterance is given by the shape of a probe position by latency curve. The obtained shape was an inverted V with the apex, i.e., the longest latency, at the phrase boundary.

When evaluated against syntactic criteria, the technique was found to separate noun and verb phrases and also appeared sensitive to structural variations within phrases. This was true for both children and adults.

In the same study of adults, an attempt to alter probe-latency structure by varying the meaningfulness of the input failed. Both

meaningful inputs and syntactically equivalent anomalous inputs (e.g., "The hard bird stops red ladies.") produced the same shaped curves, corresponding to syntactic structure. It seemed then that syntactic structures as indexed by the probe-latency method was independent of at least one semantic characteristic of the input, and that whatever semantic processing occurred was not made apparent by the technique. One aim of the present study was to assess the replicability of this finding 1) with children and 2) with one other semantic variable. The new variable was the comprehension ability of the subjects as measured by a standard comprehension test.

It is possible that the manner in which input is organized and comprehended is such that semantic processing is reflected by the probe-latency structure only under certain conditions -- conditions not invoked in the validating study and yet to be discovered. It is also of course possible that probe-latency structure will never reflect semantic processing -- that regardless of conditions, only syntactic relations will be reflected. Such independence between syntactic and semantic processing is proposed by Chomsky (1965, 1967). Probe-latency structure may correspond to Chomsky's "surface structure" and not to his "deep structure" which is presumably representative of some of the semantic aspects of grammar. If the probe-latency technique is indeed limited to syntactic structure and cannot validly tap semantic processes, then it is obviously necessary to seek still other techniques which might hold promise as operational approaches to semantic processing. It was the second aim of this study to test the validity of the "question technique", which seemed to hold some promise as an approach to semantic factors.

The finding that semantic and syntactic factors are independent could be put to test in still another way: If some means for altering probe-latency structure was found -- other than syntactic or semantic -- would semantic processing then be affected? To date, with a given syntactic word order, the probe-latency structure remained unaltered by semantic characteristics of the input. Given this constant word order, and holding semantic characteristics constant, first, could a means for altering probe-structure be found, and second, given the alteration, would semantic processing be affected? Early pilot work with adults (unpublished) had shown that reliable probe-latency structure changes could be quite readily induced by inserting a short pause at a given point in the input. Therefore pause, a non-semantic, non-word-order variation in the input, was adopted as a variable in this study. In addition to requiring a means for altering structure, this problem also required that techniques for assessing semantic processing be developed. The "question technique", if valid, could serve this purpose.

In developing the question technique as an approach to semantic processes it became necessary to formulate a rough conceptual framework of what semantic processing might be. This was done on the basis of several existing theoretical approaches, but the primary source for the framework used is Chomsky (1965, 1967).

The independence of syntactic and semantic processes has theoretical basis in several sources. Miller and Chomsky (1963) illustrate it with the two sentences "John is eager to please" and "John is easy to please," which are identical in surface structure but differ in meaning. This same distinction is made by Katz and Fodor (1963): "....the grammar provides identical structural descriptions for sentences that are different in meaning and different structural descriptions for sentences

that are identical in meaning" (where "grammar" includes phonological structure and syntactic structure but not semantic structure). But this independence between syntax and semantics is one-way: utterances which do not follow syntactic rules are not meaningful. For example, as Lenneberg (1967) illustrates: Of the two strings (1) colorless green ideas sleep furiously and (2) furiously sleep ideas green colorless, the first sounds more like a sentence. We may say that (1) is grammatical but (2) is not. It seems then that the independence is such that successful syntactic processing is necessary but not sufficient for successful semantic processing.

Since the probe-latency technique does not seem to respond to semantic factors, other techniques will need to be explored. A possible theoretical basis for an operational approach to semantics comes from Chomsky. To Chomsky (1965, 1967) meaning is represented in the "deep structures" which differ from the surface structures. The two types of structures are related by "transformations" -- rules for lawfully mapping one structure onto another structure. Chomsky believes that meaning, which is in the deep structure, is a function of the grammatical relations between the elements of the deep structure. This deep structure, like surface structure, represents a sentence which has parts, constituents, which are related to each other as "subject of" or as "direct object of", and so on. The meaning of the represented sentence is given by these relations.

Admittedly this is not all conceptually clear, but it is operationally suggestive. For the way in which a target sentence is understood may be indexed by the ability of a subject to transform the target sentence into other, syntactically and lexically different, sentences, each of which

represents a basic grammatical relation in the target sentence. This kind of transforming is necessary for the operation used in this study. This operation, "the question technique", is based on the assumption that the time it takes to recognize and respond to a question as a correct or incorrect transformation of a relation in a given target sentence is related to some aspects (unknown) of semantic processing. The question technique requires that immediately after the subject hears a target sentence (e.g., The sly hunter followed the black bear.) he hears a question concerning a relationship between major aspects of the sentence to which he must reply "yes" or "no" as quickly as he can. The question may, for example, be about an adjective-noun relation: "Was the bear black?"; or about the subject-verb-object relation: "Did the bear follow the hunter?". Each question represents a transformation, a different structure and word order, into a sentence which directly represents a grammatical relation.

Ammon (1967) first used questions to assess "listening skills" in children and adults. His technique differs in that the response required is a lexical item from the input -- e.g., the answer to "Who followed the bear?" -- rather than "yes" or "no". He had some success in differentiating between degrees of "confusability" which was a function, in part, of semantic relations in the stimulus input.

Miller (1962) reports a study in which the speed of a task involving recognition of transformations (not questions) is used. The task suggested here is operationally different and, also unlike Miller's, is directly concerned with the time required to process a single, immediate input, instead of the total time to process several transformations. The hypothesis of this study is that the latencies of the "yes" and "no" responses to these questions are related to the rapidity with which the input

is semantically processed: latencies should be greater for anomolous inputs and for subjects who are low in comprehension ability.

Method

Stimulus Material and Instruments. Throughout this study a seven-word sentence of the following syntactic type was used: article, adjective, noun, verb, article, adjective, noun. All material was tape-recorded. The sentences were in monotone at a rate of 150 words per minute. Each sentence was either meaningful (e.g., The sly hunter followed the black bear.) or anomalous (e.g., The happy scissors ate the soft monkey.), and each sentence either had no pause or pause approximately one-third second long between the first noun and the following verb.

One half of the sentences were used in the probe condition. Approximately one-third of a second following the end of the sentence one of the words in the sentence was repeated with intonation and with greater intensity. The subjects were instructed to respond as fast as possible with the word that followed in the sentence. The article "the" and the last noun in the sentence were not used as probes. Each of the other four positions was probed five times. Each sentence was probed only once; no subject heard the same sentence twice.

The other half of the sentences were used in the question condition, wherein each sentence was followed by a question about the relationships in the sentence between (a) the first adjective and noun (Was the hunter sly?); (b) the second adjective and noun (Was the bear black?); (c) the subject-verb-object (Did the bear follow the hunter?); (d) the subject-verb (Was the hunter followed?); (e) the verb and direct-object (Did the bear follow?). Each type of question appeared four times in the

question condition, twice when the correct answer was "no" and twice when it was "yes". The questions followed the sentence after approximately one-third second and were intoned in a normal manner. Subjects were instructed to answer "yes" or "no" as fast as possible. Each subject was given eight practice trials in the initial presentation of the question condition.

The Listening test, Form 4A, of the Sequential Tests of Educational Progress (STEP), developed by the Educational Testing Service (ETS), was used to separate subjects into two levels of comprehension ability. This test was "designed to measure a student's skill in understanding, interpreting, applying and evaluating what he listens to." The test is fully described by ETS. The tests were administered by teachers according to published instructions.

Design. The stimulus variables (meaningfulness and pause) and the subject variable were combined with probe position into a 2 x 2 x 2 x 4 design and with question condition into a 2 x 2 x 2 x 5 design. The stimulus sentences were divided into sets of 20. Each set represented a stimulus condition; question, probe, pause or non-pause, meaningful or anomalous. Each subject had all stimulus conditions presented in two sessions about one week apart. Within sessions sentences were either all meaningful or all anomalous. Within sessions the order of presentation used is represented by all permutations of probe and question with pause, non-pause conditions with the requirement that probe and question conditions alternate. This requirement was adopted to vary the task for the subject. The contents of the items were completely counterbalanced across subjects so that every sentence appeared in every condition.

Subjects. The entire fourth-grade of a local elementary school was tested with the STEP listening test. Using standard scoring, the population was divided into a high (above the 91st percentile) and low group (below the 82nd percentile). Eight boys and eight girls, a total of 16 were selected from each comprehension group. The average percentile rank for the high was 95.5 and 74.6 for the low. An attempt was made in the selection to equate the two groups on an intelligence test score supplied by the school records. The average IQ for the high group was 116.1 and 111.3 for the low group.

Procedure. The subject sat in front of a microphone into which he was instructed to speak. The stimulus material was presented from a speaker behind the subject. Each sentence was preceded by the word "ready" and was presented at a rate of one per 12 seconds. A rest period, long enough to change the tape, was given between conditions. Each condition was preceded by a warm up of eight sentences the first time and four the second. The procedure for the second session, a week later, was the same.

The responses were taped. The latencies were measured from probe word onset to response onset in the probe condition and from question ending to response onset in the question condition. An oscillographic record made at 25 mm per second from the tape was used to measure latency.

Analysis. For each subject the median latency of the five latencies at each probe position and of the four latencies for each question type was found. These median values were then entered into analyses of variance done separately for probe and question conditions.

It became apparent in the course of collecting data that two of the questions were probably producing artifactual results. The questions concerning the subject-verb (Did the hunter follow?) began in exactly the same way as the subject-verb-object question (Did the hunter follow the bear?). This kind of ambiguity was also present between the verb-object and the subject-verb-object questions when the correct answers were "no" (e.g., Did the bear follow? and Did the bear follow the hunter?). It was therefore decided to remove the subject-verb and the verb-object questions from the present analysis reducing the number of questions from five to three.

Results

Probe Conditions. The results for the probe conditions are summarized in Table 1. The probe-position main effect was highly significant ($p < .001$)

Table 1 about here

in all analyses. The latency probe position curves for all conditions were the typical inverted V-shaped curves as illustrated in Figure 1. This shape materialized for both the high and low comprehension groups and for both anomalous and meaningful inputs. The apex of the V-shaped curve, i.e., the highest latency, was at the phrase boundary between the first noun and the verb.

Figure 1 about here

A probe structure change or a difference in structure as a function of some variable would be indicated by an interaction of probe-position with the variable. Only the pause condition showed such an effect. The probe-position by pause interaction was significant ($p < .05$). As the

latency curves in Figure 1 show, with a pause in the input the latency was longer at the phrase boundary and shorter for two of the three points within the phrases; i.e., a pause separated syntactic units and tightened the relations within units.

No other structural differences were found. Neither meaningfulness of stimulus input nor comprehension level of subject interacted with probe position.

Question Condition. The results for the question conditions are summarized in Table 2. In every instance the question main effect was

Table 2 about here

highly significant ($p < .001$); i.e., the questions produced different latencies. The same pattern of differences between questions occurred whether the stimulus material was meaningful or anomalous, whether the subject was in the high - or low-comprehension group, or whether there was or was not a pause in the input. The pattern of question differences is illustrated in Figure 2. The question about the subject-predicate relation always had the fastest response, the question about the first noun-adjective, the second fastest and the question about the second noun-adjective always the slowest.

Figure 2 about here

The responses to the questions were faster with meaningful material than with anomalous material in every case ($p < .001$). This was the result expected assuming that the questions tap meaning. However, the comprehension level of the subject did not produce the expected latency difference ($p > .05$). Inspection of the results indicated that under non-pause conditions and with meaningful material the high comprehension subjects were faster than the lows; but under non-pause conditions the

highs were slower with anomalous material. This interaction disappeared when the pause material was analyzed alone. With pause there was no difference in performance of the high- and low-comprehension groups. The interaction between pause, meaningfulness of input and comprehension level of subjects fell just short of significance (obtained $F = 4.03$ with $F = 4.17$ required for significance at $p < .05$).

Discussion

The results of this study indicate the following: (1) The semantic factors failed to alter probe-latency structure; therefore, the earlier finding that syntactic and semantic factors are independent may be generalized to a different subject population and to another measure of semantic processing. By the fourth-grade, syntax appears as a very powerful organizing factor in language processing, but the ability to comprehend language may be independent of this organizing factor. In light of the narrowness of the conditions this must remain a tentative notion only, but the results seem to support the hypothesis that although syntactic organization may be necessary condition, it is not sufficient for successful semantic processing.

(2) Although semantic factors seemingly do not affect probe-latency structure, pause, a non-semantic factor, does. The pause effect was as expected: it separated phrase units, but tightened word units within phrases. Thus it seems possible to vary the degrees of structure imposed on a lexically fixed input. Pause in normal speech may be a syntactic feature, but it seems clear that it is independent of any lexical content and therefore it becomes a very useful device for inducing structural change without affecting constituent structure. The pause effect on structure was equivalent under all conditions of semantic variation; i.e.,

the pause conditions did not interact with the semantic variables.

But, given that the probe-latency structure imposed on an input was successfully altered, did this change have any effect on the semantic processing of this input? To evaluate any such effect we must first consider the validity of the question technique as an assessment of semantic processing.

(3) To test the validity of the question technique, latencies of responses to questions were related to the meaningfulness of the stimulus material and to the comprehension level of the subject. It was expected that anomalies would produce longer latencies. This expectation was borne out. It was also expected that the low-comprehension group would show longer latencies regardless of the meaningfulness of the stimulus input. With the meaningful material the high comprehension group did better than the low comprehension group; with the anomalous material the low group did better. However, neither of these results was statistically reliable. After the fact, it does seem feasible that if, in processing linguistic inputs the high-comprehension subjects depend on semantic relations, the lack of such a relation in the anomalies would interfere and slow down processing. The low-comprehension subjects, on the other hand, may simply depend less on semantic factors for both kinds of stimulus inputs and therefore do about equally well with each. Such a post facto explanation limits the certainty with which we can accept the validity of the questions as an operational tap of semantic processing. But the question technique seems to hold promise as an approach to some aspects of semantic processing and therefore deserves further attention.

(4) Returning now to the effect on question response latencies of pause-induced change in structure, we must conclude that the results are

not clear. Both the high and the low comprehension groups show greater structure with pause in the input, but the associated change in semantic processing, as measured by the question technique, differs for the two groups. Under pause conditions the low group improves in its performance with meaningful input and the high group improves in its performance with the anomalous input.

A possible explanation is this: The high comprehension children already have at their disposal efficient means for semantically processing meaningful inputs. Any amount of increased structuring will not induce further improvement. This is not so with anomalous inputs which, because they violate semantic rules, interfere with processing and depress performance. Under these conditions there is room for any improvement which the structural effect might contribute.

The low comprehension subjects, on the other hand, have an inadequate semantic processing system equally inadequate with meaningful and anomalous inputs. With meaningful inputs there is certainly room for improvement and the increase in structure can have its effect. With anomalies, since the semantic processing system for the low group is already deficient there is only a minimum interference effect from violation of semantic rules. The low group is doing about as well as it can with this kind of input and an increase in structure cannot be facilitative.

(5) There are at least two unanticipated findings which would be mentioned. One is the pattern of differences between the latencies of the responses to the three questions as indicated in Figure 2. Should the questions prove to be valid as indices of semantic processes, the pattern of differences between questions would seem potentially helpful as an approach to the sequence of steps involved in processing input for meaning. For

example, the faster response to questions about the first noun-adjective indicate a left-to-right processing of phrase units.

The second is that there are very large individual differences in response latencies, on both probe and question tasks, among children. These differences increased the error terms in the analyses of variance and probably attenuated the significance level of some of the obtained differences. This is a serious problem on two counts. First it probably shadows real differences and second it prevents proper statistical analyses of data which include both adults and children. Adults, although they too exhibit a great deal of variance, are considerably more homogeneous. The resulting lack of homogeneity of variance makes comparisons between age groups tenuous.

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Tables

Table 1. Analysis of variance for probe-structure conditions.

Table 2. Analysis of variance for question-types.

Source	df	Error Term	Variance Estimate	F
m - meaningfulness	1	ms:u	1220.14	11.49**
u - comprehension level	1	s:u	32.96	---
q - question types	2	qs:u	2251 89	33.60**
p - pause	1	ps:u	115.39	1.44
s:u - subjects	30	-----	368.05	---
mq	2	mqs:u	59.33	1.13
mu	1	ms:u	293.13	2.76
mp	1	mps:u	4.50	---
ms:u	30	-----	106.11	---
qu	2	qs:u	5.28	---
qp	2	qps:u	134.09	---
qs:u	60	-----	67.01	---
up	1	ps:u	.62	---
ps:u	30	-----	79.87	---
mqu	2	mqs:u	24.89	---
mqp	2	mqps:u	50.88	---
mqs:u	60	-----	52.40	---
mup	1	mps:u	272.53	4.02*
mps:u	30	-----	67.70	---
qup	2	qps:u	13.80	---
qps:u	60	-----	540.63	---
mqup	2	mqps:u	20.76	---
mqps:u	60	-----	61.31	---
	Total: 383			

*p < 0.05

**p < 0.01

Source	df	Error Term	Variance Estimate	F
m - meaningfulness	1	ms:u	563.22	5.38*
pr - probe	3	(pr)s:u	3133.55	40.15**
u - comprehension level	1	s:u	101.53	---
pa - pause	1	(pa)s:u	14.45	---
s:u - subjects	30	-----	251.25	---
m(pr)	3	m(pr)s:u	30.10	---
mu	1	ms:u	44.54	---
m(pa)	1	m(pa)s:u	0.10	---
ms:u	30	-----	104.59	---
(pr)u	3	(pr)s:u	66.68	---
(pr)(pa)	3	(pr)(pa)s:u	72.68	3.71*
(pr)s:u	90	-----	78.04	---
u(pa)	1	(pa)s:u	0.01	---
(pa)s:u	30	-----	52.29	---
m(pr)u	3	m(pr)(pa)s:u	6.28	---
m(pr)(pa)	3	m(pr)(pa)s:u	25.86	1.54
m(pr)s:u	90	-----	34.22	---
mu(pa)	1	m(pr)(pa)s:u	16.80	---
m(pa)s:u	30	-----	56.75	---
(pr)u(pa)	3	(pr)(pa)s:u	13.90	---
(pr)(pa)s:u	90	-----	19.56	---
m(pr)(pa)u	3	m(pr)(pa)s:u	22.68	1.35
m(pr)(pa)s:u	90	-----	16.83	---
Total:	511			

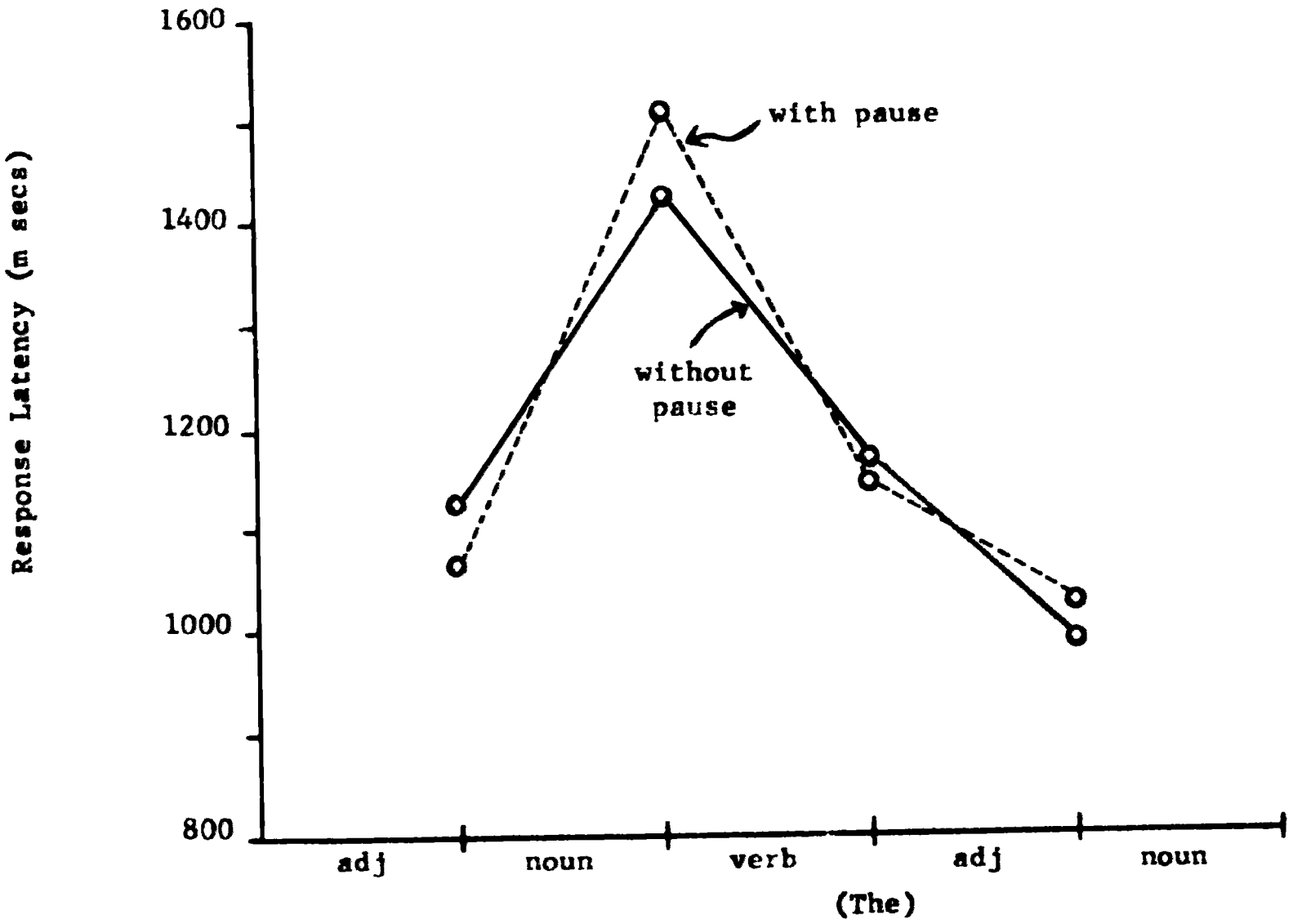
*p< 0.05

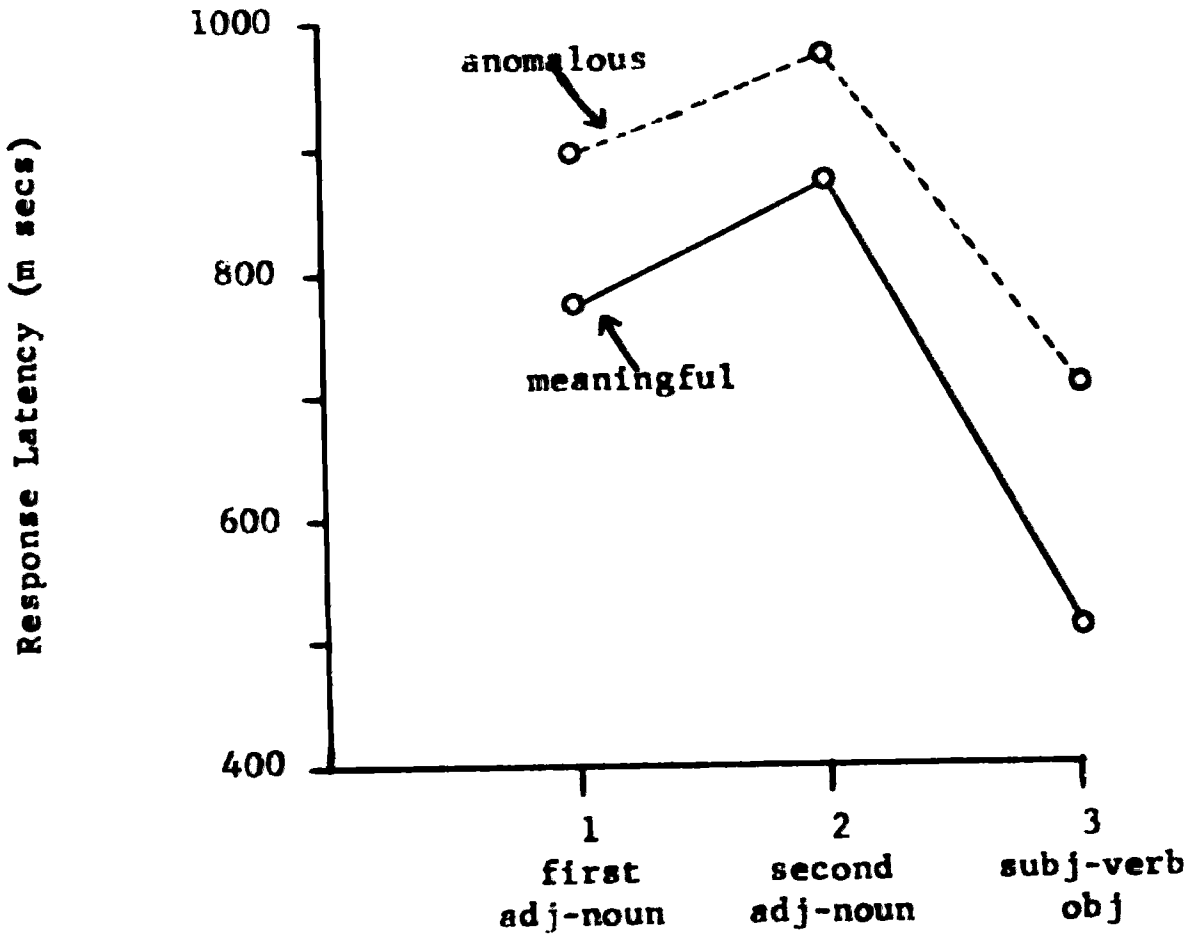
**p< 0.01

Figures

Figure 1. Probe-latency structure under two conditions with a pause and without a pause at the phrase boundary.

Figure 2. Response latency of answers to questions about grammatical relations in the input.


1600
1400
1200
1000
800
Response Latency (m secs)
with pause
without pause
adj
noun
verb
adj
noun
(The)
Probe Position


Response Latency (m secs)
1000
800
600
400
anomalous
meaningful
1
first
adj-noun
2
second
adj-noun
3
subj-verb
obj

Summary of Final Report

Project Number: OEC-1-7-078093-2711

Project Title: A Further Test of the Utility of a Technique for Assessing Structure of Language in Children and Adults.

Project Director: George J. Suci
Associate Professor
Cornell University

This is a report of six experiments concerned with the assessment of syntactic and semantic processing of auditory, linguistic inputs. The experiments centered around two techniques, the probe-latency technique developed prior to the contract period, and the question technique developed early in the contract period. The probe-latency technique is as follows: the subject hears a stimulus sentence followed by a repetition of one of the words, the probe word, in the same sentence. The subject's task is to respond as rapidly as possible with the word that follows the probe. It was found that the probe by latency curves, using every word except the last as a probe, corresponded to syntactic structure. In the following studies this technique was used to assess structure.

STUDY NO. 1

The question technique, for assessing semantic processing factors, was developed and some evidence for its validity was found. The subject answers one of three questions about some relationship given by the sentence. The latencies of his answers were measured and were found to be related to the meaningfulness of stimulus sentences as predicted if the questions validly assess semantic processing.

An earlier finding with adults that syntactic structure (probe-latency structure) and semantic factors were independent was replicated with fourth grade children.

It was found that a brief pause at the phrase boundary of an input sentence can significantly alter its structure and affect how well the sentence is comprehended, as comprehension is measured by the question technique.

STUDY NO. 2

In this study it was asked whether a syntactic factor, independently of semantic content, has impact on how a sentence is semantically processed. It was found that at least one syntactic factor did facilitate the semantic processing of a sentence. Insertion of an adjective clause in a simple sentence facilitated responses to all three questions about the modified sentence compared to the simple sentence.

STUDY NO. 3

This was a pilot study aimed at testing the question procedure and some of the results of the other two studies with adults. Eight adults were used primarily to learn if the questions showed the same validity as with children. The validity test failed. This was a serious negative finding and the study was repeated with more subjects.

STUDY NO. 4

This was a repetition of the above with 16 subjects. The results clearly supported the validity of the question technique as an assessment of semantic processing factors. It was also found that the pattern of question latencies for one type of sentence was different from one which had consistently been found

with children. This indicated that possibly adults and children process sentences differently and led to the development of a simple processing model. The model implicated the role of short-term memory in processing and the remaining two studies aimed at some memory factors.

STUDY NO. 5

In this study the time delay between input and task stimulus (e.g., between sentence end and probe word) was varied from one-third second to one second. Differential impact of these delays was expected on the probe and the question latencies, and on the latencies for the different questions. The results were completely negative to the predictions which had been made. Of most relevance here is the finding that the latencies to the question about the later portion of a sentence became longer with a longer time delay. The opposite had been predicted.

STUDY NO. 6

This was a repeat of Study No. 5 with one new variable added in. The complete analysis of data for this study could not be completed in time for this report. Preliminary analysis of the question task indicates that the above negative result was replicated--that is, that the responses to questions about later portions of the sentence slow down with a longer time delay between input and task stimulus. In addition, the analysis to date indicates that anomalous sentences (syntactically intact but less meaningful sentences) are processed differently under the two time delay conditions and differently from meaningful sentences. This would indicate that the question technique is possibly responsive to semantic factors--i.e., it gives further support to the validity of the technique.

FUTURE WORK

The question technique will be further developed and its operational implications for semantic processing and for the role of memory in processing will be further explored.