# PROBE TESTS AND SENTENCE PERCEPTION

by

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## Abstract

This dissertation presents the results of several studies about the perception of sentences. Chapter 1 deals with the theoretical framework within which these studies have been undertaken. It reviews the notions of competence and performance and discusses several models relating grammars to sentence perception. It is argued that the most important task in this area is the enunciation and motivation of a set of heuristics which accomplish at least the preliminary analysis of sentences. A plausible set of heuristics is outlined. Chapter 2 reviews the experimental literature which supports the adoption of these heuristics. A model of psychological operations consistent with the results in the literature is presented. The probe task is introduced.

Chapters 3, 4 and 5 report the results of experiments which utilize the probe task. Chapter 3 presents evidence which supports the hypothesis that words in the final clause of a complex sentence have stronger traces in perceptual storage than words before the final clause. Chapter 4 argues that ambiguous nouns are more available (as measured by recognition latencies) than unambiguous nouns during the clause in which they appear, but not after that clause is completed. The work reported in these two Chapters argues that the processing of sentences is accomplished on a clause-by-clause basis; that is, that clauses are the units which are moved from one perceptual buffer to another for different types of processing and within which decisions about ambiguities are made. Chapter 5 utilizes the representation of the acoustic parameters of the incoming sentence in perceptual storages to investigate the traces of nouns and verbs in buffers. The results, though somewhat equivocal, tend to support the view that verbs have stronger acoustic traces than nouns, which is consistent with the hypothesis that the assignment of grammatical relations is largely accomplished on the basis of the subcategorization features of the verbs of a sentence. The results, as a whole, support the heuristics presented in Chapter 1 and 2.

The experimental work documents an area in which the form of the grammar does not easily make for predictions about sentence processing. This highlights the need for continued work in order to relate the systems of knowledge and use of language.

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# CHAPTER 1

## THE ROLE OF A GRAMMAR IN SENTENCE PERCEPTION

A generative grammar is "a system of rules that in some explicit, well-defined way assigns structural descriptions to sentences." (Chomsky, 1965.) According to Chomsky, such a system constitutes speaker-hearer's "linguistic competence:"

> Linguistic theory is concerned primarily with an ideal speaker-listener in a completely homogeneous speech community who knows its language perfectly and is unaffected by such grammatically irrelevant conditions as memory limitations, distractions, shifts of attention and interest and errors (random or characteristic) in applying his knowledge of the language in actual performance. (p. 4)

Thus, current linguistic theory takes as its domain the description of the formal linguistic structure which makes up the user's knowledge of his language. The problems of so-called "linguistic performance" have been largely avoided. However, if a grammar represents psychological processes underlying some form of the use of ordinary language, then competence must be related to performance.

In speaking a user of a language attempts to produce sound patterns on the basis of intended meanings, and in understanding he presumably seeks to accomplish the inverse of this process. Since the grammar specifies a set of operations relating sound and meaning it becomes an attractive candidate for a theory of production and perception. Moreover, since certain formal aspects of grammatical descriptions appear to represent universal and profound generalizations about the systems relating sound and meaning, a generative grammar

appeals as a theory of innate strictures on the nature of human languages. Consequently, one is tempted to say that knowledge of the form of generative grammars helps to limit the class of hypotheses that a child entertains about the structure of the language which he hears in his infancy and eventually masters. In both the area of production and perception and the area of language acquisition, therefore, it is tempting to say that a grammar, in addition to being a theory of competence, is systematically related to -- or may be a part of -- a theory of performance.

However, without further consideration such a move remains unfounded. A theory of linguistic performance must describe and explain a set of facts which overlaps with but is not exhausted by those in the range of a theory of competence. That syntactic regularities fall inside the explanatory framework of a particular grammar does not add to the credibility of the grammar as a total theory of psychological operations underlying language acquisition and use. Grammatical evidence is not the same as evidence bearing on the process of computing the structures that grammars produce. Support for a grammar can only reinforce the attractiveness of the grammar as the basis for the construction of such psychological theories. These psychological theories do not take as sole evidence that one sentence is related to another in a way which explains the relationship of a third to a fourth or which predicts the non-existence of a fifth. They also take as data one's ability to produce, perceive and remember sentences -- demonstrated formally in the laboratory or informally in the everyday

use of language.[1] The ways in which a grammar may relate to sentence perception will be discussed in this chapter. The question of the relationship of a grammar to language acquisition and to ordinary production of sentences will be left untouched.[2]

The first explicit device for speech recognition based on generative grammar was the analysis-by-synthesis model (Halle and Stevens, 1964). According to this model, a set of heuristics (H1) provided a preliminary analysis of an incoming sentence which was matched for goodness of fit against internally generated signals. The internal signals were generated on the basis of a transformational grammar. Thus, analysis-by-synthesis postulated a very direct relationship between a grammar and a speech recognition device: the former was an integral part of the latter. If the signal generated internally by the grammar matched the preliminary analysis of the incoming sentence within a certain tolerance level, the sentence was "decoded"; if the match was imperfect a second set of heuristics (H2) utilized the error message so obtained to direct further internal syntheses until a match was made.

One question raised by this model is that of determining what the effect of the application of grammatical rules in the internal generation of sentences is upon the perceptual complexity of sentences. Leaving aside the question of the second set of heuristics (H2) about which nothing is known -- that is, making the simplifying assumption that the internal generator always gets the correct sentence the first time -- how do we measure the contribution of the application of

grammatical rules to perceptual complexity of sentences.

The most obvious possibility is that each operation of the grammar adds to the complexity of a sentence. The simplicity metric used in evaluation of grammars is carried over wholesale to the evaluation of perception of sentences. This view has appropriately been termed a "derivational theory of complexity" -- DTC. Fodor and Garrett (1967) make this position precise in the following way:

> DTC can be made explicit in the following way. Consider a generative grammar G of the language L and a sentence S in the range of G. It is possible, in principle, to define a metric which for every pair ($G_i$, $S_i$) specifies the number $N_i$ of rules (or elementary operations, or whatever) $G_i$ requires to generate $S_i$. DTC in its strongest form is the claim that the size of $N_i$ is an index of the complexity of $S_i$. In particular, two sentences assigned the same number are equally complex, and, of two sentences assigned different numbers, the larger number is assigned to the more complex sentence. (p. 289)

DTC predicts that sentential complexity should be proportional to the number of rules in the grammatical derivation of a sentence. It received a great deal of support from experimental studies proporting to show that the complexity of a kernel sentence increased incrementally with the application of each optional singulary transformation (Miller 1962, and references cited there.) However, later work showed that these results were confounded with other variables such as sentence length and semantic content. (Fodor and Garrett, 1966)

Moreover, there are numerous counter-examples to DTC. For instance, it has been demonstrated that particle-movement (the rule forming (2) from (1))

1) John phones up the girl.

2) John phones the girl up.

does not increase the perceptual complexity of sentences such as (2). (Fodor and Garrett, 1967). In another case it was discovered that center-embedded relatives are no more difficult when they contain adjectives than when they do not; that is, (3) is not more difficult than (4):

3) The first shot that the tired soldier the mosquito bit fired missed.

4) The shot that the soldier the mosquito bit fired missed.

In fact, on a paraphrase task in which both the number of subject-object relations correctly retrieved and the time interval in which they were retrieved were measured, sentences such as (3) were better than sentences such as (4) (Ibid.). Yet the number of operations involved in the grammatical derivation of (3) must be greater than that in the derivation of (4).[3] These experiments provided evidence that not all transformational operations add to the perceptual complexity of sentences. Fodor and Garrett (1967) suggest that:

> The complexity of a single sentence is a function not (or not only) of the transformational distance from its base structure to its surface but also of the degree to which the arrangement of the elements in the surface structure provides clues to the relations of elements in the deep structure. To a certain extent this hypothesis about complexity and DTC yield convergent experimental predictions. This is because increasing the distance from the base to surface structure tends, on the whole, to obliterate surface structure clues to deep structure. . . . . in sofar as increasing the number of

> transformations tends to increase complexity, we suggest that this is not because of increased transformational distance between base and surface structure per se, but rather because of the consequent obliteration of the surface structure clues upon which the reconstruction of deep structure depends. (p. 290)

However, analysis-by-synthesis does not necessarily imply DTC. The rules of the grammar may operate in sentence perception in a way that their form and organization are maintained, but the perceptual complexity of a sentence may not increase by an equal increment with the application of each rule in its derivation. The metric assigning perceptual complexity may accord more "weight" to certain rules than to others (thereby differing from the metric assigning grammatical complexity.) It may even be the case that the application of certain rules diminishes perceptual complexity according to the former metric. Of course, such a taxonomy of rules must be justified on independent grounds or the position is vacuous. Taxonomies of rules do, in fact, exist (cyclic and non-cyclic; obligatory and optional; chopping and copying; root, structure-preserving, and minor movement) but their relationship to perceptual complexity has not been explored. If an alternative perceptual metric can be devised, DTC will not hold although the derivational history of a sentence will still be a part of the information utilized in sentence perception, and analysis-by-synthesis can be maintained.

The second general problem posed by the analysis-by-synthesis model is in some ways more fundamental. For the model to operate in real time, the preliminary analysis must greatly restrict the class of

sentences internally generated by the grammar. Katz and Postal (1964) estimate that if the preliminary analysis simply calculated the number of words in the incoming sentence, thereby restricting the internal generator to produce sentences containing only so many words, the model would take years to compute even moderately simple sentences. Consequently the preliminary analysis must provide rather direct clues to the structures possibly instantiated in the incoming sentence. The problem is that, beyond being able to say this, there is literally no knowledge of what the necessary and sufficient conditions on the output of the preliminary analysis are which will adequately restrict the internal generator to enable the entire model to work in real time. That is to say that there is no knowledge about what the heurististics H1 must accomplish. It therefore follows that there is no knowledge currently available about what the internally generated signal matches; what the error messages look like, or what the set of heuristics H2 is.

Although nothing is known about what the heuristics H1 must logically accomplish, there are some tentative suggestions about what these heuristics do in fact accomplish. The heuristics are a set of operations, non-isomorphic to a grammar, which, in the realm of syntax, assign certain aspects of structural descriptions to an incoming sentence so that the "search space" of the grammar in generating internal signals is limited. Clearly, the more structure is assigned by the heuristics, the less need there is for internal generation of signals to be matched with the incoming sentence. In the extreme case, the heuristics will themselves be entirely

capable of assigning whatever syntactic structure is necessary for the determination of a semantic reading, and role of a grammar in generating internal signals rendered unnecessary. This is the position taken by many researchers in the field. Let us state as explicitly as possible what this position entails. It assumes that it is possible to construct a set of heuristics which has the same pairings of sound and meaning as a grammar but is not isomorphic to a grammar and which can operate on an incoming sentence to produce a semantic reading. Within this position, there are two further distinct possibilities: 1) the heuristics H1 may be completely unrelated to both the operations and structures specified by a grammer, the "radical heuristic approach"; 2) the heuristics H1 may capitalize on information provided by certain aspects of a grammar but utilize this information in a way which is not isomorphic to the operations of the grammar, "the conservative heuristic approach". The first is presented by Terry Langendoen; the second by Jerry Fodor and Merrill Garrett. Tom Bever appears to subscribe to certain aspects of both approaches.

Langendoen (1970), distinguishes three modes of linguistic performance: sentence perception, sentence production, and the prediction of acceptability and grammaticality. He contends that:

> Different tasks activate different aspects of linguistic competence. A speaker makes use of a mapping from a cognitive structure (what he wants to say) to phonetic structure -- what we called "strategies of production" and about which we could say nothing of interest; a hearer makes use of a mapping from phonetic structure (what he hears) to cognitive structure -- what we called "strategies of

> perception" and about which we had a few remarks to make. Finally, if a person is set the task of predicting or judging whether a novel, arbitrary utterance belongs to the language he knows, and what the properties of that utterance are, then he makes use of "strategies of prediction", which do involve the rules of grammar as a linguistic would describe them. Thus Noam Chomsky's oft-repeated claim that generative grammar is neutral with respect to being a model for speaker or hearer is correct because the grammar is in fact irrelevant to those tasks.
>
> /The/ discoveries that a generative grammarian makes about language on the basis of the usual techniques of sentence-comparison and introspection are psychologically real only to the extent to which people actually make use of such processes in similar tasks. We deny that the rules and universals so discovered necessarily have anything to do with the more mundane but more essential tasks of speaking coherently and understanding coherent speech. (p. 1)

In fact, in Langendoen's view, the universals of linguistic structure can all be explained by facts about perception and production:

> We do not have any reason to believe in any universals which can not be explained on external grounds; that is, universals whose justification is based solely on the form of grammars of known languages. At least we have good reason to skeptical of such universals. (p. 2)

Langendoen's position is the most conservative for a psychologist seeking to minimize the number of structures and constructs in his theory, but the most radical in that it considers "non-functional" the generalizations of the linguist. He contends that the operations of the grammar are relevant only to the psychological tasks involved in writing grammars and to no others. In fact he maintains that performance tasks such as production and perception utilize principles which constrain possible grammatical structures and that some of these

constraints have been mistaken for formal constraints imposed by the grammar itself.

If Langendoen is correct about the relationship of a grammar to the tasks of perception and production then he has in effect totally eliminated the need to relate grammars and the psychological mechanisms involved in any type of linguistic performance. The area in which he believes the grammar may underlie performance is the prediction of grammaticality but even this relation is unnecessary. A device for perceiving sentences (which he claims is independent from a grammar) can recognize abnormal sentences, if only because it cannot assign structures and meanings to them. This sentence perception device can make judgements of grammaticality and acceptability by comparing structure in abnormal sentences with structure in sentences which it handles normally. Therefore, the operations specified by generative grammars need not underlie any psychological processes.

The logical place to start a consideration of this position is with a theory of sentence perception which Langendoen probably accepts. Langendoen does not explicitly describe the general properties of the model of perception that he has adopted and therefore it is necessary to generalize from the examples he gives.

In Langendoen's view, certain aspects of surface structures are to be recognized as directly specifying meaning (or perhaps underlying structures relating to meaning). Consider as an example the "explanation" which Langendoen gives of the universals relating to WH word movement (Cf. Joan Bresnan, Foundation of Language 1970).

These universal constraints on the movement of WH words are reported by Langendoen as being:

> (1) That the movement of WH words is always to the beginning of a clause, never to the end or to some other distinguished position, and (2) that it is unbounded. (p. 2)

Langendoen suggests that a "functional explanation that will go deeper than the formal one" may be found in the notion of "the theme" CF. Halliday, Foundations of Language, 1970). The theme as defined by Halliday is "the point of departure -- the take off point of a clause." Langendoen says:

> This definition of theme makes it seem to be an element of "strategies of production" . . . .it is apparent that both interrogative and relative pronouns are themes, probably necessarily so, so that these forms too should occupy first position in the clause. But from this it follows that the rules of grammar that move them to that position should have the properties they do. (p. 3)

This analysis fails, on linguistic grounds, when one considers that first position in the clause is not necessarily occupied by "the theme". Cleft and pseudo-cleft sentences, as well as those with contrastive stress on items not in initial position, are obvious counter-examples. Moreover, there are languages in which WH-words are not moved. Are we to conclude that WH-words are not "themes" in those languages? Finally, and of paramount importance, what psychological principle explains the fact, were it true, that the theme comes in clause-initial position? Recall of words in sentences is better in initial and terminal positions than in the middle; one might as easily expect

themes to come last as first. Langendoen's "functional explanation" is simply a restatement of the facts, and has no explanatory value.

The notion of perceptual strategies which are independent of the operations of a grammar is reasonably clear, despite the short-comings of Langendoen's examples. Tom Bever (1969) has also described perceptual strategies which segment and analyze sentences to yield syntactic structures (or semantic structures) and has claimed that these strategies have no connection with the operations of a grammar:

> . . . speech behavior can also be described in terms of three aspects: basic capacities, behavioral inductions, and epistemological systems. Of course, in adult speech behavior these three systems are ordinarily merged together; presence of behavioral strategies is brought out in experimental conditions. . .; our primitive linguistic capacity (e.g. for reference) is directly revealed in our speech production; while the structural intuitions related to linguistic analysis appear only in our conscious epistemological considerations of sentences. . . (p. 42)

> . . . a proper understanding of the behavioral and phenomenological nature of "basic linguistic intuitions" forces us to reject as obvious the claim that a linguistic grammar is in any psychological sense internal to such linguistic performances as talking and listening. . . First, certain "linguistic" intuitions about the relative acceptability of sequences may themselves be functions of one of the systems of speech behavior (e.g., perception) rather than of the system of structurally relevant intuitions. Second, the behavior of producing linguistically relevant intuitions may produce some properties which are <u>sui generis</u> and which appear in no other kind of language behavior. . . Thus the formal description of a language using transformations depends on a form of intuitions which

> is irrelevant to most on-going speech behavior but which emphasizes transformational relations between sentences /emphasis Bever's/. On this interpretation it is no wonder that transformations appear in grammars but not in other speech behaviors. (pp. 105-107)

Bever gives four examples of such strategies:

(a) Segment together any sequence X. . .Y of which the members could be related by primary internal structural relations "actor. . .action. . .object . . .modifier" (p. 20)

(b) The first N. . .V. . .(N). . .clause (isolated by strategy a) is the main clause unless the verb is marked as subordinate. (p. 27)

(c) Constituents are functionally related internally according to semantic constraints. (p. 30)

(d) Any noun, verb, noun (NVN) sequence within a potential internal unit structure corresponds to "actor, action, object" (p. 34)

Bever presents a range of experimental and anecdotal evidence that such strategies operate in normal sentence perception. Some of his most striking evidence is anecdotal as he produces perfectly grammatical sentences which one tends to dismiss as incorrect because their analysis violates one or more of these strategies. Consider:

(5) The boat floated down the river sank.

In sentence (5), floated down the river is in fact a reduced relative clause modifying the subject boat, but one's immediate tendency is to take the boat floated down the river as a complete sentence. The "left over" item forces a re-analysis (or sometimes forces the hearer to dismiss the sentence as ungrammatical).

Although perceptual strategies such as the ones outlined by Bever exist, there are still serious problems with this approach to

sentence perception. In the first place, strategies (a) to (d) are certainly language specific and will not account for the general phenomenon of sentence decoding in all languages. They do not form a basis for the construction of a universal theory of sentence decoding. While such a theory is obviously impossible to construct now, it is possible to entertain theories of sentence decoding which could in principle be applied to all languages. Secondly, these types of strategies do not account for all the grammatical sentences of a language. They relate only to determination of subject-verb-complement relations within clauses. Sentences containing verbs with sentential complements, for example, cannot be analyzed completely by these strategies because (a)-(d) cannot establish relationships between clauses. Even in the area of assignment of grammatical relations, (a) - (d) are insufficient. Note that although the difficulty of (5) argues for their existence, the grammaticality of (5) shows that (a)-(d) are inadequate in dealing with every well-formed sentence in the language.

The position that sentence perception is unrelated to a grammar is in my view a curious and impoverished approach to sentence decoding. As expressed by Langendoen and Bever the model is almost probabilistic. The frequency distribution of words and the transitional frequencies between words play important roles -- not very far removed from the Markovian theories which are criticized by Chomsky, (1964), Miller and Chomsky (1963) and Fodor, Garrett and Bever himself (in preparation). There is, of course, a significant difference between

the views which I have just outlined and the views of writers in the Hullean tradition and Skinner. The people working within the general framework of stimulus-response psychology had no notion of deep structure, whereas Bever and Langendoen are obviously aware of the existence of another level beyond the surface ordering of syntactic elements. They have structured their strategies so as to relate a surface order of items to an underlying order which, if not deep structure in the sense of Chomsky (1965), is similar to deep structure. On the other hand, the similarity between the probabilistic versions of sentence processing models in the stimulus-response framework and the models that are posited in the works of Bever and Langendoen is strikingly exemplified in the following quotation (Bever, 1969):

> In the actual application of language, specific context must provide far stronger immediate constraints and basis for prediction of the most likely meaning of a sentence independent of its form. Thus, most normal perceptual processing of sentences is probably carried out with little regard to actual sequence or structure; rather the basic related functions (actor, action, object, modifier) are assigned on the basis of temporary ("contingent") and generic ("constant") semantic probabilities. (p. 33)

There is certainly much to be said for the importance of probabilistic information about function of words and likely structures in the routines which decode sentences, but I take it as a foregone conclusion that probabilistic models by themselves are not the whole answer.

Furthermore, the notion that a grammar is totally unrelated to ordinary sentence perception leaves unexplained the origin of the regularities expressed by grammar. That one could discover universal

conditions on the form of human languages which are totally unrelated to language use is indeed puzzling and must be explained by anyone maintaining that use of language is independent of a grammar.

The "weak heuristic model" on the other hand, also claims that the heuristics can accomplish all of sentence perception but that certain (but only certain) aspects of grammatical organization are involved in these heuristics:

> . . .the recovery of base structures involves fairly direct inductions from lexical and arrangement features of the surface structure. The grammar appears to be related to the heuristics which accomplish induction in a somewhat indirect and curious fashion. On the one hand, by enumerating the structures characteristic of the sentences of a language, it specifies the objects that the recognition procedure must recover. On the other hand, by characterizing the deep structure configurations into which lexical items can enter, and the types of correspondence between deep and surface structures permitted in the language, the grammar does, in a certain sense, express the information upon which the recognition heuristics capitalize. But it appears that, in the sense that we have been trying to explore, the grammar fails to characterize this information in the form required for sentence recognition. Sentence recognition heuristics look to be founded upon facts about the language that hold by virtue of the way the grammatical rules interact in permissable derivations of sentences; but it also seems probable that the grammatical rules are not themselves part of the recognition procedure and that the computational processes involved in generating a sentence in the grammar are distinct from the computational processes which underlie the actual performance of the speaker-hearer. (Fodor, 1967, p. 20)

Fodor, Garrett and Bever (1968) make the following statement about their particular view of these heuristics:

> /We presuppose/ as input to the sentence recognition process a representation of the sentence which marks at least a crude segmentation, including the identification of the main verb, That is, for a syntax recognition device to employ the lexical structure of the main verb as a clue to the possible geometry of the deep structure tree underlying an input, it must at least have available some hypotheses about what the main verb of the input string is and about what substretches of the string constitute segments of the sentence which the main verb may dominate in deep structure. (p. 460)

It is the subcategorization and selectional restriction feature of the verbs which most highly determine the possible base structures of sentences; and in Fodor, Garrett and Bever's view, the verb is therefore the most important part of the sentence to be decoded -- the item upon which the determination of the syntactic structure of the rest of the sentence depends:

> It is assumed that each verb has a characteristic lexical structure which is represented in the recognition device by a set of conditions upon deep structure trees into which the verb can enter. In particular, it is assumed that the lexical analysis of each verb in the language is part of the information a S has about the structure of his language. Applying this information to an input involves analyzing the input as a substitution instance of one or another of the base structure arrays its verb is capable of dominating. The pre-analysis routine ought thus to provide as much information as possible as to which structures in the sentence are NPs and VPs and which of the NPs each VP is related to. Given such information, a systematic exploitation of the lexical analyses associated with verbs and of transformationally introduced surface structure grammatical markers (such as inflection, relative pronouns, order, etc.) may prove to be sufficient to uniquely specify an underlying geometry for each input sentence. (p. 460)

Naturally, the particular rules for segmentation and analysis of sentences will vary with particular languages but the general procedure implicit in this position is nonetheless universal.

As indicated in the quotations from Fodor's article, this position implies a specific relationship between a grammar and sentence decoding heuristics: the operations of a grammar (e.g., the transformations) are not themselves a component of the heuristics, but the structures specified by the grammar (e.g., surface structure, deep structure) are functional in the heuristic operations. The generalizations about language structure which relate only to the form of and conditions on the operations of a grammar (e.g., the form of the base and transformational rules, the separation of phrase structure and transformational rules, the existence of the transformational cycle) are considered irrelevant to sentence decoding except insofar as they have structural correlates.[4]

To summarize the argument to this point, we have posed two questions about the analysis-by-synthesis model of speech perception: 1) need it entail a "derivational theory of complexity"? and 2) what heuristics are needed in the preliminary analysis? At the moment it is crucial not to be dogmatic about how these questions will be resolved. The best that can be done today is to set out the various theoretical positions and attempt to understand their implications for the role of a grammar in perception of sentences and for the direction of research.

It is clear that these questions can be resolved only when

much more is known about the heuristics which either accomplish sentence decoding or restrict the search space of an internal comparator. A plausible set of heuristics has been presented in the discussion of the "weak heuristic" position. It postulates that the initial segmentation of complex sentences is into sub-strings dominated by verbs -- that is, clauses -- and that subsequent hypotheses as to the base structure of the sentence are made largely on the basis of surface structure clues and the lexical analysis of main verbs. The most important theoretical problem in psycholinguistic approaches to syntax recognition today is to make this view precise. Concomitantly, the most important experimental problem to be faced now is to provide evidence for or against this rather plausible view of the heuristics involved in sentence recognition. This point is underscored by Fodor and Garrett (1967):

> . . .it is a pressing experimental problem to provide direct and conclusive evidence for the centrality of the lexical analysis (in particular of the verb) in the perceptual process. (p. 296)

Only when the heuristics are precisely stated and adequately motivated will one be able to tell whether they in fact can account for all of syntax recognition or whether (and in what circumstances) internal synthesis is needed. We therefore turn to a more careful statement of decoding heuristics and the psychological mechanisms they involve.

Notes to Chapter 1

1 The psychologist's domain is as idealized as the linguist's. Theories of performance may ignore factors like distractions, shifts of attention, errors, and idiosyncratic features of production such as tempo or slurring. Such theories may take as their domain only the processing of acceptable sentences and still differ from theories of competence.

2 It is important to understand that this discussion only bears on the question of the "psychological reality" of a grammar when this notion is understood in a restricted way. A grammar describes and predicts the structure of a natural language, which is one aspect of the output of the nervous system. It is a characterization of one's knowledge of his language. There is no reason to deny that knowledge in this sense is psychologically real, though characterizing such knowledge and characterizing its use in behaviour are separate tasks.

3 Clearly, the predictions made by DTC depend upon the derivation. If adjectives do not arise from relative clauses, this example is irrelevant. However, DTC can be tested for different formulations of the grammar. As grammars change, psychologists interested in this question will have to examine each convincing grammatical treatment individually in this regard.

4 It is clear that, in some fashion, each of the organizational aspects of grammatical rules presented as examples has structural correlates. The phrase structure rules define the canonical order of formatives. All the rules of the transformational cycle are "structure-preserving" in the sense of Emonds (1970). It may only be after the fact that one discovers that important conditions on the operations of transformations such as the transformational cycle, formulated only for economy of description, have structural correlates; the heuristic theory claims, however, that one should always look for such correlates because they may have a role in perception.

# CHAPTER 2

## EXPERIMENTAL APPROACHES AND PSYCHOLOGICAL CONSTRUCTS

Some of the most compelling evidence currently available about sentence perception relates to the initial segmentation of complex and compound sentences. Studies on the subjective localization of extraneous noises occurring during sentences suggest that segmentation of incoming sentences occurs initially at the clause (and word) level. A typical experimental paradigm is as follows. Subjects are presented an auditory version of a sentence containing a short burst of noise (30 to 50 milliseconds in duration) at some "objective" location in the sentence. The subject's task is to say where the "click" was located, his response (the "subjective localization") is of interest when it is erroneous. There are numerous variations of this task. In some versions the subject is asked to copy down the sentence which he just heard; in others he is presented with a written version of the sentence and is asked to mark the location of the click with a slash. In most versions he is asked to say how confident he is of his judgment by rating it on a five point scale ranging from "completely certain" to "just guessing".

In the analysis of the pattern of errors made by subjects, it was shown that clicks tend to be located at clause boundaries, even in sentences which control for lexical material and intonational contours. For instance, Garrett (1965) constructed sentences such

as (6) and (7):

(6) Only the metropolitan district of Hamburg was levelled by the war.

(7) Because it was a most important city Hamburg was levelled by the war.

In these sentences the major constituent boundary falls to the left of Hamburg in (7) and to the right of Hamburg in (6). The versions of the sentence which were presented to the subjects were cross-recorded and spliced in such a way that the intonational contours were identical in both versions of the relevant portion of the string. A click objectively located in the middle of the word Hamburg produced a pattern of errors so that in sentence (6) most errors were located to the right of Hamburg whereas in sentence (7) most errors were located to the left.

In a separate set of experiments, it was shown that only clause boundaries attract clicks. That is, boundaries between constituents other than clauses did not serve as loci for the subjective localization of clicks.[1] However, Bever (personal communication) demonstrated the existence of a "consolidation effect" of minor constituent boundaries by delaying subjects' responses by five seconds. When subjects were asked to say where a click was located, they tended to move it to the minor constituent boundaries much more consistently than they did immediately after the presentation of a sentence. These two results indicate the initial segmentation of sentences is into clauses and that adequate computational time will enable the subject to mark the minor constituent

boundaries which then become potential loci for the subjective positioning of clicks. In general, as Garrett (1971) says:

> /A/ possible conclusion is that clicks are indeed sensitive to all of the constituent structure that is present at the point in sentence processing where click location errors are normally made, but that minor constituent structure boundaries have not yet been developed at that point. (p. 11)

Since click studies cannot be designed to yield information about aspects of sentence processing other than segmentation, investigation of other important hypotheses about sentence decoding requires other experimental paradigms. Utilizing paraphrase and anagram tasks, Fodor, Garrett and Bever (1968) examined the notion that one determinant of sentential complexity is the number of sub-categorization features associated with the main verb of the sentence. The authors constructed sentences like (8) and (9):

(8) The box the man the child knew carried was empty.

(9) The box the man the child met carried was empty.

The verb know in sentence (8) is compatible with a larger number of sub-categorization features than the verb meet in sentence (9). In a paraphrase task in which the recovery of grammatical relations and the time it took subjects to paraphrase were scored, subjects retrieved a significantly larger number of grammatical relations in sentence (9) than in sentence (8) and did so slightly faster. Another set of experiments consisted of anagram tasks in which subjects were presented with scrambled words and asked to arrange them into grammatical sentences. The sentences which could be formed from the words were pairs like (10)

and (11):

(10) The man who the child knew carried a box.

(11) The man who the child met carried a box.

Errors in construction of sentences like (11) were significantly less frequent than in construction of sentences like (10). The general conclusion that Fodor, Garrett and Bever drew from these two experiments is that:

> It appears that the exploitation of the lexical analysis of the main verb of a sentence is a central heuristic in the strategy subjects use to recover its deep structure. (p. 460)

The results of the click studies and the anagram and paraphrase experiments provide support for the view of sentence decoding heuristics which postulates an initial segmentation of complex sentences into clauses and the determination of underlying structures largely by consideration of the lexical features of verbs. Moveover, there is a general view of the psychological processes underlying sentence decoding heuristics which can be constructed from these experimental results. A sentence decoding device initially accomplishes two operations: the segmentation of acoustic strings into phonemes and words and of complex and compound sentences into clauses. A third process is the determination of minor constituent boundaries; the experimental evidence indicates that this process waits for the results of the first two.

One model compatable with the experimental facts just described consists of operations and storages which are conveniently represented as

a flow chart. In Figure A, we have represented various aspects of the processing of sentences as discrete operations accomplished in discrete storage areas.[2]

The necessity for some sort of buffer storage in the decoding of sentences follows from the fact that even in very simple sentences such as (12):

(12) The professor who the students liked died.

The professor must be held in storage until the occurrence of the verb liked in order to be assigned its role as the object of liked.

The type of storage necessary for sentence perception must allow more than just decay over time. Consider (13):

(13) The professor the students believed to have been arrested died.

The most simple on-line analysis of this sentence would mark The professor as the object of believed as soon as believed occurred. The subsequent occurrence of the verb arrested necessitates either that the assignment of grammatical relations to The professor be delayed or that the initial portion of the string be re-analyzed. To do either, the initial material must be held in some sort of buffer storage. It seems reasonably sure that re-analysis of initial material is involved in perceiving some sentences. Sentence (14) (similar to (8)) contrasts with (15):

(14) The woman sold the vase demanded her money back.

(15) The woman sold the vase demanded by the museum.

In so-called garden path sentences like (14) one intuitively appreciates

that the first portion of the sentence is re-analyzed when the second portion is heard.

These examples show that the buffer must allow both analysis and re-analysis of the grammatical relations among the words of a sentence. In general the buffer used in sentence decoding allows extraction, replacement, and comparison of words in storage with words newly entering the storage. Experimental evidence to be presented in Chapters 4 and 5 suggests that not all items in a buffer storage decay uniformly over time, but that certain items have stronger traces at various stages in storage than others.

According to the particular system of perceptual buffers outlined in Figure A, the incoming signal is first placed into "primary storage". There are two important properties of primary storage. First, it contains only one sequence of the form $/\!\!\lceil_{S} X \vee Y /\!\!\rceil_{S}$; that is, the strings in this storage are bounded by left-sentence boundaries on the left and on the right, and contain at least one verb. The condition for dismissal of a string from primary storage is the recognition of a left sentence boundary -- that is, a succeeding clause. Thus, in a sentence such as:

(16) The man told his friend that the forecast called for rain.

The string <u>The man told his friend</u> would enter primary storage and later be replaced by <u>that the forecast called for rain</u>. Second, the decoding processes associated with primary storage are "on-line" processes (in the sense to be explained). Two routines operate simultaneously

on a sentence in primary storage. The first determines the lexical structure of the utterance and the second defines the clause boundaries. The first is basically the "preliminary analysis" described in Halle and Stevens (1964); the second has not yet been described in detail but would undoubtedly take advantage of intonational cues, obvious surface structure indicants of sentences, such statistical measures as average length of constituent sentences, and the kinds of strategies for determining sentences that are described in Bever (1969).

The signal is then moved to what is termed "secondary storage". The four most important characteristics of secondary storage are: that it permits extraction of material for comparison and re-analysis purposes; that different classes of items have different trace strengths; that it contains only one sequence with the bracketing $[_{S_i} X \vee Y_{S_i}]$ and that the operations associated with this storage are primarily "hierarchical" (in the sense to be described). The operations performed while the signal is in secondary storage are the determination of minor constituents and the assignment of underlying grammatical relations. Material remains in secondary storage until all the operations needed to determine grammatical relations under an S-node are complete. Thus, the strings in secondary storage are defined by the presence of an equal number of left and right sentence boundaries. In a sentence such as

(17) The man expected it to rain.

the whole string would remain in secondary storage until the grammatical relations were determined.

The experimental evidence that the processes in primary and secondary storage take place sequentially comes primarily from the click experiments. One imagines that the click cannot be located until the perceptual unit (or "chunk") on which the sentence decoding device is operating is complete. The click is "heard" at the point which defines the boundary of a perceptual chunk -- the clause boundary. Clicks occurring in the word just following a clause boundary would be heard at the preceding clause boundary (the sentence would now be in secondary storage); and clicks occurring in the word just prior to a clause boundary would be heard at the following clause boundary (the sentence in question would still be in primary storage). That minor constituents do not have the same effect on subjective localization of clicks argues that they are not handled in the same way as clause segmentation.

In general, the operations in the primary storage are those which demand on-line processing. As the input string comes in, it is segmented in a more or less linear fashion with respect to time and left-to-right sequencing. It is, of course, well known that certain aspects of segmentation at every level -- even at relatively "low lying" levels such as determination of phonemes where perhaps the most detailed results are available -- must partially take into account information "downstream" in the signal. Nonetheless, it is possible to conceive of both segmentation of phonemes and segmentation into clauses as processes which primarily analyze the input signal as it comes into storage. This is particularly clear in the case of

segmentation into clauses where certain words (complementizers, WH words) indicate that a sentence is to follow. In contrast, the operations grouped together in the secondary storage primarily process hierarchical information which makes use of the geometrical arrangement of formatives in both surface and deep structure. For instance, deciding which of several possible subcategorizations of a particular verb is instantiated in a given sentence mainly involves hierarchical processing.

On this model the experiments dealing with the contribution of verbs to perceptual complexity of sentences -- those showing that the more subcategorization features are associated with a particular verb the more it contributes to the perceptual complexity of the sentence -- tap information about sentence decoding processes which relates to the operations performed in secondary storage. At this point in the analysis of sentences, the number of subcategorization features associated with a particular verb determines the number of operations needed to assign the appropriate structural description to the incoming sentence.

The result of processing material in the secondary storage goes into a buffer in which other routines finally determine the semantic reading of a sentence. This process provides a semantic interpretation of the sentence after its syntactic structure has been deduced, but little more is known about it.

We have thus far elaborated a view of sentence decoding heuristics and psychological storages in which they operate. However,

all the experimental evidence supporting both the heuristics and the system of storages is based on only a few experimental paradigms. One general problem with psychological experimentation in sentence perception is that one often has only vague intuitions about what a particular paradigm will accomplish in testing a hypothesis. For instance, in the experiments reported which indicate that perceptual complexity is partially a function of the number of subcategorization features associated with a particular verb, the measure of complexity was the difficulty in paraphrasing and the time it took to paraphrase rather complicated sentences. This task, although certainly a measure of complexity of some sort, is not directly related to the processes of sentence perception. There is no way of setting up the task so as to make a subject produce a response while listening to a sentence or immediately after its presentation. In fact, Hakes (1971) showed that phoneme monitor tasks are not affected (when one monitors for phonemes within a clause)[3] by the number of subcategorization features associated with the main verb of a clause -- which suggests that the results in Fodor, Garrett and Bever (1968) have more to do with paraphrase than with perception. Similarly, the view of segmentation prescribed here depends entirely on click studies. It is always worthwhile to develop other experimental techniques the results of which may dove-tail with results already established by previous techniques. If this can be accomplished then both experimental techniques are validated as measures of perceptual complexity of sentences and the measure of complexity which results is rendered

more plausible.

The experimental technique used in studies presented in the remainder of this thesis is the probe task. In a typical experimental situation, a subject listens to a sentence and a word is presented to him. The word may be presented during the sentence or after it either auditorally or visually. The subject's task is to indicate whether the word presented was in the sentence or not by pressing a switch to one of two positions indicating an affirmative (IN) or negative (OUT) choice. A millisecond timer, activated electronically at the beginning of the presentation of the probe word, is stopped by the subject's response. The timer is started at the onset of the probe so that decoding of the probe is included in the subject's latency. The reaction times thus obtained are the raw data for analysis.

There are three features of the probe task which recommend its use in studying sentence perception. First, it is clearly related to perceptual processes since it is a test of matching words. It involves, minimally, the segmentation of a sentence into words and the comparison of the words in the sentence to the probe until a match is made. Secondly, the probe can be presented during the presentation of the sentence (either visually or dichotically) or at any interval from the end. The task can therefore be used to examine a subject's reactions while he listens to a sentence or while he is still decoding. Third, both intra-modal tests (auditory presentation of both probe and sentence) and cross-modal tests (auditory presentation of sentence and visual presentation of probe) are possible. Both variants have been

employed in the current work. Some results (reported in Chapter 5) suggest that the intra-modal presentation may have special features which make it particularly sensitive to certain processes in sentence perception.

The probe task is not a new experimental technique. Walker, Gough and Wall (1968) have used it to show that reaction latencies for the recognition of two words from a sentence are lower when the words have a grammatical relation in the sentence than when they do not. In the sentence:

(18) The scouts the indians saw killed a buffalo.

the noun-verb pairs which bear the grammatical relation subject of -- scouts killed and indians saw -- have latencies which are significantly lower than those for words for which no subject of relation exists -- scouts saw and indians killed. Thus, probe tasks are sensitive to linguistic structure. Combinations of words which are relevant to the structure of a sentence -- and presumably to its comprehension -- have shorter latencies than combinations which do not figure in the structure of the sentence.

The probe test can be used to study the heuristics described above. It has been argued that sentence perception occurs largely on a clause-by-clause basis inasmuch as clauses are moved en bloc from one perceptual storage to another. If the trace strength of a word is proportional to the number of storages in which it is represented, crossing a clause boundary ought to diminish the trace strength of a word in perceptual buffers. Similarly, if certain classes of words

cannot be dismissed from buffers because they are needed for decoding operations, they ought also to have stronger traces than classes of words which can be dismissed earlier. A stronger trace ought to facilitate recognition of a word in a probe task and make for shorter reaction times.

The remaining chapters of this dissertation will report work which bears on the decoding heuristics discussed above, particularly the initial segmentation of complex sentences into clauses and the centrality of verbs in decoding. It will be shown that statistically significant variation in recognition latencies of probes can be predicted from the sentence decoding heuristics and the perceptual storages described in this chapter. The results suggest that these heuristics and storages are operative in the preliminary analysis of the syntactic structure of incoming sentences.

Notes to Chapter 2

1 Garrett (1971) has shown that word segmentation only influences the subjective localization of clicks when possible word boundaries are clearly marked by anterior context.. A word such as nitrates which has the same sequence of phonemes as night rateswill not cause the subject to displace a click from between /nait/ and /rets/ unless the initial segmentation (as determined by anterior context) is obviously into two words. Garrett constructed quartets of sentences of the following sort:

(1) Before making any long distance calls, John inquired about both the day rates and the night rates in order to be sure not to waste money.

(2) In order to be sure not to waste money, John inquired about the night rates and the day rates before making any long distance calls.

(3) Before making any mining commitments, John inquired about both the bauxites and nitrates in order to be sure not to waste money.

(4) In order to be sure not to waste money, John inquired about both the nitrates and the bauxites before making any mining commitments.

In the first two sentences, the string /naitrats/ is segmented into two different words. In the first sentence the anterior context indicates that this must be the segmentation whereas in the second sentence only the posterior context indicates this segmentation must have taken place. Similarly, in the last two sentences, the anterior context in the third and posterior context in the fourth indicate that the segmentation of this string /naitrets/ must be into a single word. The results are reported as follows:

> The results show that prior context can affect the assignment of word boundaries, but the posterior context does not. If we consider, for example, a comparison of the "night rate" and "nitrate" versions in the pre-disambiguation condition, we find that in the version with the word boundary at the click location ("night rate") there is approximately half as many errors as the version ("nitrate") which does not have a word boundary at the click position. . . . .Posterior context conditions did not show a significant difference between interpretations with word boundaries and interpretations without word boundaries. . . .this supports

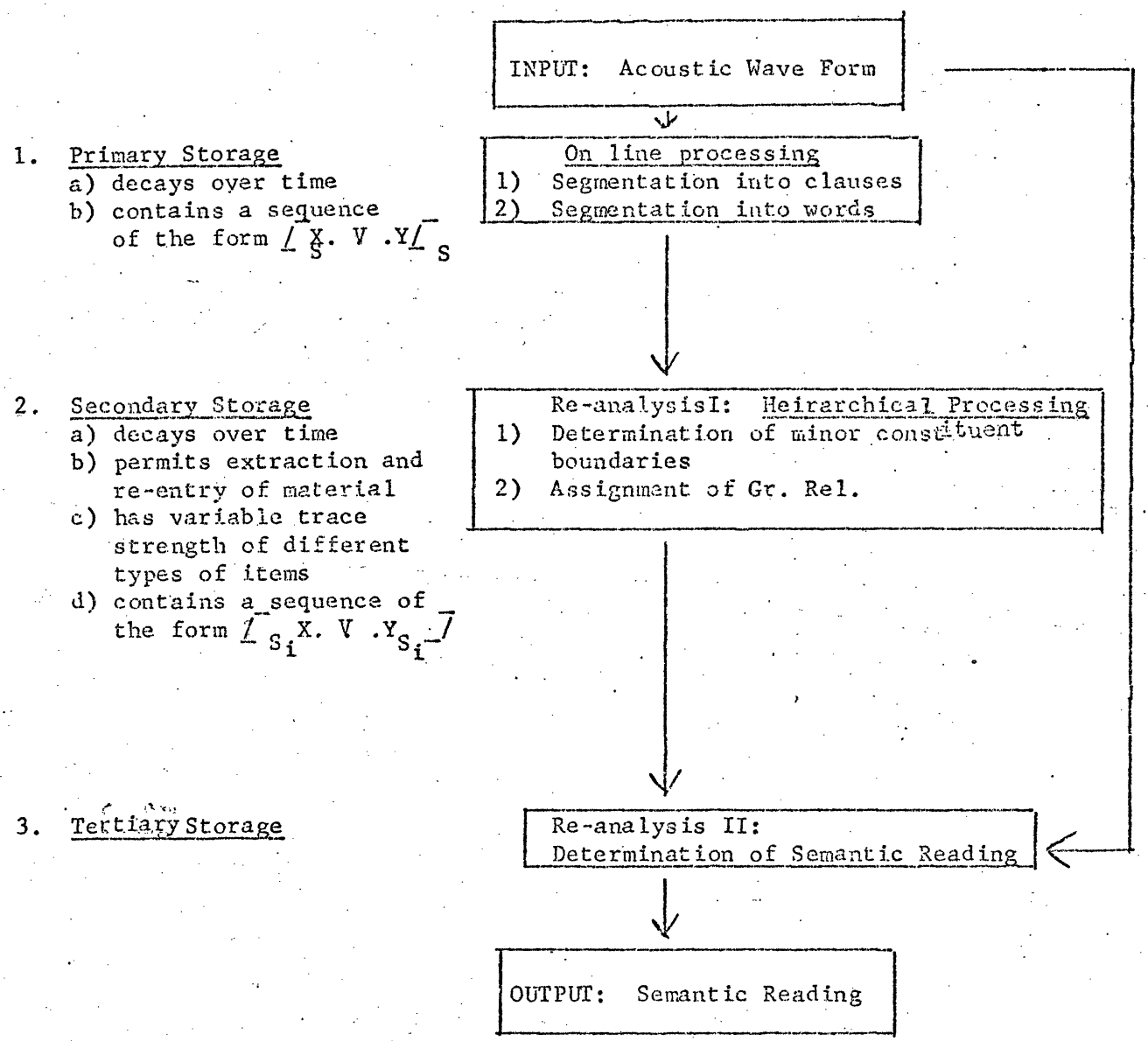
> the claim that word segmentation does not wait on posterior context, and eliminates the possibility that pre- and post- disambiguation conditions are functionally equivalent for click location. (pp. 19-20)

2 Other models are possible, including ones which allow for more parallel processing than is supposed in Figure A.

3 Hakes (personal communication) has also monitored for phomenes after a clause boundary, with the same result.

Figures for Chapter 2

Figure A: Schematic Representation of Sentence Decoding Buffers and Operations



# CHAPTER 3

## CLAUSE BOUNDARY EFFECTS IN PROBE TASKS

It has been argued that initial segmentation of complex sentences is into clauses and that once a clause is recognized it is moved from primary to secondary storage for further decoding. A word in an incoming sentence may be represented in all perceptual storages as soon as it is recognized, although the operations of secondary storage do not occur until those of primary storage have taken place. When a left clause boundary is recognized, the representation of the clause in primary storage is "erased" to allow for the recognition of the following clause. Therefore, a word in the final clause of a complex sentence has a representation in at least two perceptual storages after the sentence is over, whereas a word before the final clause is no longer represented in primary storage. If the availability of a word is proportional to the number of storages in which it is represented, words occurring in the final clause of a complex sentence should be more readily available than those occurring before the final clause. This differential availability of words should have an effect upon recognition latencies in probe tasks. It is reasonable to hypothesize that reaction times to probes within the final clause of a complex sentence will be lower than those to probes before the final clause. To test this hypothesis several experiments were run.

Experiment I

Materials: Six sets of eight sentences were constructed. All the sentences were in the form of subordinate clause/main clause and were twelve syllables in length. In two sets of sentences, the clause boundary fell five syllables from the end of the sentence; in two sets, it fell four syllables from the end; and in two sets, it fell three syllables from the end. One set of sentences in each of these three groups contained words to be probed which were within the final clause, immediately after the clause boundary; and one set contained words to be probed which were before the final clause, just prior to the boundary. Sample sentences of each type were presented below; a complete set of stimulus materials is found in Appendix A:

(19) a. Every time we visit <u>friends</u> we bring them liquor.

b. When interest rates fall on bonds, <u>stocks</u> also go down.

(20) a. Though the forecast calls for more <u>rain</u>, the sun is out.

b. If Jane plays any Beatles' songs, <u>guests</u> will soon leave.

(21) a. Even if the rain never does <u>stop</u> we will leave.

b. Whenever the goalie stops the puck, <u>fans</u> go wild.

Twenty-four filler sentences (OUT probes) were also presented.

The sentences were recorded with normal intonation, minimizing the intonational effects of clause boundaries. Naive and alerted judges agreed that intonational clues to the clause boundary were minimal (although clearly they must have been present). At the end of each

sentence, before the presentation of the probe word, a 50 millisecond 500 Hz tone of low intensity followed by 100 milliseconds of leader tape was spliced on the experimental tape. The purpose of the tone and silent tape was to indicate to the subject that the sentence was over and the probe about to be presented. (In a pilot experiment, subjects had noted that, without a tone marking the end of the sentence, they could not tell when the sentence ended and the probe began.)

On a second tape channel, inaudible to the subject, a high frequency tone was recorded so that its onset was simultaneous with that of the probe. The high frequency tone activated a millisecond timer which was stopped by the subject when he made his response.

Subjects: 11 M.I.T. undergraduates, paid for their time, participated in the experiment. All were male, native English speakers, with good hearing.

Procedure: Subjects were told that they were participating in an experiment in auditory perception. They were to listen to the sentences presented to them and to indicate whether they thought the word coming immediately after each sentence had been in the preceding sentence. If they thought the probe had been in the sentence they were to press a lever to a position marked IN; if not they were to press the lever to the OUT position. Subjects were instructed to make their responses as quickly as possible and to be as accurate as they could. They were permitted to correct any errors they thought they had made before the presentation of the subsequent sentence.

Reaction times and errors were recorded by the experimenter.

Results: The experiment was treated as a 3 x 2 within-groups design (distance of clause boundary from end of sentence, by position of probe word vis-a-vis clause boundary), with lexical material effects confounded with other variables. A full analysis of variance was performed. Very few responses were erroneous and the mean of all other scores in each cell was used to fill any empty entries.

Mean reaction times for the six types of sentences are presented in Table I. The main effect for position of the clause boundary did not approach significance. The main effect for position of the probe (within versus before the final clause) was highly significant: mean reaction time for the probes in the final clause was 422 milliseconds and for probes before the final clause 451 milliseconds. ($F = 34.222$, $p < .001$, $df = 1/10$). The 3 x 2 interaction (position of clause boundary by position of probe) was not significant.

Experiment II

The stimuli used in experiment I were used again, except that the probe was presented visually instead of auditorally. A high frequency noise burst on the second channel of the tape started the tachistoscopic presentation of the probe and the millisecond timer simultaneously. The subjects' response (made as before) stopped both the timer and the tachistoscopic presentation of the probe. Seven paid volunteers, all M.I.T. male undergraduates, who were native English speakers and had good hearing, took part. With the appropriate changes indicating that the probe word would be presented visually, the

instructions and procedure were the same as in experiment I.

Results: The experimental design was as before. Median reaction times for the six categories of sentences are presented in Table II. (Median times, rather than means, were used because of the small number of subjects). Neither the main effect for position of clause boundary nor the interaction of clause boundary with probe position approached significance. The main effect for position of probe with respect to the clause boundary was again highly significant: median reaction time for probes in the final clause was 870 milliseconds; for probes before the final clause, it was 933 milliseconds ($F = 24.981$; $p < .01$; $df = 1/6$).

Discussion of experiments I and II

The results of experiments I and II indicate that recognition of probes is facilitated when they occur in the final clause of a complex sentence rather than when they occur before the final clause. However, this result must be qualified in several respects.

First, the experimental materials were not controlled for the varying effects of lexical materials. Since different words may themselves provoke different reaction times, this is one source of variance which may have influenced the results, although the size of the set of materials is a guard against this possibility.

Second, intonational clues for the segmentation of the sentence may have influenced the results; that is, subjects may have segmented the sentence into clauses on the basis of intonation rather than lexical clues. It is worthwhile trying to differentiate the methods

of segmentation, though that the differences in latency are presumably due to what the subject does after he has achieved segmentation and not to the manner in which he achieves the segmentation.

Third, one might argue that the differences in reaction times were caused by the difference in serial position between the probes inside the final clause and those before the final clause since the former are always one syllable nearer the end of the sentence than the latter. Consideration of the means in Tables I andII, however, does not support this account. Since the probes within the final clause when the major break is five syllables from the end and those before the final clause when the major break is four syllables from the end are in the same serial position, (i.e. are four syllables from the end of the sentence) a difference in reaction times for probes in these positions cannot result from differences in serial position. (See Figure B). Comparison of these figures, as well as the means for four within and three before, indicates that the probes in the final clause produce faster reaction times than those before the final clause. These comparisons, although not statistically significant, indicate that serial position effects did not produce the results.

Since the materials in experiments I and II did not control for effects of lexical materials and did not eliminate the intonational contour associated with clause boundaries, other experiments were designed to control for these variables, as well as serial position.

Experiment III

Materials: Sixteen pairs of sentences were constructed in

which both members of each pair had the same words in the last few positions. Each sentence was in the form of subordinate clause/main clause. The syntactic analysis of the shared words differed depending on the initial context. In one member of each pair the sequence of words in question was segmented so that at least one word fell before the clause boundary, and in the other member the segmentation was such that this word was within the final clause. Examples of such pairs are:

(22) a. Now that artists are working in <u>oil</u>, prints are rare.

b. Now that artists are working fewer hours, <u>oil</u> prints are rare.

(23) a. Whenever one telephones at <u>night</u>, rates are lower.

b. Make your calls after six, because <u>night</u> rates are lower.

A complete list of stimulus sentences appears in Appendix B. Sixteen filler sentences were also presented to subjects.

The sentences were recorded in a semi-anechoic chamber on a master tape using an Ampex PR-10 tape recorder. The words from the <u>b</u> versions of the sentences (e.g., <u>oil prints are rare</u>) were spliced onto the initial fragment of the <u>a</u> version (e.g., <u>Now that artists are working in</u>) in such a way that identical copies of the words were present in both the <u>a</u> and <u>b</u> sentences. Both naive and alerted judges agreed that all the stimulus sentences sounded natural in the two versions and that they could not tell the sentences had been spliced.

Each sentence appeared in both versions throughout the

entire set of stimulus tapes. A subject heard eight sentences in one version (probe before the final clause) and eight sentences in the other (probe within the final clause).

Following each sentence, a 500 Hz 50 millisecond low intensity tone was spliced onto the tape and, following the tone, 100 milliseconds of leader tape. The probe word followed the leader tape. A high frequency noise burst was located on a second channel of the tape at the beginning of the probe word. The burst activated a millisecond timer which was stopped when the subject responded.

Subjects: Sixteen subjects, all M.I.T. undergraduates with good hearing, who were native English speakers, participated and were paid for their time.

Procedure: Subjects were told to listen to the sentence and to indicate by pushing a lever to one of two positions whether they thought the word following the sentence had been in the sentence or not. Subjects were instructed to aim for accuracy and speed in their responses. They were permitted to correct perceived errors verbally.

Results: The mean reaction time for probes occurring within the final clause was 687 milliseconds; that for probes before the final clause was 801 milliseconds ($F - 11.439$; $p < .01$; $df = 1/15$).

Experiment IV

The same stimulus materials were used but the probe words were presented visually rather than auditorally. A high frequency noise

burst located on the second tape channel at the end of the sentence started the millisecond timer and the tachistoscopic presentation of the probe. The subjects' response stopped the timer and the presentation of the probe. Subjects were instructed, as before, to aim for accuracy and speed in their responses and to correct perceived errors verbally. Sixteen M.I.T. undergraduates participated.

Results: The mean reaction time for probes occurring within the final clause was 1.004 milliseconds and for probes before the final clause it was 1.066 milliseconds ($F = 4.832$; $p < .05$; $df = 1/15$).

General Discussion

Experiments III and IV show that on both intra-model and cross-model probe tasks the position of the probed word vis-a-vis a clause boundary in a complex sentence -- independent of intonation differences or serial position effects -- influences reaction times of subjects. When a probe is within the final clause, recognition latencies are lower than when it is before the final clause. Since the trace strength of items within a final clause is greater than that of items before a final clause (as measured by lower recognition latencies) we may conclude that words are no longer represented in primary storage after a clause boundary is recognized. The results therefore strongly suggest that primary storage has as the condition for dismissal of a string the recognition of a left clause boundary and that processing of sentences -- attendent upon initial segmentation -- occurs largely on a clause-by-clause basis.

Figures and Tables for Chapter 3

Figure B.: Relationship between serial position (syllables from end of sentence) and position vis-a-vis break. (Experiments I and II)

Break at 5: To see the movie actress, men stood on car roofs.

"men" is 4 syllables from end of sentence.

Break at 4: No matter what the students say, they will all pass.

"say" is 4 syllables from the end of the sentence.

FIVE - WITHIN is in the same serial position as FOUR - BEFORE

---

Break at 4: No matter what the students say, they will all pass.

"they" is three syllables from end of sentence

Break at 3: Even though the question is minor, think it through.

"minor" is three syllables from end of sentence.

FOUR - WITHIN is in the same serial position as THREE-BEFORE

Table I: Mean RT (milliseconds) for position of probe vis-a-vis major sentential break and position of break vis-a-vis end of sentence.
Experiment I

| | | Position of major sentential break (syllables from end of sentence.) | | |
|---|---|---|---|---|
| | | 5 | 4 | 3 |
| Position of Probe | In final sentence | 409 | 423 | 434 |
| | Before final sentence | 452 | 454 | 448 |

Table II: Median RT (milliseconds) for position of probe vis-a-vis major sentential break and position of break vis-a-vis end of sentence.
Experiment II

| | | Position of major sentential break (syllables from end of sentence.) | | |
|---|---|---|---|---|
| | | 5 | 4 | 3 |
| Position of probe | In final sentence | 875 | 870 | 866 |
| | Before final sentence | 984 | 916 | 898 |

# CHAPTER 4

## AMBIGUOUS ITEMS IN STORAGE

Lexical ambiguity is a feature which one would expect contributes to the perceptual complexity of sentences. This point is made in Garrett (1971):

> If one were looking for a likely source of computational difficulty in the understanding of sentences, ambiguity is among the first candidates one would consider. The presence of an ambiguity is by definition the presence of a computational option in the analysis of a sentence. If deciding upon possible analyses of a string is a source of computational difficulty, ambiguity should contribute to the difficulty of understanding a sentence. (p. 14)

There are a number of experimental works dealing with the effect of ambiguity on the perceptual complexity of sentences. Garrett (1971) summarizes the outcome of these studies in the following terms:

> Experimental research on the effects of ambiguity have been varied in their outcome. There have been a number of studies which appear to show that ambiguities have an effect only in cases in which the situationally wrong computation is picked, and a number of studies which appear to show that the mere presence of an ambiguity increases the difficulty of comprehending a sentence, even when the situationally correct interpretation is chosen. The interesting feature which distinguishes these two classes of studies is the point at which the measures of comprehension difficulty were taken. In studies which show <u>no</u> effect (except for "garden-path" cases) of ambiguity, the measures of difficulty have been taken after the completion of the stimulus sentence. In studies which do show an effect of the presence of an ambiguity, the measure of the effect of comprehension difficulty has been taken during the presentation of the stimulus sentences. The inference is obvious: the increase in computational load associated with an ambiguity is restricted to the point in time at which the computational options have not been decided among. The suggestion being offered here is that the latest point at which computational options remain open is the end of the clause in which an

ambiguity occurs. (pp. 14-15)

The model of sentence decoding elaborated in Chapter 2 conceived of distinct storages in which different decoding operations take place. Two buffers operate sequentially: the determination of grammatical relations in a sentence is accomplished in secondary storage after the clause boundaries and words have been established in primary storage. A third buffer -- tertiary storage -- is thought to be involved in the determination of the meaning of the sentence. Though certain aspects of sentential meaning depend upon the elaboration of the syntactic structure of a sentence, it is not necessary for the routines which determine semantic reading to wait for syntactic information before "looking up" the individual lexical items isolated in primary storage. We may therefore think of tertiary storage operating in parallel with primary storage in the "lexical look-up" phase of its operation, though the determination of the entire semantic reading of a sentence must wait until after the operations of the secondary storage have been performed.

Unlike unambiguous lexical items which can be replaced by a single semantic reading on the first lexical look-up, an ambiguous word must either be represented by both its readings or marked as undetermined and looked up again later. The unique determination of the meaning of an ambiguous word cannot be accomplished until after a disambiguating context, although if Garrett is correct that "clause boundaries are preferred points for decision making" a decision (which may later have to be rectified) may be made at a clause boundary.

It has been argued that the trace strength of an item is proportional to the number of buffers in which it is retained. If an unambiguous word is replaced in tertiary storage by a set of semantic features (its semantic reading) it should have a weaker trace than an ambiguous word which is not replaced by a set of features until a decision is made either after a disambiguation or at a clause boundary.[1]

Stronger trace strength of an item in a perceptual buffer ought to facilitate comparison of that item with a probe. Therefore, it is possible to test the preceding notions experimentally. One can formulate the hypothesis that in a probe task ambiguous words will produce faster reaction times than unambiguous words if the probe is presented in the same simple sentence as the ambiguous word before the disambiguating context. The following experiments were designed to test this hypothesis.

Experiment I

Materials: Thirty-two octuplets of sentences were constructed to incorporate the following variables. At a certain position in the sentence either a lexically ambiguous noun or an unambiguous noun meaning more or less the same thing appeared. Three or six syllables further on in the sentence a disambiguating context occurred which distinguished the two possible readings of the lexically ambiguous noun. In half the 32 octuplets, a clause boundary occurred just after the ambiguous word and before the disambiguating context (in

both the three-and six-interval versions); in the other 16 octuplets, there was no clause boundary between the ambiguous word and the disambiguating context. Sentences (24) and (25) exemplify octuplets without a clause boundary and with a clause boundary, respectively. A complete list of sentences appears in Appendix C.

(24) No clause boundary intervening

a. The lawyer thought the case contained the cigarettes he had been looking for.

b. The lawyer thought the case probably contained the cigarettes he had been looking for.

c. The lawyer thought the carton contained the cigarettes he had been looking for.

d. The lawyer thought the carton probably contained the cigarettes he had been looking for.

e. The lawyer thought the case contained the precedent he had been looking for.

f. The lawyer thought the case probably contained the precedent he had been looking for.

g. The lawyer thought the trial contained the precedent he had been looking for.

h. The lawyer thought the trial probably contained the precedent he had been looking for.

(25) Clause boundary intervening

a. The men wanted a strike to win their bowling game against the archrivals.

b. The men wanted a strike to insure winning their bowling game against the archrivals.

c. The men wanted a spare to win their bowling game against the archrivals.

d. The men wanted a spare to insure winning their bowling game against the archrivals.

e. The men wanted a strike to win their demands for increased retirement pay.

f. The men wanted a strike to insure winning their demands for increased retirement pay.

g. The men wanted a slowdown to win their demands for increased retirement pay.

h. The men wanted a slowdown to insure winning their demands for increased retirement pay.

Twenty-four filler sentences were also used. The sentences were recorded with normal intonation and tempo. A high frequency tone located on the second channel of the tape activated a millisecond timer and the tachistoscopic presentation of the probe word.

The tone was placed either just before the disambiguating context or just after it. Thus, there were sixteen possible presentation versions of each lexical frame: eight sentence versions as exemplified in (24) or (25), and two positions of the probe (before the disambiguating context and after the disambiguating context) in each version. Each subject heard a given lexical frame in only one experimental version; thus across the 32 stimulus sentences he heard, he received two instances of each type of experimental condition. Throughout sixteen stimulus tapes, each sentence appeared in each possible experimental version. Subjects heard stimulus sentences with only one reading of the ambiguous item. The design was treated as a replication across readings.

A pre-test was run to determine whether the lexically ambiguous words were effectively ambiguous. Subjects were presented with incomplete sentence fragments such as:

(26) The lawyer thought the case contained the. . .

(27) The lawyer thought the case probably contained the. . .

on separate sheets of paper and were given 20 seconds to write a plausible completion of the sentence fragment. The completions were scored as belonging to one of three groups: "reading 1" of the ambiguous item; "reading 2" of the ambiguous item; and "other". It was felt that if an item was truly ambiguous, a completion task of this sort would provide instances of both possible readings. Experimental materials were rewritten so as to utilize primarily nouns which gave rise to both possible readings on this completion task.

Subjects: Sixty-four M.I.T. undergraduates, all with good hearing, able to read with glasses, and native English speakers, took part and were paid for their time.

Procedure: As in the previous experiments, subjects were told to listen to the sentence and indicate by pushing a lever to one of two positions whether they thought the word presented tachistoscopically had been in the sentence or not. Subjects were instructed to aim for accuracy and speed and to correct perceived errors verbally. Several practice trials were given before the experimental conditions. Reaction times and erros, if any, were noted.

Results: The experimental design was treated as a 2 x 2 x 2 x 2 factorial (<u>three-six</u> syllable interval, by presentation of probe <u>before</u> or <u>after</u> the disambiguating context, by <u>absence</u> or <u>presence</u> of a sentence boundary before the disambiguating context and after the ambiguous word, by <u>ambiguous</u> or <u>unambiguous</u> probe).[2] Each reading of

of the ambiguous word was first analyzed independently.

Results: The analysis of "reading 1" indicates significant main effects for the difference in positioning of the probe - before or after the disambiguating context ($F = 4.285$; $p < .05$; $df = 1/31$) and for ambiguous and unambiguous words ($F = 5.548$; $p < 05$; $df = 1/31$) -- but no other significant main effects. The only significant interaction is that between ambiguous-unambiguous words and the absence or presence of a clause boundary between the ambiguous word and the disambiguating context. Means for experimental versions without a clause boundary between the ambiguous word and the disambiguating context are .960 milliseconds and 1.011 milliseconds for ambiguous and unambiguous words respectively; and means for experimental versions in which a clause boundary is interposed between the ambiguous word and the disambiguating context are .973 milliseconds and .978 milliseconds for ambiguous and unambiguous versions respectively ($F = 4.777$; $p < .05$; $df = 1/31$). No three way or higher interactions approached significance. The mean reaction times for the three way interaction of ambiguous and unambiguous items, by position of the probe vis-a-vis disambiguating context, by the absence or presence of a clause boundary between the ambiguous item and the disambiguating context, are presented in Table III. T-tests show that several of these means are significantly different and that the means which are significantly different fall into three groups. The first group involves a comparison of means for the presentation of probes before and after the disambiguating context. The existence of significant differences between these two means

is attributable to the difference in serial position of the probe vis-a-vis the probed item and to the existence of the disambiguation. The second involves the comparison of means for probes which all fall before the disambiguating context. Here ambiguous words probed in simple sentences are significantly faster than unambiguous words probed in simple sentences ($t = 2.556$; $p < .02$, twotails, $df = 31$) but means for ambiguous words probed in complex sentences are not significantly faster than means for unambiguous words probed in complex sentences. The third class of comparisons is between means of probes which occurred after the disambiguating context. Here the only significant difference between means occured in the comparison of means for ambiguous words probed in simple sentences with unambiguous words probed in simple sentences -- again the ambiguous words are significantly faster ($t = 1.888$; $p < .05$, onetail; $df = 31$).

A similar analysis carried out on "reading 2" reveals no significant main effects or interactions in the complete analysis of variance. The means for the three way interaction, excluding the three and six syllable interval differences, are presented in Table IV. T-tests reveal no significant difference between any means except in the comparison of probes which occurred before and after the disambiguating context -- a difference which can be attributed to differences in the serial position of the probe vis-a-vis the probed word and the existence of the disambiguation.

Combining both readings, one finds significant main effects for position of the probe word before or after the disambiguating context

($F = 5.850$; $p < .05$; $df = 1/63$) and for ambiguous versus unambiguous probes ($F = 4.135$; $p < .05$; $df - 1/63$), but for no other main effects or interactions. The means for the three way interaction, excluding the three-six interval differences, are presented in Table V. Differences between means fall into two groups. The first encompasses significant differences between means for probes occurring before and after the disambiguating context which are interpretable as serial position and disambiguation effects. The second class encompasses differences between means for probes falling before the disambiguating context. In this group, means for ambiguous words are significantly faster than those for unambiguous words presented in sentences without a clause boundary intervening between the probe and probed word ($t = 2.855$; $p < .005$; 1-tail; $df = 63$) and the difference between ambiguous and unambiguous words in sentences in which a clause boundary intervenes is not statistically significant.

The F-ratio indicates a significant difference between mean reaction times for each reading ($F = 14.536$; $p < .001$; $df = 1/62$).

Discussion:

The results support the prediction that a significant difference in reaction time for ambiguous and unambiguous words on probe tests will arise when the probe is presented during the same simple sentence as the word probed and before a disambiguating context. The findings also validate the concomitant claim that there will be no significant difference between reaction times for ambiguous and unambiguous words when a clause boundary intervenes between the probed item and the

presentation of a probe. These results are compatible with the hypotheses (1) that there is a structural option associated with an ambiguous word which necessitates either a stronger trace strength or easier access to ambiguous words in buffer storages and (2) that decisions about the lexical identity of ambiguous words are made at clause boundaries as well as after a disambiguation.

One puzzling question which remains is why there is a discrepancy between mean reaction times on the two readings of the ambiguous word, since combinations of readings were assigned to subjects arbitrarily. A post hoc analysis can help rationalize these results. It was mentioned that on a pre-test there were many instances in which one reading of an ambiguous item was preferred over the other reading. Of the thirty-two lexically ambiguous nouns, only five were completed an equal number of times in both readings on the pre-test. Of the remaining twenty-seven, eighteen were completed in a way consistent with "reading 1" fewer times than they were completed in a way consistent with "reading 2", and only nine items were completed in the opposite manner. Thus although assignment of readings was arbitrary, it was not at random with respect to the pre-test. "Reading 1" was less suited to the sentential context in which it appeared than "reading 2". In fact, "reading 1" was less appropriate to the context in twice as many sentences as "reading 2". It may be that this caused computational difficulties which rendered the comparison of the probe with the item in the sentence more difficult and thus made for longer reaction times in "reading 1."

A second difficulty with this experiment stems from the fact that the sentences which contained a clause boundary between the ambiguous word and the disambiguating context were not the same as those which contained no clause boundary in that position. The results are therefore confounded with the effects of particular lexical frames.

To eliminate the second problem, a second experiment was run in which the same lexical frames were manipulated so that versions both with and without clause boundaries between the ambiguous word and the disambiguating context appeared in each lexical frame.

Experiment II

Materials: Sixteen lexical frames were devised in which the following variables could be systematically varied. At a certain point in the sentence an ambiguous word or an unambiguous word which meant more or less the same thing occurred. Three syllables further on, a disambiguating context appeared. The interval between the ambiguous word and the disambiguating context either contained a clause boundary (a relative clause or a complement sentence) or it did not (in which case it usually consisted of an expansion of the verb or verb phrase). Thus, each lexical frame represented an octuplet of sentences. A representative octuplet follows; the complete list is to be found in Appendix D.

(28) a. Joe thought the <u>washer</u> would match the <u>bolts</u> he had bought the previous day.

b. Joe thought the <u>washer</u> would match the <u>dryer</u> he had bought the previous day.

c. Joe thought the wrench would match the bolts he had bought the previous day.

d. Joe thought the hoses would match the dryer he had bought the previous day.

e. Joe thought the washer that matched the bolts was very expensive.

f. Joe thought the washer that matched the dryer was too large for his apartment.

g. Joe thought the wrench that matched the bolts was very expensive.

h. Joe thought the hoses that matched the dryer were too large for his apartment.

Sixteen filler sentences were also presented.

In each version of the octuplet, a probe was presented either just before the disambiguating context or just after it. Consequently, there were sixteen possible versions of each lexical frame in all, eight depending upon the particular form of the sentence and two versions of each particular sentence depending upon the position of the probe. The experimental sessions were counter-balanced so that each sentence was presented in only one version on each experimental tape and each subject heard all possible presentation conditions throughout the entire set of sentences. Each subject heard only one reading of the ambiguous word; that is, the experiment was treated as a replication across readings.

The probe words were cross-recorded on the second channel of a two track tape recorder. Just prior to the probe word a thirty millisecond high frequency tone was recorded which activated a millisecond timer. Subjects heard both channels dichotically. They were instructed

to indicate by pushing a lever to one of two positions marked IN or OUT whether they believed that the word which they heard in the opposite ear from the sentence had or had not been in the sentence. They were asked to make their responses as quickly and as accurately as possible and to correct perceived errors verbally.

Subjects: Thirty-two M.I.T. undergraduates and employees took part. All were native English speakers, with good hearing, and were paid for their time. Subjects were asked to return a week later for a second session in which they heard a second stimulus tape. They were not told they would hear a similar tape. The tapes were presented to subjects in such a way that, for each lexical frame, subjects heard both ambiguous and unambiguous items in the two experimental sessions. In half the experimental frames, subjects heard ambiguous items on the first session and in the second half they heard unambiguous words first.

Results: Difference scores for each subject were computed for ambiguous and unambiguous items in each lexical frame (reaction times for unambiguous words were subtracted from reaction times for ambiguous words). Each reading of the ambiguous item was first treated separately. Within each reading, the experimental design was treated as a 2 x 2 within subjects design (<u>absence</u> or <u>presence</u> of a clause boundary between the ambiguous word and the disambiguating context by presentation of the probe <u>before</u> or <u>after</u> the disambiguating context). The full analysis of variance was computed.

Means of the difference scores in the 2 x 2 table for reading 1

are presented in Table VI. Only the main effect for position of probe (before or after the disambiguating context) was significant ($F = 4.837$; $p < .05$; $df = 1/15$). No other main effects or interactions were significant. In the second reading (results tabulated in Table VII) only the main effect for the clause boundary variable (absence or presence of a boundary between the ambiguous word and the disambiguating context) was significant ($F = 4.909$; $p < .05$; $df = 1/15$). No other main effects or interactions were significant. Combining the two readings, (Table VIII), no effects were significant. The highest $\underline{F}$ was obtained for the interaction of position of probe with the clause boundary variable. The difference between mean latencies for the two readings was not significant.

T-tests performed on the 2 x 2 x 2 matrix -- ambiguous/unambiguous, by position of probe, by presence or absence of clause boundary -- showed a significant $\underline{t}$ for the comparison of ambiguous and unambiguous words probed in simple sentences before the disambiguating context ($t = 2.551$; $p < .02$ two-tails; $df = 31$) but not for ambiguous and unambiguous words probed in complex sentences ($t = 0.882$) when both readings were combined. The same pattern of results occurred in both readings individually. In reading 1, the comparison of ambiguous and unambiguous words probed in simple clauses before disambiguation yields a $\underline{t} = 1.703$ ($p < .10$ one-tail; $df = 15$). On the second reading, this comparison yields a $\underline{t} = 1.875$ ($p < .05$ one-tail; $df = 15$). Comparing these items in complex sentences shows the opposite pattern: unambiguous words are slightly faster than ambiguous words but the differences are not statistically significant.

General Discussion

In both dichotic and auditory-visual recognition tasks, latencies to probes were faster for ambiguous words than for unambiguous words, when the probe occurred clause-internally before a disambiguating context.[3] Differences between readings of the ambiguous word were significant in the auditory-visual test, perhaps indicating variations in the likelihood of one reading appearing after the initial fragment of the sentence. In one reading of the auditory-visual test, ambiguous words were recognized faster than unambiguous words when probed in simple sentences even after disambiguation, perhaps arguing that the clause boundary is more important in forcing a choice among possible readings of an ambiguous word than even a disambiguating context is. These uncertainties aside, the results argue that the representation of all lexical items in storage is not uniform but rather depends upon characteristics of an item relevant to decoding operations. In terms of the model presented in Chapter 2, an ambiguous item is not dismissed from tertiary storage (in favour of its semantic reading) until a choice is made among its possible readings. That a choice is made after a subsequent disambiguating context is not surprising. That a choice is made at clause boundaries, however, is not an obvious prediction unless one adopts a clause-by-clause view of sentence decoding.

Notes to Chapter 4

1 It is possible that an ambiguous word is dismissed from tertiary storage in favour of two or more readings. This would predict no differences in trace strength between ambiguous and unambiguous words. This prediction is not born out by the experiments reported here.

2 Absence or presence of a clause boundary is, in fact, nested within the other variables.

3 That ambiguous words do not by themselves produce faster RT was demonstrated in a pre-test. The words in 15 of the stimulus sentences were scrambled, with the ambiguous word (or the unambiguous word replacing it) occupying the same serial position from the beginning of the list as it had in the sentence. Three experimental tapes were constructed, each containing five ambiguous words, five unambiguous words with "reading 1" and five unambiguous words with "reading 2". Ten filler lists were also presented. A probe word was presented visually three syllables later in the string. Twelve M.I.T. students served as subjects, and were asked to say whether the probe had or had not been in the list. No significant differences between RT for any of the classes of probes were found.

Tables for Chapter 4

Table III: Mean Reaction Times (msec) for three-way interaction - ambiguous/unambiguous word by probe before/after disambiguation by absence/presence of clause boundary between probe and ambiguous word. Experiment I, Reading 1

| Clause boundary between probe and probed word | Position of Probe vis-a-vis disambiguation | Ambiguous Word | Unambiguous Word |
|---|---|---|---|
| Absent | Before | 952 | 1005 |
| | After | 967 | 1018 |
| Present | Before | 947 | 950 |
| | After | 1000 | 1006 |

Table IV: Mean Reaction Times (msec) for three-way interaction - ambiguous/unambiguous word by probe before/after disambiguation by absence/presence of clause boundary between Experiment I, Reading 2

| Clause boundary between probe and probed word | Position of Probe vis-a-vis disambiguation | Ambiguous Word | Unambiguous Word |
|---|---|---|---|
| Absent | Before | 769 | 804 |
| | After | 818 | 788 |
| Present | Before | 779 | 790 |
| | After | 800 | 806 |

Table V: Means Reaction Times (msec) for three-way interaction - ambiguous/unambiguous word, by probe before/after disambiguation, by absence/presence of clause boundary between probe and ambiguous word. Experiment I, Readings combined.

| Clause boundary between probe and probed word | Position of Probe vis-a-vis disambiguation | Ambiguous Word | Unambiguous Word |
|---|---|---|---|
| Absent | Before | 850 | 904 |
| | After | 898 | 903 |
| Present | Before | 863 | 870 |
| | After | 900 | 906 |

Table VI: Means for difference scores (msec)
Experiment II, Reading 1

| | | Clause boundary | |
|---|---|---|---|
| | | absent | present |
| Position of probe vis-a-vis disambiguating context | Before | -0.063 | -0.029 |
| | After | 0.103 | 0.038 |

Table VII: Means for different scores (msec)
Experiment II, Reading 2

| | | Clause boundary | |
|---|---|---|---|
| | | absent | present |
| Position of probe vis-a-vis disambiguation | Before | -0.094 | 0.090 |
| | After | -0.012 | 0.022 |

Table VIII: Means for difference scores (msec)
Experiment II,
Readings combined

| | | Clause boundary | |
|---|---|---|---|
| | | absent | present |
| Position of probe vis-a-vis disambiguation | Before | -0.079 | 0.030 |
| | After | 0.045 | 0.030 |

# CHAPTER 5

## THE REPRESENTATION OF ACOUSTIC PARAMETERS IN PERCEPTUAL BUFFERS

Recent experiments (Crowder, 1969 a, b, c, in press; Crowder and Morton, 1969) indicate that for a short time following the verbal presentation of a string of digits certain, if not all, the acoustic properties of that utterance affect the ability of subjects to recall the digits. The experimental situation constructed by these investigators was as follows: a string of nine digits from 1 through 9 inclusive was presented auditorally with an interval of one-half second between each digit. The strings of digits were randomized. After listening to the nine digits the subjects were asked to recall as many of the digits as possible in the order in which the digits appeared. The results (Figure 1) show the familiar serial position effects -- digits at the beginning and end of the string were recalled better than those in the middle.

The authors then conducted a set of experiments in which they added a stimulus suffix at the end of the string of digits. The stimulus suffix consisted of the digit zero. The subjects heard a string of nine randomized digits (as above) and then heard the word zero. They were not required to recall the word zero; they were not even required to listen to the word if they had been able to ascertain that the digit immediately predecing it was indeed the ninth and last. Otherwise, the subjects' task was identical to that in the original experiment.

The subjects' results (Figure 2) showed a different response curve for this task than for the previous one. Digits at the beginning of the string were recalled better than digits in the middle, as before. However, digits at the end of the string were not recalled better than digits in the middle as had happened previously. The digits in the seventh, eighth and ninth positions were recalled with significantly less accuracy than earlier.

The authors then conducted a third experiment using a tone as the stimulus suffix. The response curve (Figure 3) in this case was identical to the response curve in the first experiment.

A fourth experiment used as a stimulus suffix the word zero spoken by someone of the opposite sex from that of the speaker of the digit string. The results (Figure 4) indicate that the last three serial positions (seventh, eight, and ninth position) are affected by the stimulus suffix. Recall of these positions is significantly worse than recall of these positions in the first experiment but significantly better than in the second experiment.

The fifth experiment utilized the word zero spoken in the same voice in which the series of digits was spoken and played backwards as the stimulus suffix. In this condition the subjects responded as they had in the second condition (see Figure 5).

Apparently the addition of a stimulus suffix which is a word spoken by a person reduces recall of the last three positions. Moreover, if the stimulus suffix is spoken in the same voice as that of the speaker of the original string of digits recall is reduced more than if

the stimulus suffix is in the voice of a speaker of the opposite sex. It is not necessary, however, that the stimulus suffix be a word for it to reduce recall of the last three positions. What is necessary is that it be a speech-like sound (such as zero played backwards) spoken by the same speaker as the speaker of the digit string. A tone does not affect performance on this task.

To explain their results, Morton and Crowder claimed that immediately after its presentation, a digit remained in an acoustic storage for a period of time. This acoustic storage can aid recall of that digit. Each succeeding digit partially erases the preceding digit in the acoustic storage. Immediately after the presentation of the digit string subjects are thought to "rehearse" the digit string in their mind before attempting its recall and only those digits occurring in the last three serial positions still have acoustic representations which aid internal rehearsal. Crowder and Morton claimed that since the digits were presented at a rate of two per second and recall of the last three digits was affected, the last second-and-a-half must have remained in the acoustic storage.

The most interesting property of this storage is that it must indeed be acoustic. It cannot be syntactic because there is no particular structural property in a random digit string. It cannot be semantic because the last experiment (stimulus suffix zero played backwards) shows that a speech-like sound which cannot be recognized as a lexical item in English interferes with recall of digits in the last three positions as much as a word from the normal English vocabulary

does. Moreover, the discrepancy between recalled digits in the last three positions for a stimulus suffix in the same voice as the initial digit string and a stimulus suffix in a different voice from the initial digit string indicates that the actual acoustic properties of the suffix play a role in its interference with the recall of digits.

Accepting the hypothesis that acoustic storage is involved in processing auditory signals, one may explore the relationship between this storage and sentence perception. The acoustic storage may operate in the following way: all auditory phenomena including sentences enter acoustic storage for some time and a representation of their acoustic properties is retained. Crowder and Morton's experiments indicate that enough acoustic information is preserved to distinguish the sex of a speaker. One acoustic characteristic of the signal which aids in determining the sex of the speaker is the fundamental frequency of the speaker's voice; hence it is possible that the fundamental frequency is stored. Moreover, it is well known that, in most mechanical algorithms for decoding speech, ascertaining the fundamental frequency of the speaker makes computing the resonant frequencies, distinguishing individual phonemes, and even distinguishing different words easier (John Linber, personal communication). If acoustic storage plays a role in sentence perception it is likely that the fundamental frequency of the signal is preserved.

A set of experiments was designed to determine whether the existence of acoustic storage in short term storage of sentences could be demonstrated with a probe task. As is customary, each stimulus

sentence was presented auditorally, spoken either by a woman or a man. The probe word, which always followed the sentence after a 500 Hz 50 millisecond tone and a 100 millisecond silence, was also spoken either by a woman or a man. Thus, there were four possible conditions: 1) male speaker of the sentence and male speaker of the probe word (MM), 2) female-female (FF), 3) male-female (MF), and 4) female-male (FM). The first two conditions will be called "same" conditions and the last two "different" conditions.

The probe word was not copied from the tape of the sentence and was therefore not an exact replica of the word which appeared in the sentence. However, if the acoustic storage retains a representation of the fundamental frequency of the voice of the speaker of the stimulus sentence, then a subject need not compute the fundamental frequency of a probe word presented in the "same" condition. It should therefore be easier for the subject to determine that the probe is in the sentence when the probe is in the "same" condition than when the probe is in the "different" condition.

A preliminary experiment in which the position of the probe word from the end of the sentence was varied in 26 sentences and the condition of the probe (same or different) was systematically varied for each sentence was designed and run informally. The results indicate that probes are recognized faster in the same condition than in the different condition when the probed word occurs five syllables or fewer from the end of a sentence. These results are consistent with the hypothesis that the last few lexical items in a sentence maintain

some representation of their acoustic properties in short term storage after a listener hears the sentence.

This finding is useful because it broadens the range of possible intra-modal probe tests. One possible experimental paradigm is to present probes in the same and different condition either during or after a sentence.

The probe task requires that a subject say of two phonemically identical, acoustically different strings that they are identical words. He is asked to disregard the general acoustic properties of the probe item and to base his decision on the phonemic analysis. The stronger the internal representation of the acoustic characteristics is the more difficult he will find the task of saying that two words are the same if that judgment must ignore an acoustic parameter.

If the preceding line of argument is correct, one may advance the following hypothesis: reaction times to probes in the same condition may decrease for words in particular positions in sentences and not in other positions or for words belonging to certain grammatical categories and not to others, if such words have strong acoustic traces in perceptual buffers. The following experiments were designed to test both these hypotheses in turn.

Experiment I

We have elaborated a view of sentence perception in which the condition for dismissal of strings from primary storage is the recognition of a second sentence boundary in a complex sentence. If it is also true that the representation of acoustic parameters

of the spoken sentence is unique to primary storage and does not carry over to secondary storage (that is, if primary storage is an "acoustic storage" but secondary storage is not) then the duration of acoustic storage for sentential material should depend on the duration of the final clause of a complex sentence. We therefore hypothesized that probes for a word within the final clause of a complex sentence in the same condition would produce faster reaction times than probes in the different condition and that this would not occur with probes for words before the final clause.

Materials and Precedure: The materials used in this experiment were those previously described in Experiment I, Chapter 3. The reader will recall that six sets of 8 sentences conforming to the following specifications were constructed: each sentence had a subordinate clause followed by a main clause; in two sets of sentences the break between clauses came five syllables from the end of the sentence, in two sets of sentences the break came four syllables from the end of the sentence, and in two sets of sentences the break came three syllables from the end of the sentence; one group of each pair contained words to be probed just before the final clause and one group contained words to be probed within the final clause. The sentences were spoken by experienced male and female speakers and the probes were recorded by the same speakers. Each sentence was recorded either by a male or a female and the probe was recorded by a speaker of the same sex on one experimental tape and a speaker of the opposite sex on the other. Subjects were presented with one

experimental tape. They heard half the sentences in the same condition and half in the different condition. The results of the experiment were re-analyzed with respect to these additional variables.

Results: Besides the significant main effect already specified for position of probed word within or before the final clause there was only one further significant main effect: sentences spoken by males differed significantly from those spoken by females ($F = 10.123$; $p < .01$; $df = 1/10$). The only significant interaction was that between the voice of the speaker of the sentence (male-female) and the condition of the probe (same-different) ($F = 14.817$; $p < .01$; $df = 1/10$). The reason for these differences may be that only males served as subjects or that there was an interaction of voicing and the particular lexical material of each sentence. These findings do not bear on the hypothesis. The interaction between same and different voice conditions and probes before and within the final clause is not significant.

Experiment II

Materials and Procedure: The materials used in Experiment III, Chapter 3, were re-analyzed. The reader will recall that pairs of sentences containing acoustically and lexically identical material but differing in the syntactic analysis of at least one word in the last few syllable positions (<u>within</u> or <u>before</u> the final clause) were presented to subjects. The materials were also prepared so that the sentences were spoken by male and female speakers and the

probes were presented in both male and female voices. Each sentence appeared in all possible conditions (M-M, M-F, F-F, F-M) across all the stimulus tapes. One version of each sentence was presented to each subject. The results of the previous experiment were re-analyzed with respect to these additional variables.

Results: There were no significant main effects other than for probes within the final clause compared to probes before the final clause (as reported before). There were no significant interactions.

General Discussion: The results in both these experiments give no support to the hypothesis that only the final clause of a complex sentence remains in acoustic storage while a sentence is being processed. Put differently, the results indicate that the duration of acoustic storage cannot simply be seen as the duration of material in primary storage. Since previous experimentation showed that words in the same condition produce faster reaction times than probes in the different condition for words occurring five syllables or fewer from the end of the sentence, the results of these two experiments should be taken to indicate that the duration of acoustic storage is not linguistically marked by the boundaries of clauses in a complex sentence. Thus the most obvious "position" variable -- the position of a word vis-à-vis a clause boundary -- does not produce differences in this test for acoustic storage effects.

Experiment III

We have concluded that the duration of acoustic storage is

not determined by the duration of the final clause of a complex sentence. An explanation of this finding may be that not all classes of lexical items have equal acoustic traces in perceptual buffers. If there is a complex interaction between linguistic structure, acoustic storage, and decoding routines, a probe test may only show differences between the same and different voice conditions for certain classes of words in particular structural contexts.

It has been argued (Chapter 2) that determination of the grammatical relations of words in a clause and of the relation between clauses in a complex sentence is accomplished largely on the basis of the subcategorization features of the verbs in the sentence. The operations of the secondary storage can "dismiss" nouns as soon as their syntactic features are ascertained but must maintain a representation of the verb and its syntactic analysis until a decision has been reached as to which of the subcategorizations of the verb is instantiated in the sentence. Therefore the trace strength of verbs should be stronger than that of nouns and one may thus hypothesize that recognition latencies for verbs will be lower than those for nouns. This hypothesis, however, is subject to an important qualification. If the acoustic trace of a verb is sufficiently strong, it may facilitate recognition of a probe in the same condition and make the recognition of a probe in the different condition more difficult. In this case, recognition latencies for verbs will be low when the probe is in the same condition and high when the probe is in the different condition. There will be no main effects for either a verb/noun variable or a same/different

variable, but the interaction of the two will be significant.

Materials and Procedure: The materials used in Experiment I, Chapter 3 (which were re-analyzed in Experiment I in this chapter) were analyzed a third time. In addition to the variables of position of clause boundary from the end of the sentence, position of probed word within or before the final clause, and voice condition (same/different) of the probe, equal numbers of nouns and verbs were probed in each group of sentences.

Results: Besides the main effects already reported for position of probed word within or before the final clause and the speaker (male or female) of the sentence, there were no significant main effects. Nouns did not differ significantly from verbs. Nor were there any significant two-way interactions when one examined the variables noun/verb in the full analysis of variance. The three way interaction between the voice condition (same or different), position of probe vis-a-vis the major syntactic break (within or before the final clause), and form class (verb or noun) was significant ($F = 11.394$; $p < .01$; $df = 1/10$). The mean reaction times for probes presented in each of these conditions are shown in Table IX. T-tests indicate that latencies for verbs internal to the last clause in the same condition were significantly lower than those for verbs in the different condition ($t = 3.166$; $p < .02$; two-tailed; $df = 10$). These results strongly suggest that at least one source of the significance of the interaction is the RT difference between verbs in the same and different conditions within the final clause. This is not the case

for nouns either within or before the final clause or for verbs before the final clause.

Discussion: That verbs did not produce significantly lower reaction times than nouns is related to the fact that verbs were recognized significantly faster in the same condition than in the different condition. Apparently, the existence of a strong acoustic trace not only facilitates comparison of a probe with the same general acoustic properties (i.e., in the same voice condition) but also renders more difficult the comparison of a probe which has generally different acoustic properties (i.e., in the different voice condition). The combined reaction times for verbs in the same and different condition are therefore about the same as those for nouns, and verbs are recognized faster in the same than in the different condition. This effect occurs only in the final clause, however, arguing that grammatical relations are computed by routines which process one clause at a time and thus maintain a strong acoustic trace of only the verb of the final clause of a complex sentence.

Experiment IV

Materials and procedure: A replication of this experiment was attempted with another group of sentences. Two groups of ten sentences each were constructed (Appendix E). One group contained nouns to be probed which were the subject of the last clause of the stimulus sentence and were located five or fewer syllables from the end. The second group contained verbs to be probed which were verbs of the last

clause and also occupied positions five syllables or fewer from the end of the sentence. The sentences and probes were presented in all four voice combinations (across four tapes) and each subject heard one tape. Sixteen filler sentences were used. Sixteen subjects took part, all M.I.T. students, native English speakers, with good hearing. Their task was as before.

Results: The full analysis of variance (2 x 2 within-subjects design) showed no significant main effects. The interaction for form class by voice condition (NV by same-different) just failed to be significant at the .05 level ($F = 4.311$; $p < .10$; $df = 1/15$; for $p < .05$, F must = 4.54). The means in this interaction are displayed in Table X. This is perhaps the classical interaction: verbs are much faster in the same condition than in the different condition, whereas nouns are faster in the different condition than in the same condition. The results combine to yield no significant main effects for form class or voice condition. T-tests conducted on the same set of data indicate a significant difference between verbs in the same and different conditions ($t = 1.933$; $p < .05$ 1-tailed test; $df = 15$).

Discussion: This finding supports the notion that verbs have stronger acoustic traces in secondary storage than nouns do (as measured by lower recognition latencies for verbs in the same than in the different condition). The results of this experiment, as well as those of Experiment III, are confounded with the effects of lexical materials, since different sentences were used to test nouns and verbs. Therefore, a third experiment was designed to control

for these effects.

Experiment V

Materials and Procedure: Sixteen pairs of sentences were constructed to incorporate a category-ambiguous lexical item (one which could be either a noun or a verb) at a position not more than six syllables from the end of the sentence. (Appendix F) The sentence fragment initiating the sentence (up to the position of the category-ambiguous word) varied so as to force an interpretation of the word as either a noun or a verb. The sentence fragment following the category-ambiguous word was identical in both members of the pair:

(29) a. The writers decided to continue to <u>work</u> on their new book.

b. The writers decided to continue the <u>work</u> on their new book.

The sentences were recorded by experienced male and female speakers on a Master Tape. Experimental tapes were prepared so that equal numbers of nouns and verbs and equal numbers of same and different voice conditions of the probe were presented to each subject. Each sentence type appeared only once on an experimental tape, and all sixteen sentences appeared in all possible conditions across all the experimental stimulus tapes. Sixteen filler sentences were also used. The probe always followed the presentation of the sentence, separated by a 50 millisecond 500 Hz tone and 100 milliseconds of leader tape.

Subjects were asked to indicate by pushing a lever whether they thought the probe had been in the sentence or not. They were instructed to aim for speed and accuracy and to correct perceived errors verbally.

Subjects: Sixteen M.I.T. students and staff took part and were paid for their time. All were native English speakers and had good hearing.

Results: The experiment was treated as a 2 x 2 x 2 within-groups design: noun/verb, by same/different voice condition of probe, by male/female speaker of the sentence. No main effects or interactions were significant.

General Discussion: The failure of Experiment V to produce significant results for the interaction of the noun/verb and same/different variables requires that one advance conclusions tentatively. The lack of results in Experiment V may be (partially) caused by the fact that derived nouns have the same subcategorization features as their associated verbs (Chomsky, 1970). More work is necessary to determine whether the results of Experiments III and IV can be accepted. If the results are to be accepted, they would seem to show that verbs have a strong acoustic trace in perceptual buffers compared to nouns, a finding which is consistant with the view of sentence decoding which maintains that grammatical relations are assigned in sentences largely on the basis of the subcategorization of the verb.

Figures and Tables for Chapter 5

Figure 1: Recall of digits, no stimulus suffix

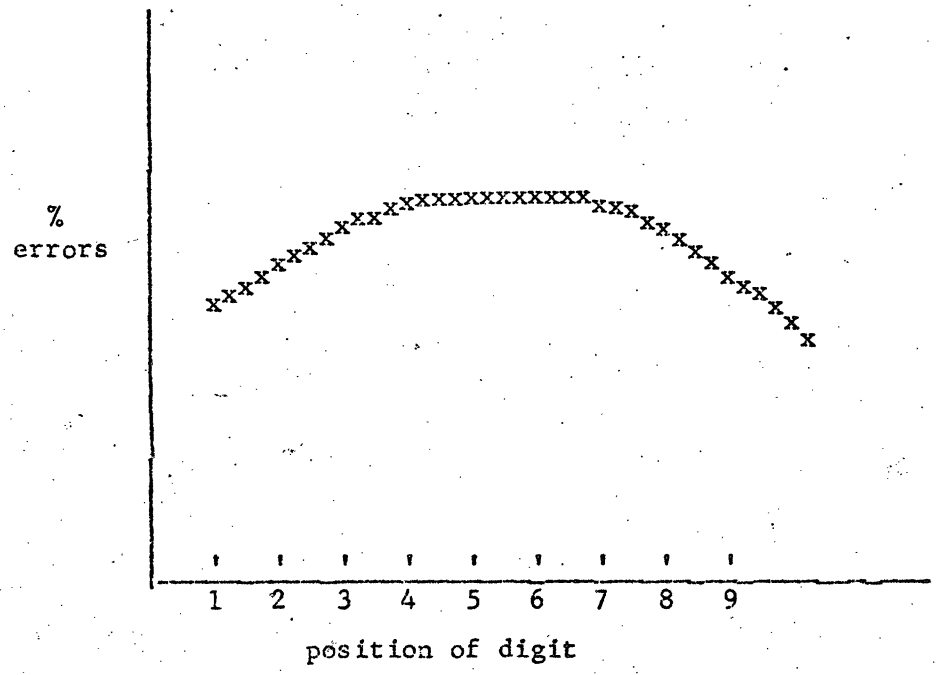


Figure 2: Recall of digits, stimulus suffix = "zero" in same voice as digits

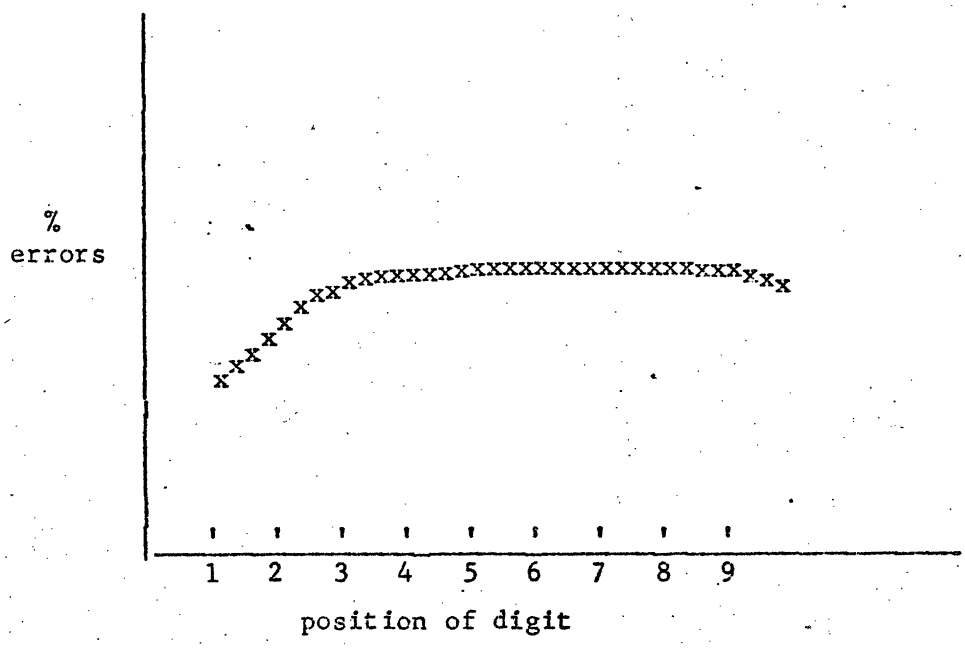


Figure 3: Recall of digits, stimulus suffix = tone

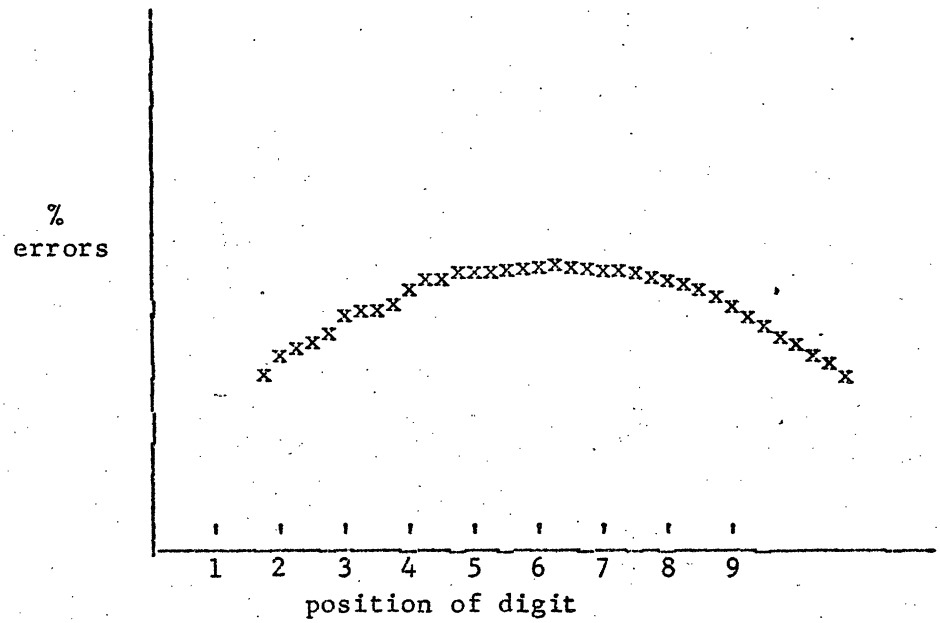


Figure 4: Recall of digits, stimulus suffix = "zero" in opposite voice from digits

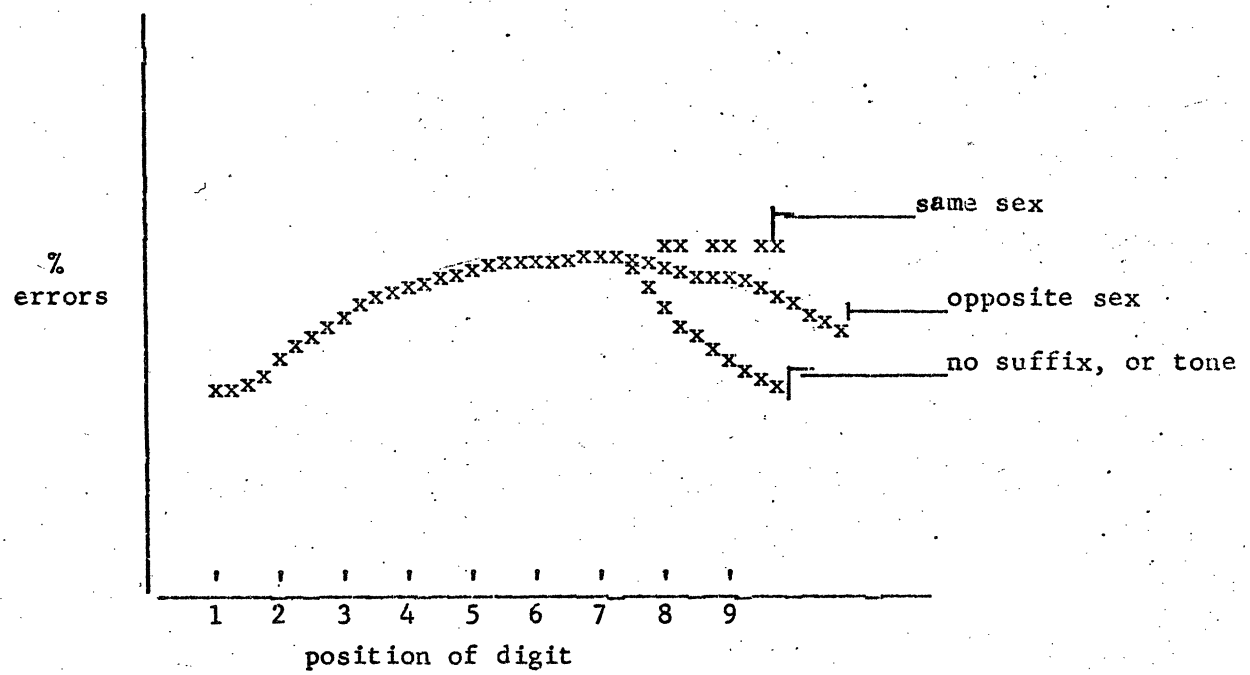


Figure 5: Recall of digits, stimulus suffix = "zero" played backward in same voice as digits

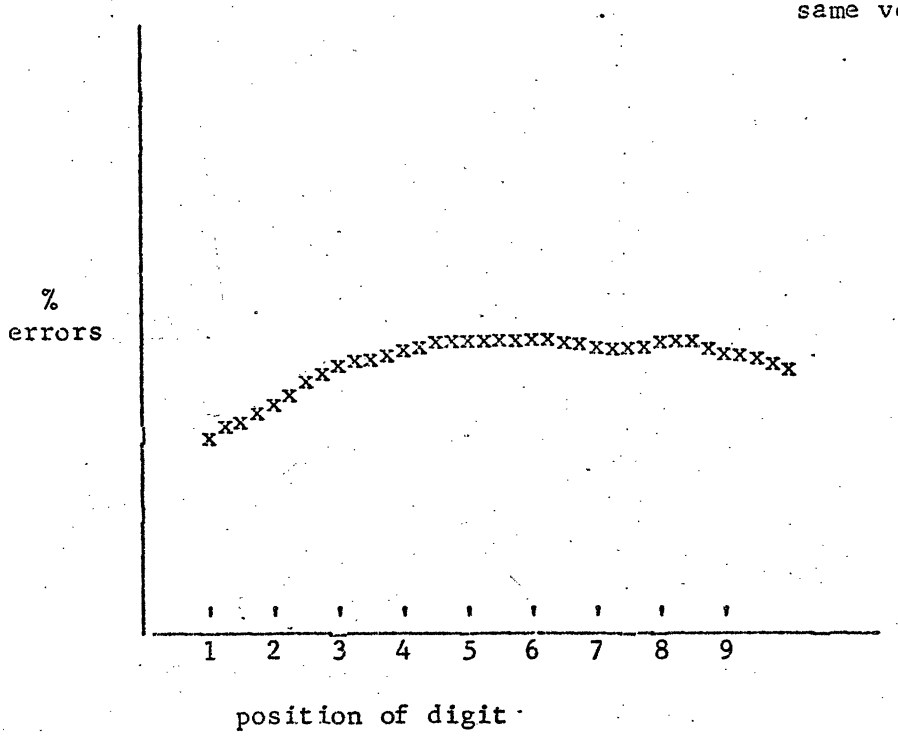


Table IX: Mean Reaction Times (msec) for three-way interaction: Noun/Verb Out/In by same/different. Experiment III

| | | IN | OUT |
|---|---|---|---|
| NOUNS | Same | 420 | 429 |
| | Diff | 400 | 454 |
| VERBS | Same | 395 | 475 |
| | Diff | 473 | 446 |

Table X: Mean Reaction Times (msec) for two-way interaction: Noun/Verb by same/different. Experiment IV

| | SAME | DIFF |
|---|---|---|
| NOUNS | 740 | 720 |
| VERBS | 715 | 747 |

# CHAPTER 6

## CONCLUDING NOTE

The problem posed at the outset of this dissertation was to specify the relationship of a grammar to the perception of sentences. It was argued that progress in this area must await the statement and motivation of a set of heuristics which accomplish at least a preliminary analysis of a sentence. Whether the heuristics are capable of accomplishing all of sentence perception or whether an internal synthetic device utilizing a generative grammar directly is needed cannot be decided until the heuristics are better understood. Likewise, whether the heuristics are related to structures and operations specified by a grammar or not can only be ascertained after the heuristics are developed.

Chapters 2 - 5 have attempted to motivate a certain set of decoding heuristics. It is clear that the statement of these heuristics is not completely unambiguous and that the evidence for their role in perception, while suggestive, is not definitive. More work must be done in both these areas. More important, however, is the consequence of accepting these heuristics for the answers to the questions posed above.

It is impossible to answer the question of the total adequacy of the heuristics on the basis of the formulation presented here. If it is possible to construct a cross-classification of surface structures in terms of the deep structures from which they arise, then a set of

decoding heuristics which utilizes this cross-classification can compute the same deep structure for a given sentence as a matching device can. If it is possible to decide among possible deep structures compatible with the surface structure of an incoming sentence on the basis of the subcategorization and selectional restriction features of the verbs in the sentence, then heuristics utilizing this information will be able to determine the particular deep structure instantiated in any given sentence. Thus, it is conceivable that heuristics developed along the lines suggested in this dissertation could accomplish all of sentence decoding. The fact is, however, that at present no cross-classification of surface structures in terms of the deep structures from which they arise is forthcoming, nor is it clear how to decide among possible deep structures on the basis of the lexical structure of verbs. These are unsolved theoretical problems in psycholinguistics, and the research reported here does not bear on them.

On the other hand, the research presented in this dissertation does add to the motivation for adopting one particular set of decoding heuristics. The primacy of clauses as units which are moved between perceptual storage areas, the importance of clause boundaries as points at which decisions about lexical ambiguities are made, and the strong acoustic trace of verbs in decoding buffers argue for the adoption of heuristics in which clauses are perceptual units and verbs play a critical role. Clearly, it is just such a set of heuristics which is being proposed. The results also rule out any set of heuristics

which do not utilize grammatical information. It is hard to see how a "functional" theory could explain these results in a non ad hoc way without reference to certain aspects of a grammar and grammatical descriptions.

The experimental work has shown that there is a rich system of decoding storages and operations which operates in ways not obviously predictable from the form of current grammars. That one cannot predict the form of man's perceptual system from the form of a grammar is not surprising. A grammar is a representation of linguistic competence and not of the performance system utilizing that competence. An adequate theory of language, however, must be concerned with both competence and performance. The type of research reported here should be of interest to linguists as well as psychologists, to the extent that they are interested in the psychological mechanisms which enable man to utilize the powerful systems of symbol organization described in grammars.

# APPENDIX A

## Intra-modal and Cross-modal test for Clause Boundary Effects

### Major Break 5 Syllables from end; Probe BEFORE last clause

| | | |
|---|---|---|
| 1. | Every time we visit friends, we bring them liquor. | FRIENDS |
| 2. | If enough money is raised, we'll stop pollution. | RAISED |
| 3. | If my husband comes in time, we'll buy some new clothes. | TIME |
| 4. | When you go to France to live, you'll learn to like cheese. | LIVE |
| 5. | Unless you want beans for lunch, don't eat at Eddie's | LUNCH |
| 6. | No matter how hard we push, we'll never move it. | PUSH |
| 7. | If you liked his first novel, you should read this one. | NOVEL |
| 8. | Unless a great change occurs, all our stocks will fall. | OCCURS |

### Major Break 5 Syllables from end; Probe WITHIN last clause

| | | |
|---|---|---|
| 1. | When interest rates fall on bonds, stocks also go down. | STOCKS |
| 2. | If you visit Chicago, see the stock-yard gates. | SEE |
| 3. | To see the movie actress, men stood on car roofs. | MEN |
| 4. | Unless the wine is too cold, put it back on ice. | PUT |
| 5. | Even though the book is old, parts are still modern. | PARTS |
| 6. | If you want to gain more strength, eat proteins daily. | EAT |
| 7. | Whenever you need a loan, banks are most helpful. | BANKS |
| 8. | Before you sign a new lease, check all the fine print. | CHECK |

### Major Break 4 Syllables from end; Probe BEFORE last clause

| | | |
|---|---|---|
| 1. | Though the forecast calls for more rain, the sun is out. | RAIN |
| 2. | Whenever my wife cleans and cooks, I give her gifts. | COOKS |
| 3. | When a pitcher throws a curve ball, his body turns. | BALL |
| 4. | No matter what the students say, they will all pass. | SAY |

| | | |
|---|---|---|
| 5. | Although we don't get good results, we keep trying. | RESULTS |
| 6. | Every time my friend tried to phone, I wasn't in. | PHONE |
| 7. | Unless this line is drawn in ink, it will soon fade. | INK |
| 8. | Even if the soup does improve, you can't eat it. | IMPROVE |

Major Break 4 Syllables from the end; Probe WITHIN last clause

| | | |
|---|---|---|
| 1. | If Jane plays any Beatles' songs, guests will soon leave. | GUESTS |
| 2. | If Sue decides to ask for help, give her this book. | GIVE |
| 3. | If you want to kick a field goal, hold the ball straight. | HOLD |
| 4. | Though no-one appeared friendlier, fights were ended. | FIGHTS |
| 5. | Whenever it rains very hard, trees seem greener. | TREES |
| 6. | If the wine is exposed to air, drink it at once. | DRINK |
| 7. | No matter what these reports say, planes are quite cheap. | PLANES |
| 8. | If you need some more exercise, run fifty yards. | RUN |

Major Break 3 Syllables from end; Probe BEFORE last clause

| | | |
|---|---|---|
| 1. | Even if the rain never does stop, we will leave. | STOP |
| 2. | Once you learn a new way to lose weight, let Jane know. | WEIGHT |
| 3. | No matter how carefully you scheme, crime won't pay. | SCHEME |
| 4. | Whenever this man wants a new coat, he calls us. | COAT |
| 5. | No matter how little you do drive, tires wear out. | DRIVE |
| 6. | Unless John says he phoned up his girl, don't ask him. | GIRL |
| 7. | If this book says those tacks will hold, buy some now. | HOLD |
| 8. | Although the patient now wants a cure, he must wait. | CURE |

Major Break 3 Syllables from end; Probe WITHIN last clause

| | | |
|---|---|---|
| 1. | Whenever this goalie stops the puck, fans go wild. | FANS |
| 2. | Unless your plan is new and daring, change it now. | CHANGE |
| 3. | When management does not raise wages, strikes result. | STRIKES |
| 4. | If you want friends to think you are rich, serve good Scotch. | SERVE |
| 5. | No matter how you try to clean it, lint stays on. | LINT |
| 6. | Even though the question is minor, think it through. | THINK |
| 7. | Though some disagreements still exist, peace is near. | PEACE |
| 8. | When this batter hits a hard line drive, watch him run. | WATCH |

## APPENDIX B

Intra-modal and Cross-modal test for Clause Boundary Effects
(Control for Lexical Material and Intonation)

1. Now that artists are working in oil, prints are rare. OIL

   Now that artists are working fewer hours, oil prints are rare

2. Although we still have not had any snow, storms are expected. SNOW

   Because the weather is cold and damp, snow storms are expected.

3. Because cassettes are so popular, tapes are cheap. POPULAR

   Because cassettes are available, popular tapes are cheap.

4. When the granite blocks are very big, cranes lift them. BIG

   When the granite blocks are raised, big cranes lift them.

5. Even though the TV set is old, parts of it work well. OLD

   This TV set was just checked and old parts of it work well.

6. When the sun warms the earth after the rain, clouds soon disappear. RAIN

   When a high pressure front approaches, rain clouds soon disappear.

7. Although the total volume of their business is quite small, country stores survive. SMALL

   Because their clientel is faithful to them, small country stores survive.

8. Whenever one telephones at night, rates are lower. NIGHT

   Make your calls after six, because night rates are lower.

9. Unless the temperature drops below freezing, rain will fall. FREEZING

   Unless the storm center moves farther north, freezing rain will fall.

10. If the results of research are successful, businesses start up. SUCCESSFUL

    When the government restricts imports, successful businesses start up.

11. Even though their representative is old, voters like him. OLD

    Because their representative does them favours, old voters like him.

12. When the school principal decided to become more strict, dress codes were set up. STRICT

    At the request of several conservative parents, strict dress codes were set up.

13. If you allow them to become wet, shoes will not last. WET

    Even when the workmanship is excellent, wet shoes will not last.

14. If you expose these drapes to the light, colours will fade. LIGHT

    Unless you give them a good second coat, the light colours will fade.

15. If you handle animals in your work, clothes get dirty. WORK

    No matter how much care you take, work clothes get dirty.

16. Because they are extremely slow, busses are safe. SLOW

    Although riding in them is not very comfortable, slow busses are safe.

# APPENDIX C

## Cross-modal Ambiguity Study

### (i) No sentence break between ambiguous item and disambiguating context

1. Harvey found the old record easy to surpass, so he hardly trained at all.
   Harvey found the old record really quite easy to surpass, so he hardly trained at all.
   Harvey found the old performance easy to surpass, so he hardly trained at all.
   Harvey found the old performance really quite easy to surpass, so he hardly trained at all.

   Harvey found the old record easy to play on his new hi-fi stereo.
   Harvey found the old record really quite easy to play on his new hi-fi stereo.
   Harvey found the old song easy to play on his new hi-fi stereo.
   Harvey found the old song really quite easy to play on his new hi-fi stereo.

2. Michael suspected that a bigger range might permit bacon to be cooked more easily.
   Michael suspected that a bigger range might be needed for his bacon to be cooked more easily.
   Michael suspected that a bigger stove might permit bacon to be cooked more easily
   Michael suspected that a bigger stove might be needed for his bacon to be cooked more easily.

   Michael suspected that a bigger range might permit conclusions to be validated.
   Michael suspected that a bigger range might be needed for his conclusions to be validated.
   Michael suspected that a bigger sample might permit conclusions to be validated.
   Michael suspected that a bigger sample might be needed for his conclusions to be validated.

3. John thought the seal would keep the envelope tightly closed.
   John thought the seal would probably keep the envelope tightly closed.
   John thought the glue would keep the envelope tightly closed.
   John thought the glue would probably keep the envelope tightly closed.

   John thought the seal would keep the ball on his nose.
   John thought the seal would probably keep the ball on his nose.
   John thought the bear would keep the ball on his nose.
   John thought the bear would probably keep the ball on his nose.

4. In chemistry class the solution seemed hard to remember since it was so closely argued.
In chemistry class the solution seemed clear and easy to remember since it was so closely argued.
In chemistry class the answer seemed hard to remember since it was so closely argued.
In chemistry class the answer seemed clear and easy to remember since it was so closely argued.

In chemistry class the solution seemed hard to filter after the instructor made it.
In chemistry class the solution seemed clear and easy to filter after the instructor made it.
In chemistry class the mixture seemed hard to filter after the instructor made it.
In chemistry class the mixture seemed clear and easy to filter after the instructor made it.

5. The child pulled the plug out of the sink in the kitchen.
The child pulled the plug rapidly out of the sink in the kitchen.
The child pulled the stopper out of the sink in the kitchen.
The child pulled the stopper rapidly out of the sink in the kitchen.

The child pulled the plug out of the socket in the kitchen.
The child pulled the plug rapidly out of the socket in the kitchen.
The child pulled the cord out of the socket in the kitchen.
The child pulled the cord rapidly out of the socket in the kitchen.

6. Joe thought the washer would match the screws he had bought the previous day.
Joe thought the washer would probably match the screws he had bought the previous day.
Joe thought the bolts would match the screws he had bought the previous day.
Joe thought the bolts would probably match the screws he had bought the previous day.

Joe thought the washer would match the dryer he had bought the previous day.
Joe thought the washer would probably match the dryer he had bought the previous day.
Joe thought the attachments would match the dryer he had bought the previous day.
Joe thought the attachments would probably match the dryer he had bought the previous day.

7. The doctor was sure that his pupil appeared to enlarge as a result of the drugs.
The doctor was sure that his pupil would continually enlarge as a result of the drugs.
The doctor was sure that his eyelid appeared to enlarge as a result of the drugs.
The doctor was sure that his eyelid would continually enlarge as a result of the drugs.

The doctor was sure that his pupil appeared to flunk the regional exams.
The doctor was sure that his pupil would continually flunk the regional exams.
The doctor was sure that his student appeared to flunk the regional exams.
The doctor was sure that his student would continually flunk the regional exams.

8. They filled the vacant chair with a new appointment in record time.
They filled the vacant chair with yet another new appointment in record time.
They filled the vacant job with a new appointment in record time.
They filled the vacant job with yet another new appointment in record time.

They filled the vacant chair with a new cushion they bought on sale.
They filled the vacant chair with yet another new cushion they bought on sale.
They filled the vacant bench with a new cushion they bought on sale.
They filled the vacant bench with yet another new cushion they bought on sale.

9. Finding a ring of deep-set dirt on the side of the tub annoyed Ted's aunt.
Finding a ring of deep-set, finely ground dirt on the side of the tub annoyed Ted's aunt.
Finding a layer of deep-set dirt on the side of the tub annoyed Ted's aunt.
Finding a layer of deep-set, finely ground dirt on the side of the tub annoyed Ted's aunt.

Finding a ring of deep-set gems at the jewelers delighted the young woman.
Finding a ring of deep-set, finely ground gems at the jewelers delighted the young woman.
Finding a necklace of deep-set gems at the jewelers delighted the young woman.
Finding a necklace of deep-set, finely ground gems at the jewelers delighted the young woman.

10. I was thankful that the cold had missed my throat, thus letting me perform that night.
I was thankful that the cold had not affected my throat, thus letting me perform that night.
I was thankful that the virus had missed my throat, thus letting me perform that night.
I was thankful that the virus had not affected my throat, thus letting me perform that night.

I was thankful that the cold had missed my crops and had not been able to destroy them.
I was thankful that the cold had not affected my crops and had not been able to destroy them.
I was thankful that the fire had missed my crops and had not been able to destroy them.
I was thankful that the fire had not affected my crops and had not been able to destroy them.

11. Sue thought that the waves in the new hairdo were quite becoming.
Sue thought that the waves in the very latest hairdo were quite becoming.
Sue thought that the curls in the new hairdo were quite becoming.
Sue thought that the curls in the very latest hairdo were quite becoming.

Sue thought that the waves in the new storm were quite dangerous.
Sue thought that the waves in the very latest storm were quite dangerous.
Sue thought that the winds in the new storm were quite dangerous.
Sue thought that the winds in the very latest storm were quite dangerous.

12. To make a strong base for a good soup use tomato concentrate.
To make a strong base for a good, old-fashioned soup use tomato concentrate.
To make a strong broth for a good soup use tomato concentrate.
To make a strong broth for a good, old-fashioned soup use tomato concentrate.

To make a strong base for a good cabinet use mahogany plywood.
To make a strong base for a good, old-fashioned cabinet use mahogany plywood.
To make a strong shelf for a good cabinet use mahogany plywood.
To make a strong shelf for a good, old-fashioned cabinet use mahogany plywood.

13. The Marine commander worried about his position high on the hierarchy running the company.
The Marine commander worried about his position near the bottom of the hierarchy running the company.
The Marine commander worried about his status high on the hierarchy running the company.
The Marine commander worried about his status near the bottom of the hierarchy running the company.

The Marine commander worried about his position high on the mountain close to the enemy camp.
The Marine commander worried about his position near the bottom of the mountain close to the enemy camp.
The Marine commander worried about his location high on the mountain close to the enemy camp.
The Marine commander worried about his location near the bottom of the mountain close to the enemy camp.

14. Joyce thought the match between the tennis players would end in a draw.
Joyce thought the match between the very large tennis players would end in a draw.
Joyce thought the contest between the tennis players would end in a draw.
Joyce thought the contest between the very large tennis players would end in a draw.

Joyce thought the match between the logs would start the fire quickly.
Joyce thought the match between the very large logs would start the fire quickly.
Joyce thought the twigs between the logs would start the fire quickly.
Joyce thought the twigs between the very large logs would start the fire quickly.

15. John removed the scales from his wife's bathroom when the fat guest arrived.
John removed the scales very quickly from the bathroom when the fat guest arrived.
John removed the mirror from his wife's bathroom when the fat guest arrived.
John removed the mirror very quickly from the bathroom when the fat guest arrived.

John removed the scales from his wife's fish to help prepare dinner.
John removed the scales very quickly from the fish to help prepare dinner.
John removed the fins from his wife's fish to help prepare dinner.
John removed the fins very quickly from the fish to help prepare dinner.

16. The lawyer thought the case contained the cigarettes he had been looking for.

The lawyer thought the case probably contained the cigarettes he had been looking for.

The lawyer thought the carton contained the cigarettes he had been looking for.

The lawyer thought the carton probably contained the cigarettes he had been looking for.

The lawyer thought the case contained the precedent he had been looking for.

The lawyer thought the case probably contained the precedent he had been looking for.

The lawyer thought the trial contained the precedent he had been looking for.

The lawyer thought the trial probably contained the precedent he had been looking for.

(ii) Sentence boundary between ambiguous item and disambiguating context

1. The men wanted a strike to win their bowling game against the archrivals.
The men wanted a strike to ensure winning their bowling game against the archrivals.
The men wanted a spare to win their bowling game against the archrivals.
The men wanted a spare to ensure winning their bowling game against the archrivals.

The men wanted a strike to win their demands for increased retirement pay.
The men wanted a strike to ensure winning their demands for increased retirement pay.
The men wanted a slowdown to win their demands for increased retirement pay.
The men wanted a slowdown to ensure winning their demands for increased retirement pay.

2. The president wanted the important office filled with new appointees in two weeks.
The president wanted the important office filled with very different appointees in two weeks.
The president wanted the important committee filled with new appointees in two weeks.
The president wanted the important committee filled with very different appointees in two weeks.

The president wanted the important office filled with new furniture in two weeks.
The president wanted the important office filled with very different furniture in two weeks.
The president wanted the important lounge filled with new furniture in two weeks.
The president wanted the important lounge filled with very different furniture in two weeks.

3. They decided to open up the chest to look for cancerous lung tissue.
They decided to open up the chest in order to look for cancerous lung tissue.
They decided to open up the throat to look for cancerous lung tissue.
They decided to open up the throat in order to look for cancerous lung tissue.

They decided to open up the chest to look for cigars and tobacco.
They decided to open up the chest in order to look for cigars and tobacco.
They decided to open up the box to look for cigars and tobacco.
They decided to open up the box in order to look for cigars and tobacco.

4. Mark tried to cut the dirty nails using the scissors he bought at the 5 and 10.
Mark tried to cut the dirty nails using the expensive scissors he bought at the 5 and 10.
Mark tried to cut the dirty hangnails using the scissors he bought at the 5 and 10.
Mark tried to cut the dirty hangnails using the expensive scissors he bought at the 5 and 10.

Mark tried to cut the dirty nails using the plyers he bought at the 5 and 10.
Mark tried to cut the dirty nails using the expensive plyers he bought at the 5 and 10.
Mark tried to cut the dirty screws using the plyers he bought at the 5 and 10.
Mark tried to cut the dirty screws using the expensive plyers he bought at the 5 and 10.

5, The lecturer liked the stand that had been enunciated by the President.
The lecturer liked the stand that had been carefully enunciated by the President.
The lecturer liked the policy that had been enunciated by the President.
The lecturer liked the policy that had been carefully enunciated by the President.

The lecturer liked the stand that had been built for the ceremony.
The lecturer liked the stand that had been carefully built for the ceremony.
The lecturer liked the podium that had been built for the ceremony.
The lecturer liked the podium that had been carefully built for the ceremony.

6. I wanted the paper to hide the facts that might upset my father.
I wanted the paper to hide the disgraceful facts that might upset my father.
I wanted the report to hide the facts that might upset my father.
I wanted the report to hide the disgraceful facts that might upset my father.

I wanted the paper to hide the spots on the living room walls.
I wanted the paper to hide the disgraceful spots on the living room walls.
I wanted the paint to hide the spots on the living room walls.
I wanted the paint to hide the disgraceful spots on the living room walls.

7. The official adopted his stance to block the success of the rent-control bill.
The official adopted his stance to block the oncoming success of the rent-control bill.
The official adopted his view to block the success of the rent-control bill.
The official adopted his views to block the oncoming success of the rent-control bill.

The official adopted his stance to block the students from entering the hall.
The official adopted his stance to block the oncoming students from entering the hall.
The official adopted his pose to block the students from entering the hall.
The official adopted his pose to block the oncoming students from entering the hall.

8. The general filled the tanks with gas to store fuel during the attack.
The general filled the tanks with gas in order to store fuel during the attack.
The general filled the barrels with gas to store fuel during the attack.
The general filled the barrels with gas in order to store fuel during the attack.

The general filled the tanks with gas to deploy them against the enemy.
The general filled the tanks with gas in order to deploy them against the enemy.
The general filled the jeeps with gas to deploy them against the enemy.
The general filled the jeeps with gas in order to deploy them against the enemy.

9. Jack bought a new file today to store all his old research papers.
Jack bought a new file today in order to store all his old research papers.
Jack bought a new desk today to store all his old research papers.
Jack bought a new desk today in order to store all his old research papers.

Jack bought a new file today to smooth his metal cabinet.
Jack bought a new file today in order to smooth his metal cabinet.
Jack bought a new shellac today to smooth his metal cabinet.
Jack bought a new shellac today in order to smooth his metal cabinet.

10. Jack bought new glasses for Sue to wear with her new dress.
Jack bought new glasses for his fiancee to wear with her new dress.
Jack bought new earrings for Sue to wear with her new dress.
Jack bought new earrings for his fiancee to wear with her new dress.

Jack bought new glasses for Sue to use when guests dropped in.
Jack bought new glasses for his fiancee to use when guests dropped in.
Jack bought new ashtrays for Sue to use when guests dropped in.
Jack bought new ashtrays for his fiancee to use when guests dropped in.

11. The pilots created a storm by quickly striking for much higher wages.
The pilots created a storm by continually striking for much higher wages.
The pilots created a backlash by quickly striking for much higher wages.
The pilots created a backlash by continually striking for much higher wages.

The pilots created a storm by quickly seeding the clouds at high altitudes.
The pilots created a storm by continually seeding the clouds at high altitudes.
The pilots created a hailstorm by quickly seeding the clouds at high altitudes.
The pilots created a hailstorm by continually seeding the clouds at high altitudes.

12. They need new clubs for us to hold during the play.
They need new clubs for the actresses to hold during the play.
They need new props for us to hold during the play.
They need new props for the actresses to hold during the play.

They need new clubs for us to join for recreation.
They need new clubs for the actresses to join for recreation.
They need new groups for us to join for recreation.
They need new groups for the actresses to join for recreation.

13. Frank studies bats to be a baseball coach by understanding the game.
Frank studies bats to become a better baseball coach by understanding the game.
Frank studies batting to be a baseball coach by understanding the game.
Frank studies batting to become a better baseball coach by understanding the game.

Frank studies bats to be a biologist who deals with animal vision.
Frank studies bats to become a better biologist whodeals with animal vision.
Frank studies rodents to be a biologist who deals with animal vision.
Frank studies rodents to become a better biologist whodeals with animal vision.

14. Finding the broken pipe kept us from smoking any more that day.
Finding the broken pipe kept the principal from smoking any more that day.
Finding the broken lighter kept us from smoking any more that day.
Finding the broken lighter kept the principal from smoking any more that day.

Finding the broken pipe kept us from watering the lawn that day.
Finding the broken pipe kept the principal from watering the lawn that day.
Finding the broken hoses kept us from watering the lawn that day.
Finding the broken hoses kept the principal from watering the lawn that day.

15. John ruined the sole by quickly walking in deep puddles in his new shoes.
John ruined the sole by idiotically walking in deep puddles in his new shoes.
John ruined the leather by quickly walking in deep puddles in his new shoes.
John ruined the leather by idiotically walking in deep puddles in his new shoes.

John ruined the sole by quickly defrosting it in a pan of hot water.
John ruined the sole by idiotically defrosting it in a pan of hot water.
John ruined the shrimp by quickly defrosting it in a pan of hot water.
John ruined the shrimp by idiotically defrosting it in a pan of hot water.

16. The band high on the dress was very colorful.
The band placed at the top of the dress was very colorful.
The brooch high on the dress was very colorful.
The brooch placed at the top of the dress was very colorful.

The band high on the jazz charts was very brassy.
The band placed at the top of the jazz charts was very brassy.
The combo high on the jazz charts was very brassy.
The combo placed at the top of the jazz charts was very brassy.

# APPENDIX D

## Dichotic Ambiguity Experiment

I. Sentences with complement sentences as clause boundary

1. They stole the bats in order to play baseball with their friends.
   They stole the bats in order to dissect an unusual type of rodent.
   They stole the bats from the school gymnasium to play a game of ball.
   They stole the bats from the school laboratory to dissect an unusual type of rodent.

   They stole the gloves in order to play baseball with their friends.
   They stole the mice in order to dissect a common type of rodent.
   They stole the gloves from the school gymnasium to play a game of ball.
   They stole the mice from the school laboratory to dissect a common type of rodent.

2. Harvey found a pipe so Max could smoke after his dinner.
   Harvey found a pipe so Max could repair the leaking sink.
   Harvey found a pipe at the same tobacconist where he had bought tobacco.
   Harvey found a pipe at the same plumbing supply store where he had bought faucets.

   Harvey found a cigar so Max could smoke after his dinner.
   Harvey found a valve so Max could repair the leaking sink.
   Harvey found a cigar at the same tobacconist where he had bought tobacco.
   Harvey found a valve at the same plumbing supply store where he had bought faucets.

3. Phillip got the colorful glasses for Sue to wear with her new dress.
   Phillip got the colorful glasses for Sue to fill with ice cubes and lemonade.
   Phillip got the colorful glasses from Martha's optician in the medical building.
   Phillip got the colorful glasses from Martha's dishwasher near the sink.

   Phillip got the colorful jewelry for Sue to wear with her new dress.
   Phillip got the colorful pitchers for Sue to fill with ice cubes and lemonade.
   Phillip got the colorful jewelry from Martha's optician in the medical building.
   Phillip got the colorful pitchers from Martha's dishwasher near the sink.

4. Richard bought a new file so Sam could store his old research papers.
   Richard bought a new file so Sam could cut the old lock on his cabinet.
   Richard bought a new file at the best office-supply store in town.
   Richard bought a new file at the best hardware store in town.

Richard bought a new desk so Sam could store his old research papers.
Richard bought a new saw so Sam could cut the old lock on his cabinet.
Richard bought a new desk at the best office-supply store in town.
Richard bought a new saw at the best hardware store in town.

5. Jack removed the scales so Rose could sweep everywhere in the bathroom.
Jack removed the scales so Rose could cook the trout he caught.
Jack removed the scales from his wife's bathroom so that she could sweep easily.
Jack removed the scales from his wife's fish to help prepare dinner.

Jack removed the rugs so Rose could sweep everywhere in the bathroom.
Jack removed the fins so Rose could cook the trout he caught.
Jack removed the rugs from his wife's bathroom so that she could sweep easily.
Jack removed the fins from his wife's fish to help prepare dinner.

6. Finding a ring of deep set gems at the jewelers delighted the young woman.
Finding a ring of deep set dirt on the tub enraged Ted's aunt.
Finding a ring for Beth to wear with her necklace delighted the salesgirl.
Finding a ring for Beth to scrub off the tub irritated Ted's aunt.

Finding a bracelet of deep set gems at the jewelers delighted the young woman.
Finding a stain of deep set dirt on the tub enraged Ted's aunt.
Finding a bracelet for Beth to wear with her necklace delighted the salesgirl.
Finding a stain for Beth to scrub off the tub irritated Ted's aunt.

7. They decided to open his chest to look for cigars and tobacco.
They decided to open his chest to look for concerous lung tissue.
They decided to open his chest with the strong chisel they just bought.
They decided to open his chest with the strong scalpel they just bought.

They decided to open his box to look for cigars and tobacco.
They decided to open his throat to look for cancerous lung tissue.
They decided to open his box with the strong chisel they just bought.
They decided to open his throat with the strong scalpel they just bought.

8. The manager thought that some fans for us to talk to at half-time would raise our moral.
The manager thought that some fans for us to cool the dressing room with would make us more comfortable.
The manager thought that some fans would quickly criticize the poor pitching staff.
The manager thought that some fans would quickly cool the hot, stuffy dressing room.

The manager thought that some girls for us to talk to at half-time would raise our moral.
The manager thought that some drinks for us to cool ourselves with would make us more comfortable.
The manager thought that some girls would quickly criticize the poor pitching staff.
The manager thought that some drinks would quickly cool the hot and tired players.

II. Sentences with relative clauses as clause boundary

1. Joe thought the washer would match the bolts he had bought the previous day.
Joe thought the washer would match the dryer he had bought the previous day.
Joe thought the washer that matched the bolts was very expensive.
Joe thought the washer that matched the dryer was too large for his apartment.

Joe thought the wrench would match the bolts he had bought the previous day.
Joe thought the hoses would match the dryer he had bought the previous day.
Joe thought the wrench that matched the bolts was very expensive.
Joe thought the hoses that matched the dryer was too large for his apartment.

2. Robert found that the best record was in the album he had put on the sofa.
Robert found that the best record was in the relay-race at last year's track-meet.
Robert found that the best record that he had bought was in the album on the sofa.
Robert found that the best record that he had set was in last year's race.

Robert found that the best picture was in the album he had put on the sofa.
Robert found that the result was in the relay-race at last year's track-meet.
Robert found that the best picture that he had bought was in the album on the sofa.
Robert found that the best result that he had set was in last year's race.

3. The men hoped that the strike would win their bowling game against the arch-rivals.
The men hoped that the strike would win their demands for increased retirement pay.
The men hoped that the strike that won their bowling game would not be disqualified.
The men hoped that the strike that won their demands had not angered the company management.

The men hoped that the spare would win their bowling game against the arch-rivals.
The men hoped that the vote would win their demands for increased retirement pay.
The men hoped that the spare that won their bowling game would not be disqualified.
The men hoped that the vote that won their demands had not angered the company management.

4. In Chemistry class, the solution was being boiled when it suddenly exploded.
In Chemistry class, the solution was being written down when someone noticed an error.
In Chemistry class, the solution that Merrill boiled exploded violently.
in Chemistry class, the solution that Merrill wrote on the board was totally wrong.

In Chemistry class, the mixture was being boiled when it suddenly exploded.
In Chemistry class, the answer was being written down when someone noticed an error.
In Chemistry class, the mixture that Merrill boiled exploded violently.
In Chemistry class, the answer that Merrill wrote on the board was totally wrong.

5. Jane thought the seal would keep the envelope closed well enough.
Jane thought the seal would keep the fish in his mouth.
Jane thought the seal that held the envelope closed was strong enough.
Jane thought the seal that held the fish in its mouth was very cute.

Jane thought the glue would keep the envelope closed well enough.
Jane thought the bear would keep the fish in his mouth.
Jane thought the glue that held the envelope closed was strong enough.
Jane thought the bear that held the fish in its mouth was very cute.

6. The lawyer thought the case contained the cigarettes he had been looking for.
The lawyer thought the case contained the precedent he had been looking for.
The lawyer thought the case that had the cigarettes in question was in his room.

The lawyer thought the case that had the precedent in question was in this volume.

The lawyer thought the box contained the cigarettes he had been looking for.
The lawyer thought the book contained the precedent he had been looking for.
The lawyer thought the box that had the cigarettes in question was in his room.
The lawyer thought the book that had the precedent in question was in this setume.

7. The lecturer thought that the stand should have been announced and implemented by the President.
The lecturer thought that the stand should have been built differently for this type of ceremony.
The lecturer thought that the stand that had been announced by the President was entirely appropriate.
The lecturer thought that the stand that had been built for the ceremony was entirely appropriate.

The lecturer thought that the law should have been announced and implemented by the President.
The lecturer thought that the room should have been built differently for this type of ceremony.
The lecturer thought that the law that had been announced by the President was entirely appropriate.
The lecturer thought that the room that had been built for the ceremony was entirely appropriate.

8. It was unfortunate that the cold had reached Tom's nose and throat, thus keeping him from performing that night.
It was unfortunate that the cold had reached Tom's fields and orchards and had totally destroyed his crops.
It was unfortunate that the cold that reached Tom's nose and throat had not let him perform that night.
It was unfortunate that the cold that reached Tom's fields and orchards had totally destroyed his crops.

It was unfortunate that the flu had reached Tom's nose and throat, thus keeping him from performing that night.
It was unfortunate that the frost had reached Tom's fields and orchards and had totally destroyed his crops.
It was unfortunate that the flu that reached Tom's nose and throat had not let him perform that night.
It was unfortunate that the frost that reached Tom's fields and orchards had totally destroyed his crops.

# APPENDIX E

## Acoustic Storage Experiment

NOUN PROBES.

| | | |
|---|---|---|
| 1. | It soon became very obvious that our luck would not last. | LUCK |
| 2. | It is an old tradition in New England for ships to be christened. | SHIPS |
| 3. | The exam was so hard that only one girl finished it. | GIRL |
| 4. | All good French cookbooks stress that white wine goes well with fowl. | WINE |
| 5. | Grease marks are the hardest kind of stain for soap to clean. | SOAP |
| 6. | In terms of its overall effect, Brecht's latest play was brilliant. | PLAY |
| 7. | The purpose of effective air cover is to assure that few troops are lost. | TROOPS |
| 8. | Brushing after each meal is a cardinal principle of good dental care. | CARE |
| 9. | What bothers old women shoppers most of all is that clerks ignore them. | CLERKS |
| 10. | Which blue chip stocks to invest in is not something for one's wife to decide. | WIFE |

VERB PROBES.

| | | |
|---|---|---|
| 1. | At the time the Great War broke out, Austen lived in England. | LIVED |
| 2. | By piecing together isolated bits of evidence, the detectives traced the killers | TRACED |
| 3. | The greatest natural disaster in the century occurred when the hurricane struck New Mexico. | STRUCK |
| 4. | A considerable amount of time was lost when Chuck broke his right arm. | BROKE |
| 5. | It is a major priority of the administration to build low-cost housing. | BUILD |
| 6. | A growing number of voters now trust the government. | TRUST |
| 7. | This store buys cosmetics in bulk and sells them quite cheap. | SELLS |

| | | |
|---|---|---|
| 8. | When John's father decided to retire, he moved to the country to live. | LIVE |
| 9. | Eating chocolate is thought to cause poor complexions. | CAUSE |
| 10. | Polyurethane is the varnish most builders tend to recommend. | TEND |

# APPENDIX F

## Study on Category-Ambiguous words in Acoustic Storage

1. N) On our last visit we saw a play in Central Park.
   V) Our oldest boys almost always play in Central Park.

2. N) The director put the new commemorative stamp on all his mail.
   V) The director gave her a signature to stamp on all his mail.

3. N) The maid put the dirty clothes into piles in the corner.
   V) We noticed the dirt which she always piles in the corner.

4. N) The parents scheduled the dance from nine to twelve.
   V) The couples thought they would dance from nine to twelve.

5. N) My wife was disturbed by a loud laugh in the hall.
   V) Sue heard her boy-friend suddenly laugh in the hall.

6. N) The patient wanted to get rid of his cough.
   V) The patient suddenly felt he had to cough.

7. N) Paul was thankful to have passed the latest test in Geometry.
   V) The teacher found nothing hard enough to test in Geometry.

8. N) Bill helped install a push button phone for his friend.
   V) Bill asked the secretary to phone for his friend.

9. N) The student asked a very incisive and pertinent question about the war.
   V) The committee insisted on having the general to question about the war.

10. N) The workmen put the elaborate plumbing for the sink into the ground.
    V) We were afraid that the heavy cabinet would sink into the ground.

11. N) The writers decided to continue the work on their new book.
    V) The writers decided to continue to work on their new book.

12. N) Louise reminded Jack to watch the parade in the park.
    V) Louise liked to watch the high school band parade in the park.

13. N) The boys were exhausted from their long climb up the mountain.
    V) The boys packed their gear in order to climb up the mountain.

14. N) Bill was known for the warmth of his smile.
    V) Bill's drama coach taught him how to smile.

15. N) Mary was awakened by her child's <u>cries</u> all night long.
    V) Mary can't sleep well because her child <u>cries</u> all night long.

16. N) The sailors took their new <u>ship</u> out to sea.
    V) The sailors prepared to <u>ship</u> out to sea.

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