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Slutsky, Harvey, Ph.D.

City University of New York, 1989

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SERIAL, PARALLEL AND DELAY STRATEGIES IN THE PROCESSING
OF
STRUCTURALLY AMBIGUOUS LANGUAGE CONSTRUCTIONS

by
HARVEY SLUTSKY

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York.

1989

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

Serial, Parallel and Delay Strategies in the Processing
of
Structurally Ambiguous Language Constructions
by
Harvey Slutsky

Adviser: Professor Martin S. Chodorow

Through a set of two experiments, the present study attempted to determine which of three language processing strategies, that is, serial, parallel or delay is employed in parsing two kinds of structurally ambiguous visually presented sentences (transitive and verb complement). The study used a relatively new technique, a self paced syntactic decision task whose sensitivity to local parsing complexity was demonstrated in the first experiment through a partial replication of Ford's (1983) work with relative clause sentences. The findings showed Object relatives to be harder to process at the position of the main verb. The same findings from a followup experiment in which the relative clause was lengthened lent support to a Filler-gap explanation of parsing Object relatives proposed by Ford (1983). Also found in the first experiment was weak support for either a parallel or delay parsing of ambiguous

transitive sentences and strong support for a parallel parsing of verb complement sentences. As followup, in the second experiment, an attempt was made to differentiate the parallel from delay parse of transitive sentences. In addition, an examination of the parsing strategy used for verb complement sentences with lengthened ambiguous regions was motivated by Kurtzman's (1984) work. Results of Experiment 2 suggested a mixed parsing strategy for the processing of verb complements with lengthened ambiguous regions. The findings for modified transitives suggested a serial parsing strategy which was unexpected given findings from the first experiment and findings by Kurtzman (1984). Biasing by lexical preference was deemed unlikely but not definitively ruled out. The strength of lexical preference (i.e., verbs biasing parsing strategies) was not found to be significantly related to the strength of garden pathing (i.e., degree of difficulty reassigning NP's from a direct object to complement subject structure) in complement clause sentences. A second methodological variable (i.e., grammaticality judgement errors) was examined and ruled out as an alternative measure of local parsing complexity. Post hoc analysis of standard errors from ambiguous and unambiguous sentences raised questions regarding differentiation of parallel processing from mixed subject strategies, which should be addressed in future work.

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Introduction

The current study falls within the more general area of testing theoretical models for how humans understand the language they use in communicating with one another. In recent years, the means by which computers have been programmed to "understand" or process the languages used by humans ("natural languages") have served for some experimenters as theoretical models for human language comprehension (Chodorow, 1975, 1979, 1980). The present study is an extension of such work.

One of the language understanding tasks proposed as common to computer and human alike is the derivation of meaning from a natural language despite its ambiguities. Winograd (1984) states "The problem is that natural language does not embody meaning in the same way that a cryptographic code embodies a message. The meaning of a sentence in a natural language is dependent not only on the form of the sentence but also on the context"...which can be seen "most clearly through examples of ambiguity" (p.131).

Ambiguity and Disambiguation

Providing a perspective for the issue of ambiguity within natural languages generally entails consideration of two complementary questions about sentence comprehension. The first is what might confound a listener or a reader by giving a sentence more than its one intended interpretation (double

entendres, garden path jokes and evasive replies excluded)? The other question, which has two components, is what prevents such confounding from occurring or resolves such confounding once it has occurred for a listener (reader)? The term "disambiguation" has generally been used for the recognition process in which there is resolution of an "ambiguity" once it arises at some point within a sentence. The term "undetermined" is synonymous with "ambiguous" and "determined" is used synonymously with "unambiguous". Thus it can be said that the point in a sentence at which a given ambiguity is disambiguated is the point at which the intended alternative becomes determined. This process contrasts with potential ambiguities which are somehow prevented by the use of preceding or local linguistic information, in which case the specificity of the intended alternative is said to be "determined" because it is unambiguous to begin with.

Some sentences can be multiply ambiguous. Jacobs and Rosenbaum (1968) suggest six possible interpretations of the sentence "The seniors were told to stop demonstrating on campus" (p.6).

1. The seniors were demonstrating on campus and were asked to desist.
2. The seniors were demonstrating and were asked, on campus, to desist.
3. The seniors were demonstrating and were asked to

desist on campus (although they could demonstrate elsewhere).

4. People were demonstrating on campus, and seniors were asked to stop them.

5. People were demonstrating and seniors were asked, on campus, to stop them.

6. People were demonstrating and seniors were asked to stop them from doing this on campus (although they could do it elsewhere).

Forms of Ambiguity. Frazier, Clifton and Randall (1983), distinguish two forms of ambiguity within a given sentence, "vertical" and "horizontal". Vertical ambiguities are those which arise at points because of incomplete use of prior information (termed "left context") from the sentence. Horizontal ambiguities are those which remain even after full use of all such prior information but can be resolved with later information within the given sentence. For example, in a sentence beginning with "The teacher believed the girl...", it is unclear when the phrase "the girl" is encountered by a reader whether it will be a direct object ending the sentence or be the subject of an upcoming complement clause such as "the girl would improve her grades". Thus the phrase "the girl" introduces a horizontal ambiguity which can only be resolved by information coming later in the sentence. However, in a

sentence beginning "The teacher believed the room..", a reader has enough information to determine that the phrase "the room" should be the subject of a complement clause because "rooms" are inanimate. Nevertheless, if a reader does not use this information, a vertical ambiguity is created.

Winograd (1984) has distinguished five forms of "ambiguity" which may confound a reader by giving a sentence more than one interpretation.

In "lexical ambiguity", considered the simplest form, the intended interpretation of a single word within a sentence is unknown due to more than one possible meaning of the word. Also termed "polysemy", it is very common for a word to have more than one definition or express more than one concept. For example the word "bank" in the sentence "Stay away from the bank" may refer to a money depository or the land next to a body of water.

In "structural ambiguity" of which there are two subcategories, more than one word in a sentence contributes to the ambiguity. Winograd (1984) gives the following as an example of a surface structure ambiguity. In the sentence "He saw that gasoline can explode", based upon two different interpretations of the words "that" and "can", the sentence has two possible grammatical structures and in turn two possible interpretations. In one interpretation, "gasoline can" is part of a noun phrase referring to a container of gas. In

the other interpretation "gasoline" is the subject of a subordinate clause of which "can" is the auxiliary verb.

In the more subtle form of "structural ambiguity" involving deep structure, two readings of a sentence may have the same grammatical form and yet differ in meaning. Winograd (1984) offers the sentence "The chickens are ready to eat" in which it is unclear whether the chickens are to be eaten or do the eating.

In "semantic ambiguity" a phrase can play different roles in a sentence. For example, the phrase "a Canadian" in the sentence "He wants to meet a Canadian" can be used "referentially" to indicate a particular person is intended with the phrase being used to further distinguish the particular person. If the phrase "a Canadian" is used "attributively", no particular person need be intended, only someone of Canadian background.

The fifth and last form of ambiguity, termed "pragmatic ambiguity", arises from the use of pronouns and special nouns such as "one". In Winograd's (1984) example "When a bright moon ends a dark day, a brighter one will follow", it is unclear whether a brighter day or a brighter moon is intended.

MacKay and Bever (1967) characterize the surface structure of a sentence as representing the manner in which words can be grouped together. Thus for them "ambiguity at the surface structure level involves the possibility of two distinct

groupings of adjacent words" (p. 193). They give as an example the sentence "Small boys and girls are frightened easily" in which the word "Small" may be grouped with (qualify) the word "boys" or both the words "boys" and "girls", thus giving the sentence two distinct alternative meanings. In contrast, MacKay and Bever (1967) characterize the underlying structural level of sentences as representing the "essential 'logical' relations between words and phrases" (p.193). In their example of underlying structural ambiguity, the sentence "the mayor will ask the police to stop drinking ", the word "stop" is considered ambiguous because it can be interpreted as either "to forbid" or "to cease", making it unclear whether or not it is the police or some other parties who are doing the drinking.

Generally, surface structure ambiguities arise at points in sentences where the grammatical role of a word within a sentence cannot be established until more information in the sentence is used. Particular parts of speech have greater potential for such ambiguity, for example, verbs that take complements as opposed to simple transitive verbs, even when the complement verbs are used transitively. Furthermore, Bever (1970) in reviewing studies of perceptual or psychological complexity in relation to complement verbs (whose role may vary within different sentences) concludes that the greater the number of potential grammatical roles a complement verb could have, the greater its psychological complexity.

Another way in which ambiguities have been characterized is either as "local" or "global", which essentially refers to whether or not the ambiguity can be resolved by the end of the sentence in which it arises. Local ambiguities are temporary, having a region of ambiguity, a point of disambiguation and only one valid parse (grammatical interpretation) within a sentence. For example, in the sentence "The teacher knew the boy had missed the exam", the noun phrase "the boy", is a region of temporary ambiguity in which it cannot be determined whether this noun phrase will end the sentence as the object of the verb "knew" or if this noun phrase will be the beginning of the complement clause "the boy had missed the exam". With the introduction of the verb "had" the ambiguity is resolved in favor of the complement clause.

In contrast, although global ambiguities have a region of ambiguity, there is no point of disambiguation in the sentence, thus leaving two or more valid parses. For example, in the sentence "The man saw the boy with the telescope", the phrase "with the telescope" is the ambiguous region. However, by the end of the sentence, it cannot be determined from information within the sentence whether the man used a telescope to see the boy or the man saw a boy who had a telescope, and so the ambiguity remains.

Contextual Disambiguation. Jacobs and Rosenbaum (1968) indicate that use of the ability to "perceive the ambiguity in

a grammatical string" is making use of "knowledge of the grammar of your language". Winograd (1984) notes in pointing out some difficulties computer programs have that in many potentially ambiguous sentences the intended interpretation is obvious to a human reader because the human has an understanding of context. The sentence "The food is ready to eat" is unambiguous to a human because the human knows foods are eaten rather than eat.

Miller (1978) in discussing "lexical disambiguation" distinguishes several types of contextual information which, if available, people may (but do not necessarily) use in recognizing "quickly and accurately which one or two of a large number of alternative meanings a word expresses on any particular occasion"(p.98). Generally some use of "the immediate linguistic context", "the discourse context", "the situation in which the communication occurs" or a general knowledge of the topic under discussion facilitates lexical disambiguation.

A more detailed categorization of contextual information types required for disambiguation is presented below (Miller (1978) pp.62-63):

A. Pronunciation (and spelling for written languages)

- (i) Phonology (including stress features)
- (ii) Morphology (including inflected and derivative

forms)

B. Syntactic categorization

- (i) Major category (noun, verb, adverb, preposition...)
- (ii) Subcategorization (syntactic contexts)

C. Meaning

- (i) Definition (concept expressed; relation to other concepts)
- (ii) Selectional restrictions (semantic contexts)

D. Pragmatic constraints

- (i) Situation (relation to general knowledge)
- (ii) Rhetoric (relation to discourse contexts)

Miller (1978) cites Kelly and Stone (1975) in their estimate that between 60 and 70 percent of disambiguations involve determining the part of speech. Such ambiguities are considered by Miller the easiest to resolve because the contextual information required to determine a word's syntactic category is given by its alternative subcategorizations, which in turn is the kind of information "that a good parsing system provides" (p.99).

Parsing Problems and Models

Chodorow (1980) states "a parser can be defined as any set of procedures (abstract, mechanical, or mental) used to assign structure to an input" (p. 3). Characterizing the parsing of a natural language such as English, he further states "the input

to the parser might consist of letters and spaces, and the output might contain words organized into phrases (e.g., noun phrase, verb phrase) and structural relations (e.g., subject, predicate, direct object)". Winograd (1984), in describing a parser within a hypothetical language comprehension program calls it the "syntactic-analysis component, which applies the rules of grammar to determine the structure of the sentence" (p.138).

Design problems. Winograd (1984) elaborates upon two problems which arise in the design of adequate parsers, the first of which has received much attention over the past thirty years, that is, "the specification of a precise set of possible sentence structures in a language" (p.138).

In characterizing the second problem for a parser, he states "It is not always possible to tell, when a part of a sentence is encountered, just what role it plays in the sentence or whether the words in it go together" (p.138). Giving the example "'Roses will be blooming in the dark gardens we abandoned long ago'", he points out that if as encountered, the words "in the dark" are taken as a complete phrase, then "Roses will be blooming in the dark" may mistakenly be interpreted as a complete sentence, thus leaving the remaining words in the sentence without a role to play.

Frazier, Clifton and Randall (1983) characterize this same

problem of a parser another way. In their discussion and postulation of a "sentence comprehension mechanism", they speak of the "temporary ambiguities" pervasive in natural languages which "a language user can demonstrate by interrupting sentences at arbitrary points and considering the implications of all possible continuations for the analysis of already analyzed material" (p.189).

Chodorow (1980) studied structural ambiguity using an "augmented transitional network (ATN)" parsing model in which the parser is characterized in terms of transitions between successive finite states, augmented with a recursion mechanism, a set of registers that can hold pieces of structure and arbitrary conditions and actions that can be taken at transitions of the network (Woods, 1972; Kaplan, 1972; Wanner & Maratsos, 1978). Structural ambiguity within an ATN model is conceptualized as "a successor state which is not uniquely determined" and "the parse is said to be nondeterministic" (p.4).

Multiple models. Winograd (1984) elaborated upon the various strategies that existing computer parsers adopt for exploring the multiple ways phrases can be put together. "Some work from the top down, trying from the outset to find possible sentences; others work from the bottom up, trying local word combinations. Some backtrack to explore alternatives in depth if a given possibility fails; others use parallel processing to

keep track of a number of alternatives simultaneously".

Frazier, Clifton and Randall (1983) write "In principle, the sentence comprehension mechanism might cope with temporary ambiguity by projecting all possible analyses of the ambiguous string, by choosing just one possible analysis, or by delaying making any decision about the analysis" (p.189). They go on to say, "Each of these options has costly consequences in terms of processing or memory load. Computing all possible analyses entails substantial extra work. Choosing one analysis means that errors may have to be corrected. Delaying analysis will occasion a heavy memory load for unprocessed material" (p.189).

The above parsing strategies referred to as the "parallel", "serial" and "delay" (also termed "look ahead") models, respectively, (MacKay, 1966; Kimball, 1973, Chodorow, 1979) have all been incorporated in mechanical parsing systems for natural languages (Woods, 1972; Heidorn, 1976; Marcus, 1974).

Purpose and Derivation of the Current Study

Focus and objectives. The current study attempts to determine which of the three language processing strategies, serial, parallel or delay, best explains how structurally ambiguous, that is, nondeterministic, visually presented

sentences are processed. The study focuses upon "surface" structure ambiguity as conceptualized by Winograd (1984) and MacKay and Bever (1978) which can be resolved (disambiguated) through use of contextual information Miller terms "syntactic categorization", i.e., local ambiguities arising and resolvable within a given sentence. In addition, the study attempts to extend the understanding of processing strategies through the use of a relatively new measurement method. The current project is derived from a set of auditory language experiments (Chodorow, 1979) that attempted to determine which of the above mentioned strategies is used in processing structurally ambiguous auditorally presented sentences. The results of these studies were somewhat equivocal due to the nature of the two processing measures that were used. The current project seeks to address such methodological shortcomings.

Background. In the above set of auditory language experiments and generally in studies from which the current experimental method is derived, subjects are presented two or more sentence types of experimental interest that are grammatically different (albeit otherwise matched) to serve as the independent variable. Typical sentence types that have been compared are subject relative clause sentences vs. object relative clause sentences, sentences containing simple transitive verbs vs. sentences containing complex transitive verbs, sentences containing complementized complement clauses

vs. sentences containing uncomplementized complement clauses. Transitive sentences and verb complement sentences are the focus of the current study.

Transitive sentences containing simple verbs such as "injured" in the form of "John injured Mary" are considered structurally unambiguous whereas transitive sentences containing complex verbs such as "believed" in the form of "John believed Mary" are considered temporarily structurally ambiguous. Similarly, sentences containing complement clauses which begin with the word "that" (termed a 'complementizer') of the form "John knew that Mary was in the house" are considered structurally unambiguous. These contrast with complement sentences lacking the complementizer "that" such as "John knew Mary was in the house", which are considered temporarily structurally ambiguous.

In the transitive sentence with the simple verb "injured", a transitive syntactic construction containing a direct object such as "Mary" is expected to follow. However with the complex verb "believed", more alternative constructions might be expected to follow, as for example "John believed Mary" in which "Mary" is a nonsentential direct object or "John believed Mary was sick" in which "Mary" begins a complement clause "Mary was sick". It is thus after the verb "believed" that structural ambiguity is introduced into these two sentences because a reader or listener cannot know or determine what

syntactic relationship the words which follow will have to the word "believed" until some point later in these sentences is reached. Thus these sentences remain structurally ambiguous or undetermined until a point of disambiguation is reached when the reader or listener can determine what the syntactic relationship between the noun "Mary" and the verb "believed" is to be. In the sentence "John believed Mary" a punctuation mark such as a period (in the case of a written sentence) or a voice drop (in the case of a spoken sentence) permits a reader or listener respectively to determine that the word "Mary" is a nonsentential direct object of the verb "believed". In the sentence "John believed Mary was sick" the structural ambiguity following the verb "believed" continues until the verb "was" when the sentence becomes disambiguated because it can then be determined that the word "Mary" is to be the start of a complement clause and not a nonsentential direct object.

In the transitive sentence "John injured Mary", with the introduction of the simple verb "injured" it can already be expected that a transitive construction with a direct object will follow and thus no ambiguity is introduced by such a simple verb. The expected syntactic relationship between "Mary" and "injured" can synonymously be said to be unambiguous or determined by such a verb or constrained by such a verb. In sentences of the form "John believed Mary was sick" and "John knew Mary was in the house", it is following the verbs

"believed" and "knew" that the same kind of structural ambiguity is introduced. This ambiguity continues until the verb "was" when it can be determined that the noun "Mary" begins a complement clause and is not a nonsentential direct object. If however the complementizer word "that" were to be added to these sentences as with "John believed that Mary was sick" and "John knew that Mary was in the house" the word "that" sets the expectation for the complement clause. In so doing, the complementizer plus the determiner (or proper noun) terminates the structural ambiguity at an earlier point in such sentences than if the complementizer were omitted (Hakes, 1972).

As formerly noted, computers designed to process natural languages have been programmed to process language containing structural ambiguities using serial, parallel or delay procedures. These three processing models have been proposed for humans. Each model suggests a different distribution of processing loads, that is demands upon some finite hypothetical cognitive pool of attention, memory and effort resources. Given two or more alternative syntactic constructions which may follow from a structurally ambiguous point in a sentence, the parallel model suggests that people hold more than one alternative in mind until that point in the sentence where the syntactic relationship becomes disambiguated. A serial processing model suggests that people assign only one of all

possible alternative relationships and only choose another alternative if they are wrong when they reach the point of disambiguation. In the delay model, the words beginning within the ambiguous portion of the sentence are stored unparsed until a disambiguating word is encountered so that the structure of the stored portion can be assigned. Parsing then resumes from the point of ambiguity.

In reporting on an earlier set of auditory language experiments examining syntactic processing, Chodorow (1979) concluded that a parallel processing strategy was employed when parsing the ambiguous region of verb complement sentences such as those previously described. The sentences contain a noun phrase which when first encountered might equally well be analysed as a direct object or as the subject of an expected complement clause. Subjects were presented time-compressed verb complement sentences of two forms, ambiguous sentences lacking a complementizer and unambiguous sentences containing a complementizer. For comparison, other subjects received a matched set of sentences in which ambiguous and unambiguous forms were reversed. Thus, for example some subjects heard the sentence "The mathematics teacher believed the girl would improve her grades" and other subjects heard the sentence "The mathematics teacher believed that the girl would improve her grades". Following each sentence subjects received a list of unrelated words and were then required to recall both the sentence and

the word list. Chodorow found not only that the recall of word lists was poorer following ambiguous sentences but that ambiguous regions were most difficult to recall (less words were recalled). This latter finding was interpreted as indicative of increased processing load within the ambiguous region and consistent with a parallel parsing strategy.

Time-compression is a technique which permits speeded up presentation of auditory sentence material without noticable sound distortion. The technique was employed to limit processing resources during sentence presentation with the expected finding that processing demands would interfere and be reflected in sentence and word list recall decrements.

Time-compressed speech can be considered one form of Rapid Serial Presentation (RSP) of auditory sentence material. It has a visual presentation counterpart or analog in what is termed Rapid Serial Visual Presentation (RSVP). The RSVP paradigm is one in which sentences are generally displayed either tachistoscopically or on a computer video monitor word by word for brief fixed durations controlled by the experimenter. Dependent variables typically used with this technique include mid or post sentence measures of sentence comprehension, verbatim sentence recall or list memorization. It is the sensitivity of such indirect post sentence measures to on-line processing load which is questionable.

Criticism of earlier studies. In a review and criticism of several studies employing post-sentential measures of sentence processing (eg. Foss, Bever & Silver, 1968; Lackner & Garrett, 1973) including that of Chodorow, Gorrell (1987) contended that caution is required when interpreting results from post-sentential measures. Gorrell notes that post-sentential measures may reveal information about a subject's final analysis while shedding little light on the process by which it is reached. On-line tasks which serve as measures of processing timed to occur during the presentation of a sentence are recommended by Gorrell (1987). He states " The process of sentence comprehension may well involve the computation of structure which is not part of the final analysis....This type of intermediate structure may take the form of structures which are reanalyzed or alternative representations which are abandoned as they prove incompatible with lexical input" (p.2ff).

In Foss, Bever & Silver (1968), subjects verified whether or not a picture which shown at the end of an auditorilly presented seentence. represented the meaning of a sentence. The verification time (VT) following the ambiguous sentences was no slower than VT following unambiguous sentences if the picture

represented the "expected" meaning (as determined on a pretest) of the ambiguity. However, the VT for a picture representing the "unexpected" meaning of the ambiguity was longer. This suggested a serial strategy in which subjects initially computed only the favored meaning of ambiguous sentences and needed to reanalyze if the picture did not correspond to that meaning. A later study by Foss (1970) employed auditorily presented sentence material with a phoneme monitoring task in which target phonemes to be recognized were placed within a sentence one or two words after the onset of the ambiguity. Subjects were found to be significantly slower and less accurate in locating the target phoneme in ambiguous sentences than unambiguous sentences. Thus, it was concluded by Foss (1970) that a parallel parsing strategy was being employed earlier in the ambiguous sentences on the assumption that additional computational resources were being used to construct multiple syntactic analyses. Foss (1970) had argued that the post-sentential picture verification task was unable to reveal a processing stage prior to the final analysis which was revealed by the phoneme monitoring task timed to occur before the completion of the parse.

In the Lackner and Garrett (1974) study which claimed support for a parallel processing of auditorily presented ambiguous sentence material, subjects were to paraphrase ambiguous sentences following the presentation of those sentences to one

ear along with the simultaneous presentation of potentially diambiguating biasing sentences presented 5 to 10 decibels lower to the subjects' other ear. Subjects were instructed to attend to the ear to which the ambiguous sentences were presented. Despite subjects being unable to report information from sentences presented to the unattended ear, there was a significant influence from the biasing context of the unattended ear upon the ambiguous sentences in the paraphrasing of subjects. Gorrell (1987) contended that an alternative explanation to that of parallel processing of sentence material presented to the two ears is that biasing content permitted rapid reanalysis of the structure in the time before paraphrasing was required in the post sentential task.

Gorrell (1987) criticized Chodorow's (1979) conclusion that a parallel parsing strategy was employed for the ambiguous verb complement sentences of that study since post sentential measures of processing load were used (i.e., recall of unrelated word lists and recall of sentence material). Gorrell (1979) contends that subjects may not have pursued multiple analyses of the ambiguous sentences with the result of increased processing load contributing to poorer recall for the group of subjects on the whole. He claimed that perhaps poorer recall for the group of subjects was due to mixed preferences within the subject group or even within a given subject such that one interpretation of an ambiguity was pursued in serial

fashion, albeit the wrong interpretation. This then required reanalysis for both readings of the ambiguity which in turn increased the processing load.

Some reconciliation of studies with findings favoring parallel processing and those favoring serial processing of ambiguity is provided by the work of Bever, Garrettt & Hurtig (1973). Using ambiguous and unambiguous sentence fragments of various lengths along with sentence completion time measures, they concluded that multiple interpretations are computed within a structurally ambiguous clause although only one interpretation is retained beyond a clause boundary. Thus, typically, studies with measures taken within ambiguous sentences favor parallel parsing while studies with measures taken after the end of ambiguous sentences favor a serial parsing strategy.

Gorrell (1987), recommends on line tasks which serve as measures of processing timed to occur during the presentation of sentences. Despite criticism of Frazier & Rayner (1982), Gorrell (1987) considers that eye movement and fixation duration measures as those employed by Frazier and Rayner (1982) have "the advantage that there is no need to interrupt the parsing of the input string for the presentation of a secondary task" (p.12). In Frazier and Rayner's (1982) work with ambiguous sentences eye movement data in which increased fixation durations have been found at the point of

disambiguation and regressive eye movement from this point to the ambiguous region of those sentences whose resolution violates a minimal attachment parsing strategy suggested a serial parsing, one in which subjects had adopted a preferred analysis at the onset of the ambiguity and reanalyzed if the preferred analysis was incorrect.

Gorrell (1987) criticized Frazier and Rayner's study for not employing adequate (i.e., unambiguous) controls to differentiate a serial parsing effect in response to ambiguity per se from a response to increased sentence complexity at the clause boundary which coincidentally fell at the disambiguating verb. In Gorrell's own work (1987) with ambiguous sentences of a type similar to those of Chodorow (1979), that is verb complements, he combined results from a syntactic priming paradigm and a grammaticality judgment task, and claimed evidence for parallel processing. Gorrell's conclusion was based on the finding that a significant priming effect was observed for targets belonging to categories predicted by the structure associated with the non-preferred reading of the ambiguity. Gorrell (1987) further claimed that the inclusion of unambiguous controls enabled the demonstration that the effect did not result from the parser rapidly reanalyzing its existing structure in response to the target item.

However Gorrell's evidence appears to be insufficient. As he himself states, "Although this model is, at present

underdetermined by the available experimental data, it can serve as a framework for future research into basic issues involving the parser's response to structural ambiguity" (p. 2). The "model" referred to for which he recognized insufficient evidence is the parallel model. By comparing ambiguous sentences to unambiguous simple and complex control sentences and combining results from the two experiments, one employing a syntactic priming technique, the other a grammatical judgment task, Gorrell claims support for parallel processing which could not be found with either experiment alone. However his conclusion seems at be equivocal and his reasoning somewhat circular. Gorrell claims support for parallel processing should be based not only upon the evidence he found that "targets which were syntactically appropriate only to the non preferred reading of the ambiguity could be recognized significantly faster than inappropriate targets" but additionally upon evidence that the preferred reading was also computed. With the grammatical acceptability judgment task, Gorrell (1987) found that "the simple sentences patterned with responses to ambiguous sentences with both being significantly faster and more accurate than responses to the complex sentences" (p. 52). This latter finding, he claims, is also support for or "straightforwardly" explained by a parallel strategy. However, he attempts to justify this explanation as possible if the subject bases his judgment response on the first reading, the

simpler one computed before going on to compute the second more complex one. He refers to this as the "most plausible explanation". Yet it sounds rather serial in nature. A more parsimonious explanation might be that the primary task found serial processing of the non-preferred i.e., more complex reading of the sentence and the grammatical judgment task also found evidence for serial processing, albeit for the preferred, i.e., minimal attachment reading of the ambiguity.

Perhaps the use of an on-line measure or technique having advantages similar to that of eye movement and fixation duration measures might permit examination of local parsing throughout sentences and not rely upon inference from measurements taken at one point in a sentence, for a given set of subjects. Just such a technique was developed by Ford (1983) albeit a technique considered less costly and complex to interpret.

Recent study methodologies. Recent studies have examined visual language processing, employing computer monitor presentation and computer controlled timing of experimental stimuli along with computerized response recording thus introducing many new methodological stimulus/response alternatives. Similarly, experimental methods have incorporated

tasks as diverse as "probe recognition" (Kurtzman, 1985), "recall" and "comprehension" (Aaronson and Ferres, 1984) or "continuous decision" (Ford, 1983). In turn researchers have been forced to consider similarities and differences not only between results obtained from visual and auditory forms of presentation (Just and Carpenter, 1980) but also from various formats of visual presentation (Chih-Chen, 1986; Cocklin, Ward, Chih Chen and Juola, 1984; Dixon, 1984) with respect to the implications of such results for reading in general (Aaronson, 1984; Young, 1984), or language comprehension (Carrithers and Bever, 1984) and parsing in particular (Ford, 1983). The introduction of a variety of methodologies makes generalization from any one difficult. The use of more than one methodology within a single study such as Gorrell (1987) appeared to reflect such a problem rather than reducing uncertainty through some confluence of findings.

Framework of the current study. The current study consists of two experiments, both of which employ a continuous syntactic decision Self Paced Visual Presentation (SPVP) task. The two experiments test for serial vs. parallel vs. delay processing strategies in structurally ambiguous transitive and complement sentences. As part of the first experiment, the efficacy of the current SPVP task is assessed. In the second experiment, the continuous syntactic decision SPVP method is again used, this time along with the lengthening of structurally ambiguous

sentence regions to explore more extensively the processing strategies identified in the earlier experiment of the study.

The SPVP task. With the methodological paradigm termed Self Paced Visual Presentation (SPVP), subjects visually present themselves sentence material one word at a time at their own pace. Response times to individual words are measured as a dependent variable. Significant differences in response time within sentences or across sentence types are considered reflective of differential processing load effects. Typically in SPVP experiments which do not request that subjects memorize or comprehend sentences, some form of "carrier" task is employed to prevent rhythmic response patterns by subjects. Rhythmic responding usually produces relatively invariant response time patterns (Ford, 1983). Some form of continuous decision task is thus required such as detecting nonword letter strings embedded in sentences (a lexical decision) or judging the grammaticality of successive words presented relative to earlier portions of sentences (a syntactic decision), as in the present study.

The SPVP task used in the present study was derived from that used by Ford (1983). In order to study syntactic processing, Ford (1983) used a modification of a self paced reading task first employed by Aaronson and Scarborough (1976) that yields reaction time data for each word in a sentence. Aaronson and Scarborough (1976) had subjects view sentences one

word at a time at their own pace by pressing a response key to bring on each new word. Viewing times were recorded for two subject groups, one which was required to recall each sentence verbatim in writing after viewing (recall group) and a second group which was required to answer yes-no questions about the sentences after viewing (comprehension group). Reaction time patterns throughout sentences differed for the two groups. Aaronson and Scarborough considered the recall data to show a chunking effect which seemed to tap the grouping of words for storage in memory but not fluctuations in processing complexity. For the comprehension group, there was an effect of semantic content in which major content words were viewed longer than minor content words, but the effect of phrase structure was not evident. Ford (1983) noted that later researchers nevertheless believed the comprehension task to have potential for measuring local parsing complexity and reported from personal communication two unsuccessful attempts to use the task (Frauenfelder, Holmes). From Ford's participation in one such experiment, she concluded that there is a tendency for subjects to press the response key at a steady pace, slowing down only for some relatively complex word or idea, and this made the technique ineffective as an on-line measure sensitive to structural effects.

Ford (1983) considered that a simple decision made for each word as it appeared would prevent rhythmic responding. Thus in

place of either a recall or comprehension task, Ford introduced a lexical decision for subjects to make, that is, a judgment about whether or not a string of letters is a real word or a non-word. Ford reasoned that the latency to respond to a word depended both upon the difficulty of judging the word itself and the extra processing load due to parsing complexity at the location of the word. Along with experimental sentences of interest which were judged one word at a time, the lexical decision task required filler sentences containing "non-word" strings of letters. To establish that the continuous lexical decision task was an effective means of measuring local parsing complexity, the task was employed in two experiments, the first to demonstrate that while performing the task subjects treated sentences as sentences and a second in which the task was shown to be sensitive to structural effects.

It was concluded that subjects performing the task treat sentences as sentences from findings in which implausible sentences took longer to process (showed longer per word mean reaction times) than matched plausible sentences. The plausibility effect had been reported as a robust effect in earlier work employing different methods (Forster & Olbrei, 1973). Ford (1983) compared a second independent group's judgments regarding the word of onset of implausibility with reaction times from the first group. Ford concluded that "there is not a lag between the point at which a sentence starts to

become implausible and an increase of reaction time". The plausibility effect is strongest at the onset of the implausibility. Ford further reasoned that "since semantic interpretation presumably occurs after syntactic analysis", the syntactic effect found with the continuous lexical decision task actually occurs at the significant point in the sentence.

Ford (1983) also employed the continuous lexical decision task to compare performance on matched Subject and Object relative clause sentences since it had been quite well established in earlier work (Fodor, Bever & Garrett, 1974; Holmes, 1979) that Subject relatives are easier to process than Object relatives. To determine if the task was sensitive to differences in local parsing complexity throughout sentences, Ford not only expected to find Object relatives harder to process but also to find where in these sentences they were harder to process. Using matched sentences differing only with respect to Subject or Object relative form (eg. The manager that praised the designer examined the sketches vs. The manager that the designer praised examined the sketches), Ford (1983) found Object relatives to be harder to process than Subject relatives at three consecutive locations within the Object relative sentences (i.e. the relative clause verb, the main clause verb and the main clause determiner).

Furthermore, on a more theoretical level, through her

analysis of reaction times not only at these positions but throughout the relative clause, Ford (1983) proposed a Filler-gap explanation for greater Object relative than Subject relative difficulty. Thus, she contested the "Hold-hypothesis" explanation formerly proposed by Wanner & Maratsos (1978).

The SPVP used in the current study differs from the SPVP from which it was derived (Ford, 1983) in two ways that are expected to produce increased intra-sentence sensitivity to processing effects. First, in place of successive words accumulating across the computer video monitor (which might permit visual review), words appear at the center of the screen and are replaced by successive words. Thus, factors influencing readability (Cocklin, Ward, Chih-Chen, and Juola, 1984), possibilities for reinspection of prior within sentence stimuli (Kennedy and Murray, 1984) as well as possibilities for consolidation (Chih-Chen, 1986) might be expected to differ from the earlier work of Ford (1983). Secondly, in the current study a syntactic decision task is used instead of a lexical decision task, a change which preliminary work of Ford (1983) suggested is more sensitive than the lexical decision task she initially employed. Along with structurally ambiguous sentence material of current interest, subject and object relative clause sentences formerly employed by Ford (1983) were included to test the efficacy of the current task variant through partial replication.

Experiment 1

Rationale

One aim of Experiment 1 is to show that the current continuous decision task, just as the task from which it was derived (Ford, 1983) can locate a difference in the difficulty of processing simple subject vs. object relatives, thus "showing that the task is sensitive to variations in local parsing complexity" (p.209). In keeping with results obtained by Ford (1983) one might expect longer response times for object relative sentences than subject relative sentences at several comparable points, i.e., the relative clause verb, the main clause verb and the main clause determiner. For example, compared with matched positions in a Subject relative sentence, response times would be expected to be higher in Object relative sentences in underlined positions as follows:

The expert that the doctors phoned solved the crimes

Sensitivity to a difference in difficulty of processing transitive sentences should be reflected in longer response times at comparable key points within complex sentences (as predicted by serial, parallel, or delay parsing models).

Similarly, sensitivity to a difference in processing complement clause sentences should be reflected in longer response times at comparable key points within uncomplementized sentences. Both parallel and delay processing strategies predict that one would expect longer response times to be maintained within the region of ambiguity in complex transitive sentences and in uncomplementized complement sentences. In contrast, one would not expect longer response times within the region of ambiguity but longer response times at the point of disambiguation in the same sentence types if a serial processing strategy is employed. Lastly, one would expect longer response times in the region of ambiguity as well as at the point of disambiguation in uncomplementized complement sentences if a delay parsing strategy is employed.

For example, compared to an unambiguous complement control sentence, one would expect higher response times at the following underlined positions in accord with serial, parallel or delay parsing models:

Serial: The mathematics teacher believed the girl would
improve her grades

Parallel: The mathematics teacher believed the girl would
improve her grades

Delay: The mathematics teacher believed the girl would

improve her grades

The use of transitive sentences does not permit differentiation of the parallel from the delay model because the transitive sentences end before a point of disambiguation. Nevertheless, differentiation of a serial from either a parallel or delay parsing model would be reflected in response time differences throughout the ambiguous region of the sentence. Thus compared with an unambiguous control (simple transitive) sentence, response times would not be expected to be higher in an ambiguous (complex) transitive sentence if a serial parsing strategy is employed. However, if a parallel or a delay strategy is employed, higher response-times would be shown, for example, at the following underlined positions in an ambiguous transitive sentence:

The helicopter crew discovered the wreckage in the
mountains

Method

Subjects. The subjects were 20 unpaid volunteer native speakers of English who were either Hunter College students or acquaintances of Hunter College students.

Procedure. A complete session took approximately forty-five minutes. Upon entry for a session, all subjects were seated in front of a Model III Radio Shack computer which

had a styrofoam keyboard mask permitting keyboard entry of responses through only two "buttons" marked "YES" and "NO". Following a consent form signing routine, directions were read aloud to the subject by the experimenter (for exact instructions see Appendix B).

On the computer monitor, in a centered rectangle, subjects presented themselves with full sentences or incomplete sentences (fragments) one word at a time. Each word was replaced in the rectangle by successive words. The task of the subjects was to judge if each successive word was grammatically acceptable, that is, if it would permit a grammatical completion of the preceding fragment. Given the hypothetical example that they had already seen the words "The child decided" subjects were told that if the fourth word presented was "could", the word would not be grammatically acceptable because a grammatical sentence could no longer be made no matter how it was completed. In contrast if the fourth word was "that", the subject was told it was acceptable because it still could be completed grammatically. Subjects were told to press a "YES" key for grammatically acceptable words and a "NO" key for unacceptable ones. Subjects were first shown the rectangle containing four stars before the presentation of any new item (sentence or fragment). Since, as they were told, subjects actually presented successive words to themselves, they were to press the "YES" key one time to bring on the first word of each

item and press the "YES" key a second time because "all first words in sentences are grammatically correct". If either the "YES" key was pressed throughout an item or the "NO" key was pressed to any word, a new item was presented. New items were preceded by the enclosed set of stars to signal their onset since there were "no periods to mark the end of items". Subjects were instructed to make their choices "as quickly as possible while trying not to make errors". They were also informed that words would stay on the screen until a choice was made and that "it should be clear when a sentence becomes ungrammatical".

All subjects received oral instructions as to task requirements, then received 12 practice items with the experimenter in attendance to answer any procedural questions. During the presentation of all test items, the experimenter was in a nearby cubicle, neither observing nor observable by the subjects but available to receive any post-test parting comments or questions and to provide mid-test instructions. Subjects received mid-test instructions to introduce a changeover between two experimental conditions. The two experimental conditions ("Immediate" and "Delay") which are related to another study, were included in the present experiment. The Delay condition (not to be confused with the delay parsing model described previously) was a condition in which a slight pause occurred when a subject pressed the

computer response key, before the next word to be viewed was presented. In the Immediate condition there was no such interword pause (delay).

All subjects were assigned at the time of participation in accordance with a predetermined randomized listing to receive one of two matched stimulus files under one of two presentation orders, "immediate first" or "delay first". That half of the subjects who were assigned to the "Immediate" group received the practice items along with the first 44 test items which were displayed without interword delay. This was followed by the mid-test instruction break during which subjects were given a description of the presentation change that was to occur for the remainder of their items. Those next 44 items were then displayed with interword delays. The other half of the subjects who were assigned to the "delay" group received their practice and initial 44 test items with interword delays. This was followed by their instruction break and the remainder of the items which were displayed without interword delays. The division of experimental sentence types between earlier and later portions of the experimental test block assured presentation of equal numbers of all sentence types with and without interword delays.

Stimuli. Two stimulus files were used (see Appendix A). Ten subjects received one file of stimulus materials and the remaining subjects received the other file. Both files

contained the same 12 practice items, which consisted of three grammatical items and nine ungrammatical items. Within the grammatical items, there were two incomplete sentences (fragments) and one complete sentence. Within the ungrammatical items, all of which were fragments, there were three short items (4 words or less), three medium items (5-7 words) and three long items (8-11 words). These lengths were varied in practice and test items to correspond with the initial, mid and end portion of grammatical items in order to prevent subjects from forming an anticipatory set by which to differentiate grammatical from ungrammatical items as they were presented. Along with the practice items in both files was a test block of 88 items. Forty-four of these were experimental items (complete sentences) consisting of 10 subject relative clause sentences, 10 object relative clause sentences from Ford (1983), 6 simple transitive sentences, 6 complex transitive sentences, 6 complementized complement clause sentences and 6 uncomplementized complement clause sentences from Chodorow (1979).

Experimental sentences in one file were matched with those in the other file. That is, sentences which were subject relatives in one file were matched with object relatives in the other. For example, the subject relative sentence "The expert that phoned the doctors solved the crimes" in one stimulus file was matched to the object relative form "The expert that the

doctors phoned solved the crimes" in the other. Both sentences contained all the same words with only a verb shifted to produce the subject to object difference. Sentences that were simple transitives in one file corresponded to complex transitives in the other. For example, the simple transitive sentence "The helicopter crew located the wreckage in the mountains" was presented from one stimulus file. The complex transitive sentence "The helicopter crew discovered the wreckage in the mountains" was presented from the other file. They were identical except for the verbs which were matched for word length and frequency of occurrence. Complementized sentences in one file were uncomplementized in the other differing only with respect to the presence or absence of the complementizer "that". For example, the complementized form "The mathematics teacher believed that the girl would improve her grades" appeared in one stimulus file and the uncomplementized form "The mathematics teacher believed the girl would improve her grades" appeared in the other.

The remaining 44 items in the test block were filler sentence fragments of varying structure consisting of 14 short, 14 long items and 16 medium length items. Each ended with a word that was ungrammatical given the syntax of the previous words in each fragment. All items appeared in the normal case, that is, lower case except for the first letter of a sentence or sentence fragment. Experimental and filler items were randomly

distributed within the overall test block of 88 items after an initial division of half of each type of experimental material between the earlier and later portions of the block.

Subject and object relative sentences were taken verbatim from Ford (1983) where they were employed in an SPVP lexical decision task. The remainder of the experimental sentences were taken verbatim from Chodorow (1980) where they were employed in an auditory RSP task. The ungrammatical fragment filler items were produced from filler items employed by Ford (1985) in an SPVP syntactic decision task. Adaptation was required to obtain approximately equal numbers of specific fragment length.

General Results

Decision response times for "YES" key presses in experimental items were the primary data analysed by analysis of variance. Experiment 1 constitutes a set of two way factorial designs. In order to determine generalizability of results, ANOVAS were performed once with sentences used as the repeated measure (item analysis), and then with subjects used as the repeated measure (Clark, 1973).

Prior to presenting the results of the data analyses, there will be a description of the general procedures employed for

data selection. This will be followed by a comparison of data analysis treatments primarily associated with differences between and within the three kinds of sentences which were included in Experiment 1. This will then be followed by separate presentations of the specific predictions, results and discussion associated with the three kinds of sentences.

It should be recalled from the introduction that relative clause sentences were included as partial replication of Ford (1983), to assess the sensitivity of the current methodological variant. Transitive and complement clause sentences were included to test predictions regarding serial versus parallel versus delay processing of structurally ambiguous verb phrases, which is central to theoretical issues addressed in the current experiment. Thus, when presented, the results of analyses for relative clause sentences will be first, followed by transitive sentences and finally that of complement clause sentences.

Data Selection. Prior to data analysis, any subject's data was eliminated and replaced by a new subject's data if failures to correctly respond with "YES" or "NO" key presses to grammatical or ungrammatical items respectively, reached beyond two standard deviations above the initial subject group mean. Data from 5 of the initial twenty subjects were thus replaced, 1 due to "insufficient" recognition of grammatical items and 4 due to "insufficient" recognition of ungrammatical items. Thus,

25 subjects were examined before the final subject group that met the above criteria was obtained.

Within the final subject group there were 41 "NO" responses to experimental items; 13 such errors were made to the twenty relative clause sentences, 5 to the twelve transitive sentences and 23 to the twelve complement clause sentences.

Data Treatment. Ford (1983), from whom relative clause sentences of the present experiment were taken verbatim, and with whom results of the present experiment are compared, trimmed reaction time data for "extreme" response times prior to performance of ANOVAS in a process presumed to reduce variance and enhance real effects. Similarly, Ford (1983) found subjects' responses to the first word in sentences were erratic and therefore eliminated them from calculations. The same policy was adopted in the analysis of the present data.

All data were trimmed for reduction of variance. However, for data employed in ANOVAS with subjects used as a repeated measure, a modified procedure was required for transitive and complement clause sentences. The modified procedure was used because of the inconsistent varying length amongst transitive sentences and the consistently longer complementized form of complement clause items.

Thus, in all the ANOVAS with sentences used as the repeated measure, mean reaction times were calculated for all positions

(except the first) within a sentence, across all five subjects, within a given condition (immediate or delay). For trimming purposes, from these mean reaction times, means and standard deviations were calculated for all positions within a given sentence across both forms of the sentence (ex. subject relative and object relative). Any mean response that was two standard deviations from the sentences' mean was set at that two standard deviation cutoff value. Only 5% of the positions were influenced by this procedure for relative clause sentences, 3% for transitive sentences and 8% for complement clause sentences.

In the relative clause sentence ANOVAS with subjects used as the repeated measure, mean reaction times were calculated for individual subjects for all positions (excluding the first) within a sentence across all sentences of a given type (ex. subject relative or object relative) within a given condition (immediate or delay). For the relative clause experimental items, data were trimmed in a manner similar to that previously described. Cutoff values were thus those determined for individual subjects. Only 5% of the positions were influenced by this procedure for relative clause sentences.

For both ANOVAs performed on relative clause experimental sentences, means were then selected for comparison from those key positions postulated in accordance with experimental hypotheses (the entire relative clause, the main clause verb

and the determiner in the final noun phrase).

In contrast, for transitive and complement clause sentence ANOVAS in which subjects were used as the repeated measure, prior to trimming, reaction time means were calculated for individual subjects across all sentences of a given type within a given condition, not from all positions but only from those key positions postulated in accordance with experimental hypotheses (ex. positions within the ambiguous region and at the point of disambiguation for transitive and complement clause sentences). Thus cutoff values were determined on the basis of fewer sentence positions than for data of ANOVAS in which sentences served as the repeated measure. Only 8% of these positions were influenced by this procedure for transitive sentences and 7% for complement clause items.

Relative Clause Sentences

Predictions and Results. One aim of Experiment 1 was to show that the current continuous decision task with central presentation and syntactic decision, just as the task from which it was derived (Ford, 1983) could locate a difference in the degree of difficulty for processing subject vs. object relatives, thus "showing that the task is sensitive to variations in local parsing complexity" (p.209). In keeping with results obtained by Ford (1983) one might have expected longer response times for object relative sentences than

subject relative sentences at several comparable points, i.e., the relative clause verb, the main clause verb and the main clause determiner following the verb.

For relative clause sentences, the two way factorial design consists of two sentence types (subject relative and object relative) x five positions crossed with the repeated measures variable. The positions consist of the entire relative clause, the main clause verb and the determiner of the final noun phrase. For example, response times were analyzed for the matched set of relative clause sentences in underlined positions as follows:

The expert that phoned the doctors solved the crimes

The expert that the doctors phoned solved the crimes

For the purpose of most direct comparison in ANOVAS, all first verbs in the subject relative form of these sentences were compared to the position the verbs occupied in the object relative form of that sentence, as follows:

Subject Relative-The expert that the doctors (phoned) solved
the crimes

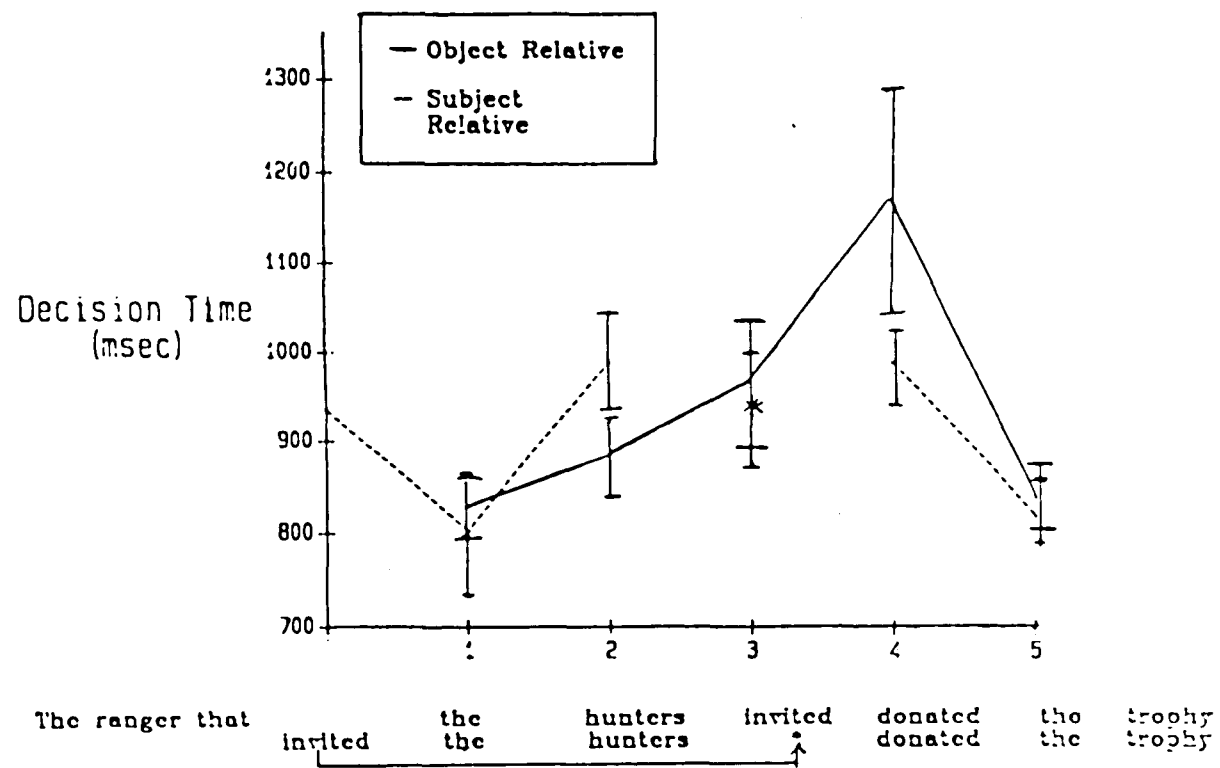
Object Relative-The expert that the doctors phoned solved
the crimes

Mean response times across sentences and subjects for those positions selected in the two relative clause sentence types

(subject and object) are shown in Figure 1. Mean response times shown were averaged from subject and item analyses.

Figure 1.

Experiment 1: Mean decision times for Subject relative and Object relative sentences (averaged from subject and item analyses).



Highly significant effects were found for sentence position in both the subject analysis, $F_1(4,76)=10.18$, $p<.0001$ and the item analysis, $F_2(4,76)=6.90$, $p<.001$. Significant effects were also found for the interaction of sentence type with position in both the subject analysis, $F_1(4,76)=2.89$, $p<.05$ and in the item analysis, $F_2(4,76)=2.63$, $p<.05$.

Orthogonal contrasts were performed to see which positions yielded significant differences between subject and object relative clause sentence types. The difference at position 4 (the verb of the main clause) was significant in both the subject analysis, $F_1(1,76)=10.17$, $p<.01$ and the item analysis, $F_2(1,76)=8.0$, $p<.01$ and is reflected in Figure 1 mean response time profiles of the two sentence types. It can therefore be concluded that the Object relative sentences are more difficult (require more decision time) at one location, that of the verb of the main clause.

Discussion. It has been well established that Object relatives are harder to process than Subject relatives (Fodor, Bever, & Garrett, 1974; Wanner & Maratsos, 1978; Holmes, 1979).

The current task variant, just as that of Ford (1983) from which it was derived, appears sensitive to variations in local parsing complexity, having located a difference in the degree of difficulty in processing Subject and Object relative sentences. Nevertheless, differences in findings between the

current experiment and Ford (1983) raise questions regarding theoretical issues which overlap with questions regarding the sensitivity of the two task variants.

From the current experiment the central presentation continuous syntactic decision task shows that Object relatives are harder to process than Subject relatives at the location of the main verb. Ford (1983), using a cumulative presentation continuous lexical decision task found results which showed that "Object relative structures are harder than Subject relatives at three locations (p.209)", the positions of the relative clause verb, the main clause verb and the main clause determiner. Those positions would correspond to positions 3 through 5 in the current experiment, thus additionally including the two words flanking the main clause verb in the Object Relatives. Ford (1983) concluded from these findings that the difficulty of Object relatives in comparison to Subject relatives lies in assignment of the head as filler of the gap (Filler-Gap parsing explanation).

Object relative sentences are but one form of sentence containing filler-gap dependencies, whose correct grammatical characterization, Frazier, Clifton and Randall (1983) state "is a topic of considerable theoretical interest". On purely theoretical grounds, it might be argued that the present finding provides stronger support for the Filler-Gap parsing procedure proposed by Ford (1983) as that used in processing

Object relative sentences. Ford (1983) contended that the findings using the continuous lexical decision task, (which Ford considered a more sensitive method than some earlier methods for measuring local parsing complexity), tended to counterindicate an earlier postulated HOLD model of parsing for Object relative sentences (Kaplan, 1974; Wanner & Maratsos, 1978) in which increased response time should have been found throughout the relative clause, reflecting an increase in transient memory load during the region of the relative clause. In fact, Ford (1983) contended that the findings of Kaplan (1974) as well as Wanner & Maratsos (1978) were equivocal due to flaws in the methodologies purported to measure ongoing memory load and their interpretation of results.

In addition, Ford (1983) claimed that had they unequivocally been able to demonstrate increased processing difficulty within the relative clause of Object relative sentences, this could not be exclusively attributed to a HOLD parsing strategy. On linguistic grounds alone one could make predictions comparable to Wanner & Maratsos (1978). Briefly summarized, Ford (1983) claimed that Wanner & Maratsos (1978) proposed in the HOLD model that "the head NP of a relative is stored in a HOLD cell as an unstructured list of elements that have not been assembled into a noun phrase or assigned a function (p.210)." During the time the head NP is so held it could not be integrated with the rest of the sentence and thus the memory

requirements involved in storing the head NP would be great and reflected throughout the relative clause. Ford claimed it to be a linguistic property of the Object relative that

"the head NP cannot be integrated with the succeeding sentence fragment consisting of the relative pronoun and the relative subject but not the verb or the gap. The head of the relative must be bound to the gap; therefore fragments of the clause that do not contain the gap must be incoherent. No matter what the processing strategy, the head NP cannot be assigned as the argument of the predicate (p. 210)."

It is due to this linguistic property which Ford (1983) claims is independent of any processing strategy that findings suggesting increased processing load within the object relative clause could not support a HOLD parsing model per se. In contrast, Ford (1983) argued that the finding of increased response times at the three locations within the Object relative sentences indicated that parsing complexity increased at the gap and remained higher for the next couple of words.

However Ford's (1983) finding of increased response time at the end of, albeit within the relative clause, (i.e., at the relative clause verb) tends to weaken the Filler-gap parsing explanation. In contrast, results from the current experiment in which increased response time is found precisely where it

might be expected, at the gap (at the main clause verb) are more in accord with the parsing explanation that Ford (1983) proposes. In fact although there is independent support for Ford's (1983) explanation that increased processing load on the relative clause verb suggested subjects "predicted the gap in the Object relatives before the gap was actually encountered (p.213)", at the very least it is not parsimonious and perhaps warranted an acknowledgement of somewhat equivocal results. Further support for an expectation of greatest response time precisely at the point of the main clause verb comes from the work of Holmes and O' Regan (1981) also cited by Ford (1983). In their study of eye fixations during the reading of French Subject and Object relatives, particularly those which have the same structure as their English "counterparts", they found that regressive eye movements occurred more often in Object than Subject relatives. Those regressive eye movements were back to the head as if checking the head by reexamining it in the string. Such regressive sequences of eye movements from that place and point in time coincided with the first fixation of the main clause verb.

It would seem from Ford's argument regarding the incoherence of the relative clause fragment, that what Wanner & Maratsos fail to differentiate is increased processing complexity from the increased transient memory load they purport to measure. Ford appears to contend that the process of searching for the

filler makes for increased processing complexity, expressed most strongly at the gap when that search ensues, that no head NP is placed in a cell which has to be held in memory to the point of the gap. Any increased processing difficulty or complexity were it to be shown throughout the relative clause could be explained by the inability to integrate the head NP prior to the gap despite probable attempts to integrate the head. Therefore one need not hypothesize transient memory loads for storing and retaining the head NP in a HOLD cell.

It is possible to interpret Ford's (1983) findings as well as those of the present study in a manner which does not place the HOLD hypothesis of Wanner & Maratsos (1978) in contention with the Filler-gap explanation. If for instance the continuous lexical decision methodology employed by Ford (1983) and the methodological variant of the current study which were used to measure local parsing complexity are insensitive to transient memory loads, the finding of neither variant sheds light on, nor negates the HOLD model proposed by Wanner & Maratsos (1978).

One might wish to consider (as in Experiment 2) what would result from lengthening the region of the relative clause. Assuming the current task variant were sensitive to transient memory loads, but the memory load was insufficient to have shown up in the current experiment, it is possible that by lengthening the relative clause that any prevalent transient

memory load might be increased and be exhibited within the relative clause. Alternatively, the filler-gap effect at the verb of the main clause might be increased due to the additional relative clause material through which subjects would have to search.

Those central issues regarding ambiguous sentences and the serial versus parallel versus delay parsing models will now be addressed.

Transitive Sentences

Predictions and results. Sensitivity to a difference in the difficulty of processing transitive sentences would be reflected in longer response times at comparable key points within the complex transitive sentences. In addition, in keeping with a serial processing model, one would not expect longer response times within the complex transitive sentences within the ambiguous region, whereas one would expect longer response times to be maintained throughout the region of ambiguity in keeping with a parallel or delay processing model. It should be noted that in the current set of complex transitive sentences no point of disambiguation is encountered within the sentence and thus differentiation of a parallel from a delay parsing model is precluded. In the delay model

increased response time would be expected not only throughout the ambiguous region but would also be expected at the point of disambiguation and beyond.

For transitive sentences, the two way factorial design consists of the two sentence types (simple and complex) x four positions crossed with the repeated measures variable. The positions consist of the verb through the two words following the verb plus the final word in the sentence. For example, response times were analyzed for the matched set of transitive sentences in underlined positions as follows:

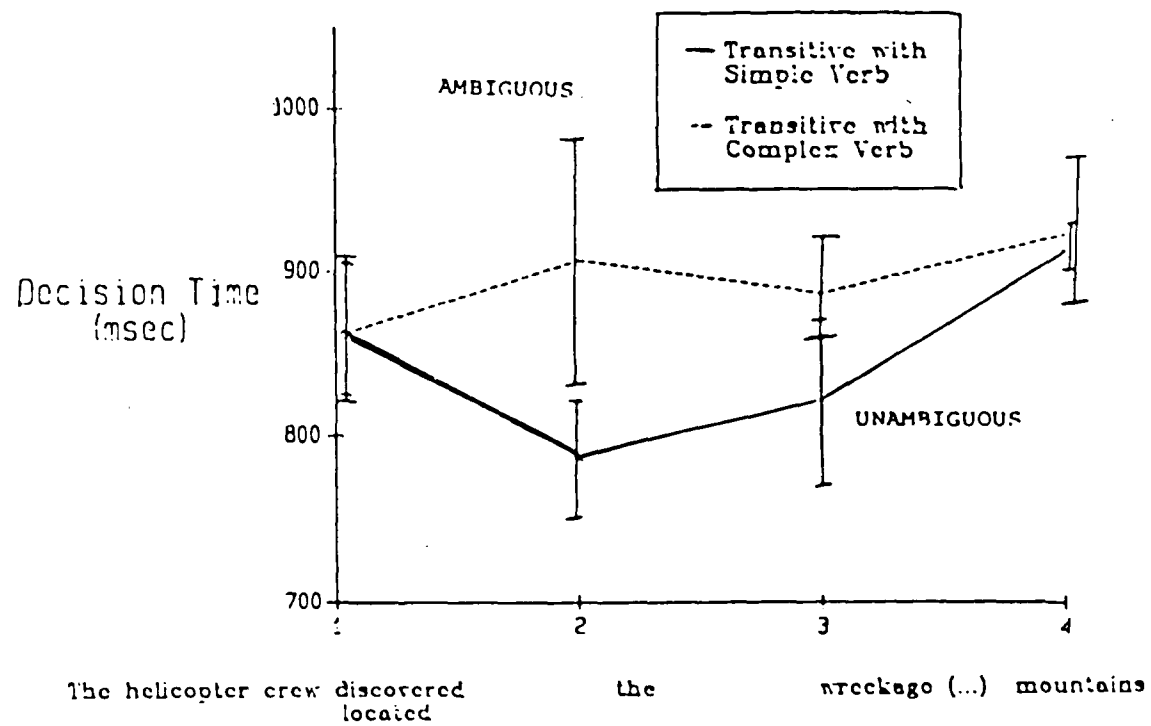
The helicopter crew located the wreckage in the mountains

The helicopter crew discovered the wreckage in the mountains

Mean response times across sentences and subjects for those positions selected in the two transitive sentence types (simple and complex) are shown in Figure 2. Mean response times shown are from the subject analysis only.

Figure 2.

Experiment 1: Mean decision times for Simple Transitive and
Complex transitive sentences (taken from the subject analysis).



A significant effect was found in the subject analysis for the interaction between sentence type and position, $F_1(3,57) = 2.82, p < .05$. The effect for sentence type in the item analysis closely approached significance, $F_2(1,11) = 4.55, p < .06$. No other effects achieved or approached significance.

Orthogonal contrasts were performed in the subject analysis to see which positions yielded significant differences between simple and complex sentence types. The difference at position 2 (the first word following the complex verb) was significant, $F_1(1,57) = 4.54, p < .05$.

It can be seen in Figure 2 that mean response time profiles of the two transitive sentence types (simple and complex) are close at positions 1 and 4 (differences of 11 and 15 milliseconds respectively) and diverge at positions 2 and 3. Orthogonal contrasts indicate a significant difference at position 2. It can thus be seen that the complex transitive sentences are more difficult at the word following the complex verb.

Discussion. Findings in the current experiment reflect the sensitivity of the current task variant to differences in local parsing complexity between simple and complex transitives but only tend to weakly support a parallel processing model in which increased processing time would be expected throughout

the ambiguous region created by the complex verb. Similarly, there is weak support for the delay model in which higher response time would also be expected throughout the ambiguous region.

It is clear that no significant difference in the degree of difficulty exists at three of the four positions selected including the fourth position, that of the final word of transitive sentences. However, it is unclear from the present results whether or not a difference in the degree of difficulty might have been found (had it been assessed) earlier in complex transitive sentences prior to the final word. Such assessment was somewhat problematic due to varied transitive sentence length, particularly the variation of the number of words within the region preceding the final word, which ranged from 2 to 4 words as in the following underlined examples:

The helicopter crew located (discovered) the wreckage in the
mountains

The birdwatcher spotted (observed) a very rare species in the
woods

Therefore, calculations of mean response times were averaged across the words in this region and compared between simple and complex transitive sentences. A four (4) millisecond difference

was obtained, which is smaller than any differences previously obtained at other positions for ANOVAS.

Thus, it appears that both the parallel and the delay model of parsing remain weakly supported, given the absence of differences in processing difficulty through the ambiguous region, that is beyond the word following the complex verb in the current set of complex transitive sentences.

It should be noted that the current set of transitive sentences end without a point of disambiguation being reached, thus precluding the differentiation of a parallel from a delay parsing strategy (if one considers that there is even weak support for either a parallel or delay parsing model). Such differentiation would additionally require an examination of the sentences from the point of disambiguation on, for continued higher response time. This would be expected for complex transitives with the resumption of parsing at the point of disambiguation as hypothesized by the delay model.

Therefore one might wish to consider (as in Experiment 2) what would result from an extension of the current transitive sentences to include a point of disambiguation beyond which they might be examined.

Complement Clause Sentences

Predictions and results. Sensitivity to a difference in the difficulty of processing complement clause sentences would

be reflected in longer response times at comparable key points within the uncomplementized complement clause sentences. In addition, in keeping with a serial processing model one would expect longer response times within the uncomplementized sentences at the point of disambiguation, whereas one would expect longer response times to be maintained within the region of ambiguity from a parallel processing model. From a delay parsing model, one would expect not only longer response times maintained within the region of ambiguity but also through the point of disambiguation and perhaps somewhat beyond.

For complement clause sentences, the two way factorial design consists of the two sentence types (complementized and uncomplementized) x six positions crossed with the repeated measures variable. The positions consist of the verb introducing the complement clause through the word following the disambiguating verb of the complement clause plus the final word in the sentence (excluding the complementizer "that" in the complementized form). For example, response times were analyzed for the matched set of complement clause sentences in underlined positions as follows:

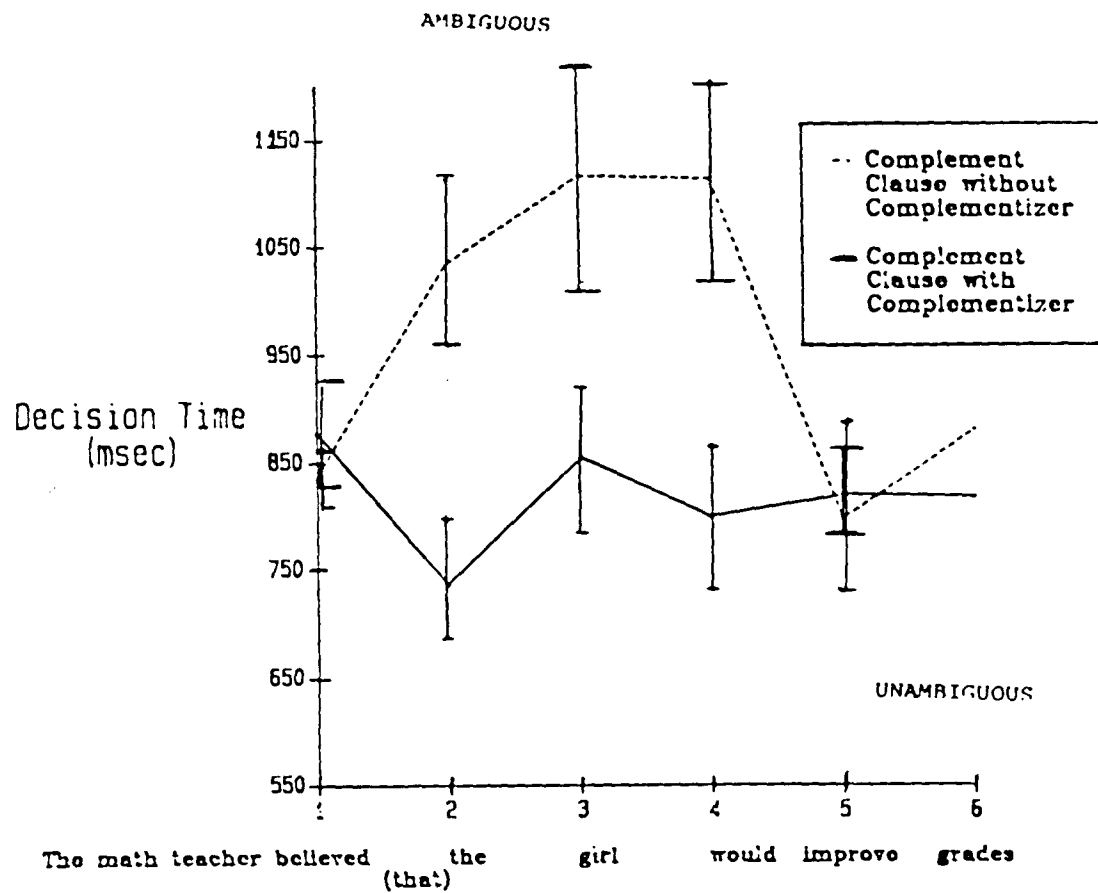
The mathematics teacher believed that the girl would
improve her grades

The mathematics teacher believed the girl would improve her
grades

Mean response times across sentences and subjects for those positions selected in the two complement clause sentence types (complementized and uncomplementized) are shown in Figure 3. Mean response times shown were averaged from subject and item analyses.

Figure 3.

Experiment 1: Mean decision times for Complementized and Uncomplementized verb complement sentences (averaged from subject and item analyses).



Significant effects were found in the subject analysis for sentence type $F_1(1,19) = 11.92$, $p < .01$, for position, $F_1(5,95) = 4.01$, $p < .01$ and for the interaction of sentence type with position, $F_1(5,95) = 5.15$, $p < .001$. Significant effects were found in the item analysis for sentence type, $F_2(1,11) = 13.62$, $p < .01$ and for the interaction of sentence type with position, $F_2(5,55) = 6.28$, $p < .001$.

Orthogonal contrasts were performed to see which positions yielded significant differences between complementized and uncomplementized complement clause types. In the subject analysis as well as the item analysis, differences were significant at position 2, $F_1(1,95) = 19.83$, $p < .01$; $F_2(1,55) = 18.48$, $p < .01$, at position 3, $F_1(1,95) = 12.65$, $p < .01$; $F_2(1,55) = 16.16$, $p < .01$ and at position 4, $F_1(1,95) = 18.48$, $p < .01$; $F_2(1,55) = 22.48$, $p < .01$, (the noun phrase and auxiliary verb of the complement clause).

It can be seen from Figure 3 that mean response time profiles of the two complement clause sentence types (complementized and uncomplementized) are close at positions 1,5 and 6 and are markedly divergent at positions 2,3 and 4 with differences between the two sentence types at these positions of divergence determined to be significant by orthogonal contrasts. It can be seen that uncomplementized complement clause sentences are more difficult beginning with the complement clause through the auxiliary verb of the disambiguating verb phrase.

Discussion. The central presentation continuous syntactic decision task of the current experiment appears to be sensitive to differences in local parsing complexity between complementized and uncomplementized complement clause sentences. In addition, findings dramatically support either a parallel or a delay processing model in which increased differences of processing time occur beginning with the ambiguous region created by the missing complementizer and terminate once the disambiguating verb phrase is encountered.

The differentiation of a parallel from a delay strategy appears to be a pragmatic as well as a theoretical problem. This appears to be so even though Ford (1983) concluded (regarding the sensitivity of her continuous decision task) that there was no lag time in her on-line measuring instrument. Three questions can be raised with respect to criteria for such differentiation. Should one expect that a dropoff of increased processing time between ambiguous and unambiguous sentences with the termination of the ambiguous region, precisely with the auxiliary verb, but not beyond that point, represents a parallel parsing strategy? Does a continuation of increased processing time beyond a disambiguating verb phrase represent a delay parsing strategy? Should both of these findings be considered necessary for the differentiation of a parallel from delay strategy? Former studies do not offer a definitive answer to these questions. Studies employing other measurement

paradigms would tend to preclude the differentiation of a serial from a delay parsing strategy with respect to the temporal localization of the processing load.

Recently Kurtzman (1984) conducted some exploratory work using a very small sample of similar materials, albeit sentence fragments. Kurtzman (1984) employed a different "on line" measure of sentence parsing purported to be more sensitive than past eye movement measures of Frazier and Rayner(1982). In Kurtzman's (1984) work as well as in the present work, judgments of grammaticality were required and judgment time measures were used as dependent variables. However, Kurtzman required a judgement only at one point in a given sentence (fragment) as opposed to the requirement for continuous judgements throughout the entire length of sentences in the current task. In the current task, continuous measures when compared between ambiguous and unambiguous versions of sentences reflect differences in processing difficulty and suggest the parsing strategy employed.

In Kurtzman's (1984) work, subjects were required either to judge the grammaticality of a sentence fragment ending after a noun phrase which was employed in either a direct object construction or a complement clause construction exemplified respectively as follows:

The financial committee failed to mention the error but

The financial committee failed to mention the error was

The first sentence fragment is structurally similar to the full transitive sentence, and the second is similar to the full complement clause sentences employed in the current experiment.

In addition, Kurtzman (1984) presented longer versions containing adjectival qualifications of the final noun phrase (thus lengthening the ambiguous region) as follows:

The financial committee failed to mention the very large error but

The financial committee failed to mention the very large error was

Kurtzman (1984) found significantly shorter reaction times to direct object constructions in longer versions. In contrast, Kurtzman (1984) also found an absence of significantly different reaction times between the two constructions in shorter versions. These findings were interpreted as evidence of a commitment to a direct object parse in the longer versions and lack of commitment between more than one maintained alternative in the shorter versions. Thus, he concluded that there was a parallel parsing strategy for the shorter sentence fragments. It appears that for sentences with shorter ambiguous regions the findings of the current experiment are in keeping

with those of Kurtzman (1984) in suggesting a parallel parsing strategy. However Kurtzman's conclusions do not appear to be unequivocally supported by his own findings due to limitations of his methodology. It is not clear why his findings were not interpreted as supporting a delay parsing strategy for sentence fragments containing shorter ambiguous regions. Given the possibility that no commitment at all had been made at the point a judgment was required or the possibility that not more than one alternative was being maintained by subjects up to the point that a judgment was required in the shorter versions, a delay parsing strategy might be equally likely. Similarly, Kurtzman's methodology does not permit conclusions regarding when commitment to a direct object construction takes place in the longer fragments and in turn whether a serial, parallel or a delay parsing strategy is employed. We are obliged to infer that if commitment has not taken place in shorter versions by the end of fragments that the resolution in favor of a direct object construction in the longer versions takes place within and as a consequence of the lengthened ambiguous region. The current experimental methodology appears to permit examination of processing complexity throughout sentences. Thus, it also appears to be more definitive regarding the parsing strategy employed in complement sentences with shorter ambiguous regions. Therefore, it should be able to shed some light on the parsing strategy employed in complement clause sentences with

longer ambiguous regions. This will be examined in Experiment 2.

Rationale for Experiment 2. Thus, Experiment 2 will attempt to address those questions raised in discussion of results from Experiment 1 through application of the on-line continuous syntactic decision task to modified sentence sets from Experiment 1. The difficulty encountered in Object relative sentences will be further examined by lengthening the test materials of Experiment 1 in the relative clause region. Transitive sentences will be lengthened to create a point of disambiguation beyond which examination might permit differentiation of a parallel from delay parsing strategy. Finally, verb complement clause sentences with lengthened ambiguous regions will be examined for comparison with results of Kurtzman (1984) who found a direct object parse of such sentences using a methodology which left unclear the parsing strategy by which the direct object parse was reached.

Experiment 2

Method

Subjects and procedure. With the exception of 20 new subjects and some stimulus sentence modifications described below, the methodology was maintained the same as that in

Experiment 1, for comparative purposes.

Stimuli. Practice and ungrammatical filler fragments remained the same. Subject and object relative sentences taken verbatim from Experiment 1 were altered only by padding them with two word qualifying adjectives in a position preceding the noun phrase in relative clauses in order to test the current hypothesis (see Appendix C). Thus, in Experiment 2, subject and object relatives contained two additional words as underlined in the following examples:

The expert that phoned the world famous doctors solved the crimes

The expert that the world famous doctors phoned solved the crimes

Similarly, complementized and uncomplementized two clause sentences taken verbatim from Experiment 1 were padded with a five word qualifying phrase in the position following the subject noun in the complement clause. Possessive pronouns (i.e. "his") were changed to articles in several sentences in order to preserve grammaticality for uncomplementized matching sentences, which would otherwise have become ungrammatical. Thus, in Experiment 2, the complementized and uncomplementized complement clause sentences contained additional words as underlined in the following examples:

The mathematics teacher believed that the girl from the
slowest reading group would improve her grades

The mathemaics teacher believed the girl from the slowest
reading group would improve her grades

All one clause transitive sentences were extended by the addition of a verb phrase at the end of each sentence, thus transforming them in essence to complement clause sentences. Only complex transitive sentence versions taken from Experiment 1 were employed in the two stimulus files of the current experiment. Each file contained six complementized and uncomplementized transitives. For example in Experiment 2 the following two forms of the sentences with additional words underlined were presented:

The helicopter crew discovered that the wreckage in the
mountains was on fire

The helicopter crew discovered the wreckage in the mountains
was on fire

Complementized and uncomplementized complement clause sentences were thus created. These sentences will hereafter be referred to as transformed transitives to distinguish them from the other complement clause sentences employed in Experiment 2. For matching purposes, complementized sentences in one file

were uncomplementized in the second file.

General Results

Data selection. With only the exception of number of positions selected, data were analyzed as those in Experiment 1. As with Experiment 1, prior to data analysis, any subject's data was eliminated and replaced by new subject data if failures to correctly respond with "YES" or "NO" key presses to grammatical or ungrammatical items respectively, reached beyond two standard deviations above the initial subject group mean. Data from 2 of the initial twenty subjects were thus replaced. The 2 were due to "insufficient" recognition of ungrammatical items. Twenty-two subjects were examined before the final subject group was obtained meeting the above criteria.

Within the final subject group, errors, that is "NO" responses, in which grammatical sentences were judged ungrammatical at some point prior to complete presentation, were made 113 times to the forty-four experimental items; 38 such errors were made to the twenty relative clause sentences, 36 to the twelve transformed transitive sentences and 49 to the twelve complement clause sentences.

Data treatment. As in Experiment 1, in order to determine generalizability of results, ANOVAS were performed first with sentences used as the repeated measure and then with subjects used as the repeated measure.

In the ANOVAS with sentences used as the repeated measure, only 8% of the positions in relative clause sentences were influenced by the trimming procedure, 2% in transformed transitive sentences and less than 1% in complement clause sentences. In the ANOVAS with subjects used as the repeated measure, only 6% of the positions in relative clause sentences were influenced by trimming, 4% in transformed transitive sentences and 6% in complement clause items.

During the running of the experiment, errors made by subjects resulted in no reaction time being recorded for sentence positions from the error on. Thus for a given subject, positions without reaction times in all sentences of a given type (ex. subject relative) in a given condition (i.e. immediate or delay), resulted in no mean reaction time for that position for that subject. These positions were filled with mean reaction times calculated from those means available up to that point from within a given sentence type and from means available from the other form of that sentence in a manner consistent with the calculation of means for the aforementioned trimming procedure.

Relative Clause Sentences

Predictions and results. As followup to Experiment 1, it was proposed that a lengthening of the relative clause might reconfirm and/or enhance the filler-gap effect already

suggested in Experiment 1. This should again be reflected in longer response time in Object relative sentences than Subject relative sentences occurring at the position of the main clause verb. In contrast, assuming the current task variant is sensitive to transient memory loads, then an increased memory load concomitant with a lengthening of the relative clause in this experiment should be reflected in longer response times in Object relative sentences than Subject relative sentences within the relative clause.

For relative clause sentences, the two way factorial design consists of two sentence types (subject relative and object relative) x eight positions crossed with the repeated measures variable. The positions consist of all the words beginning with the relative clause. For example, response times were analyzed for the matched set of relative clause sentences in underlined positions as follows:

The expert that phoned the world famous doctors solved the crimes

The expert that the world famous doctors phoned solved the crimes

As in Experiment 1, for the purpose of most direct comparison in ANOVAS, all first verbs in the subject relative form of these sentences were compared to the position the verbs occupied in the object relative form of that sentence, as

follows:

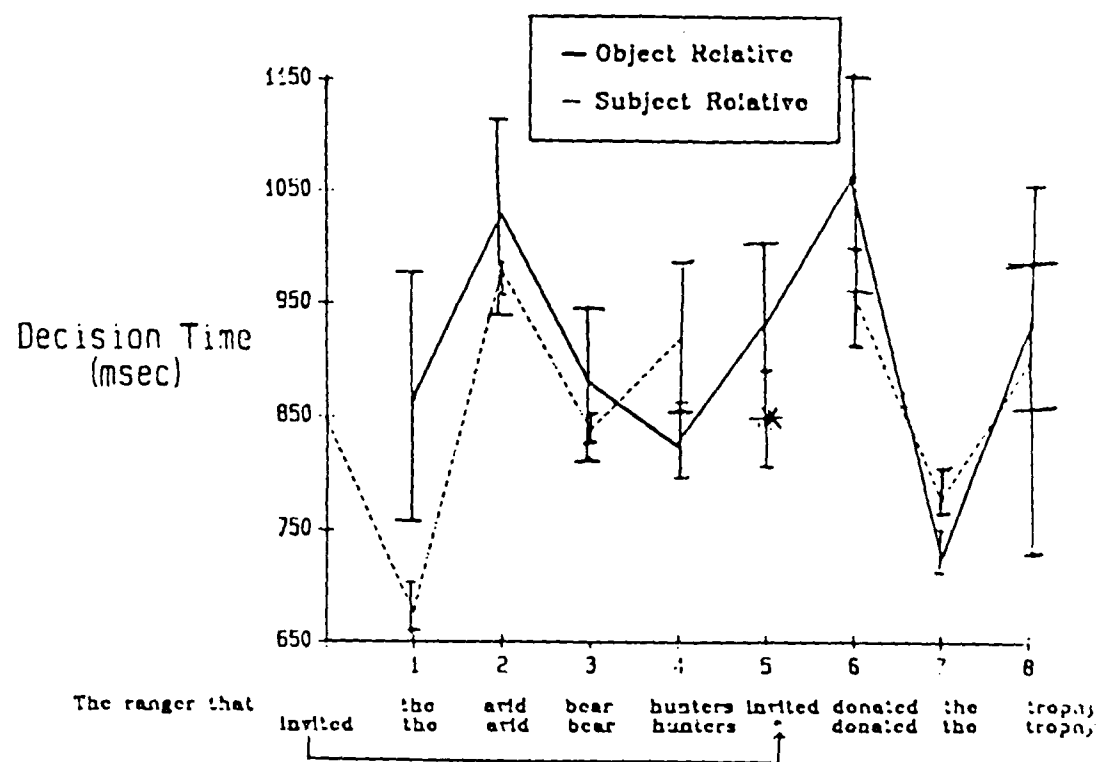
Subject Relative-The expert that the world famous doctors
(phoned) solved the crimes

Object Relative-The expert that the world famous doctors
phoned solved the crimes

Mean response times across sentences and subjects for those positions selected in the two relative clause sentence types (subject and object) are shown in Figure 4. Mean response times shown were averaged from subject and item analyses.

Figure 4.

Experiment 2: Mean decision times for lengthened Subject relative and Object relative sentences (averaged from subject and item analyses).



Highly significant effects were found for sentence position in both the subject analysis, $F_1(7,133) = 8.34$, $p < .0001$ and the item analysis, $F_2(7,133) = 6.92$, $p < .0001$. Significant effects were also found for the interaction of sentence type with position in both the subject analysis, $F_1(7,133) = 3.31$, $p < .01$ and in the item analysis, $F_2(7,133) = 3.05$, $p < .01$.

Orthogonal contrasts were performed to see which positions yielded significant differences between subject and object relative clause sentence types. The difference at position 1 (the determiner in the object relative clause) was significant in both the subject analysis, $F_1(1,133) = 14.74$, $p < .01$ and the item analysis, $F_2(1,133) = 13.86$, $p < .01$, as was the difference at position 6 (the main clause verb), $F_1(1,133) = 5.16$, $p < .05$; $F_2(1,133) = 4.38$, $p < .05$. The difference at position 2 (the second word in the relative clause) was significant in the subject analysis, $F_1(1,133) = 25.26$, $p < .05$.

It can be seen in Figure 4 from mean response time profiles of the two sentence types (subject and object relatives) that the two positions with greatest divergence are the determiner of the relative clause and the main clause verb.

Discussion. The finding and direction of the response time difference at the main clause verb is in keeping with the finding from Experiment 1, suggesting that the difficulty of Object relatives compared to subject relatives lies in the

assignment of the head as filler of the gap rather than from increased processing complexity throughout the relative clause. Again, assuming sensitivity of the current task to increased demands incurred by increased transient memory load, it is certainly not apparent throughout the relative clause.

What is to be made of the significant difference at the position of the relative clause determiner. It suggests greater processing complexity at that point in Object relatives compared to Subject relatives, but this was not found in Experiment 1. After all, it would seem that the lengthening of the relative clause in a given sentence should not influence response time at the position of the determiner which precedes the lengthened portion of the sentence in time unless the lengthening influenced expectancies over the course of the experimental session for subjects. Nevertheless the relationship of sentence lengthening per se to greater processing complexity at the determiner of object relatives is not apparent. However, an explanation based upon expectancies influenced by changes in other experimental sentences is possible. If one considers that in Experiment 2, the transitive sentences from Experiment 1 were transformed to complement sentences which in the complementized form contain a "that the" construction, then the probability that subjects in Experiment 2 would encounter such constructions is greater in Experiment 2. In these complementized complements, the "that the"

construction is preceded by a verb. It is in the Object relative sentences that a "that the" construction is also encountered albeit without a preceding verb which in turn may puzzle or surprise a subject because of its absence thus increasing the processing complexity when the determiner is encountered in the object relative clause. No such "that the" construction is encountered in Subject relative sentences and so a verb is not expected nor missed when the determiner is encountered.

Complementized and Uncomplementized Transformed Transitive Sentences

Predictions and results. As followup to Experiment 1, it was proposed that a lengthening of transitive sentences might help differentiate a delay parsing strategy from that parallel strategy weakly suggested in Experiment 1 by introducing a point of disambiguation which did not exist in those transitives. As previously detailed in the methodology section, such extension in Experiment 2 transformed complex transitives into uncomplementized complement clause sentences, the control counterparts of which were complementized complement clause sentences. It thus would be expected if a parallel parsing strategy is employed that longer response times will be shown for uncomplementized sentences throughout the region of ambiguity whereas if a delay parsing strategy is employed then

in addition longer response times will be shown at and beyond the point of disambiguation in those sentences.

For these sentences, the two way factorial design consists of the two sentence types (complementized and uncomplementized) x eight positions crossed with the repeated measures variable. The positions consist of the verb, the three words following the verb (excluding the complementizer), plus the last word of the ambiguous region, the position of the disambiguating word, the following word and the final word in the sentence. For example, response times were analyzed for the matched set of transitive sentences in underlined positions as follows:

The helicopter crew discovered that the wreckage in the mountains was on fire

The helicopter crew discovered the wreckage in the mountains was on fire

Initially, using all the complementized and uncomplementized sentences, significant effects were found for sentence position in both the subject analysis, $F_1(7,133) = 7.33$, $p < .0001$ and the item analysis, $F_2(7,77) = 3.62$, $p < .01$ as well as for the interaction of sentence type with position, $F_1(7,133) = 7.36$, $p < .0001$; $F_2(7,77) = 3.13$, $p < .01$. Although a significant effect was found for sentence type in the subject analysis, $F_1(1,133) = 7.20$, $p < .05$, the effect merely approached significance in the item analysis, $F_2(7,77) = 3.47$, $p < .09$.

Orthogonal contrasts were performed to see which positions yielded significant differences between complementized and uncomplementized sentence types. Significant differences were found at position 6 (the disambiguating verb) in both the subject analysis, $F_1(1,133) = 70.57$, $p < .01$ and the item analysis, $F_2(1,77) = 21.48$, $p < .01$. A significant difference was also found at position 7 (the word following the disambiguating verb) in the item analysis, $F_2(1,77) = 8.0$, $p < .01$.

Due to the possibility of spuriously large unrepresentative differences having been introduced by especially long response times as well as "errors" made by seven out of ten subjects at position 6 in a specific uncomplementized sentence, that sentence was deleted (i.e., "The students learned (that) most of the material in their textbooks could be wrong") from the item analysis and the item ANOVA was recomputed on the basis of one less sentence. Although the differences at positions 6 and 7 were reduced, main effects were found to be significant for sentence type, $F_2(1,70) = 20.91$, $p < .01$, for sentence position, $F_2(7,70) = 9.98$, $p < .0001$ and for the interaction of sentence type with position, $F_2(7,70) = 11.49$, $p < .0001$. From orthogonal contrasts a significant difference was again found at position 6, $F_2(1,70) = 48.30$, $p < .01$.

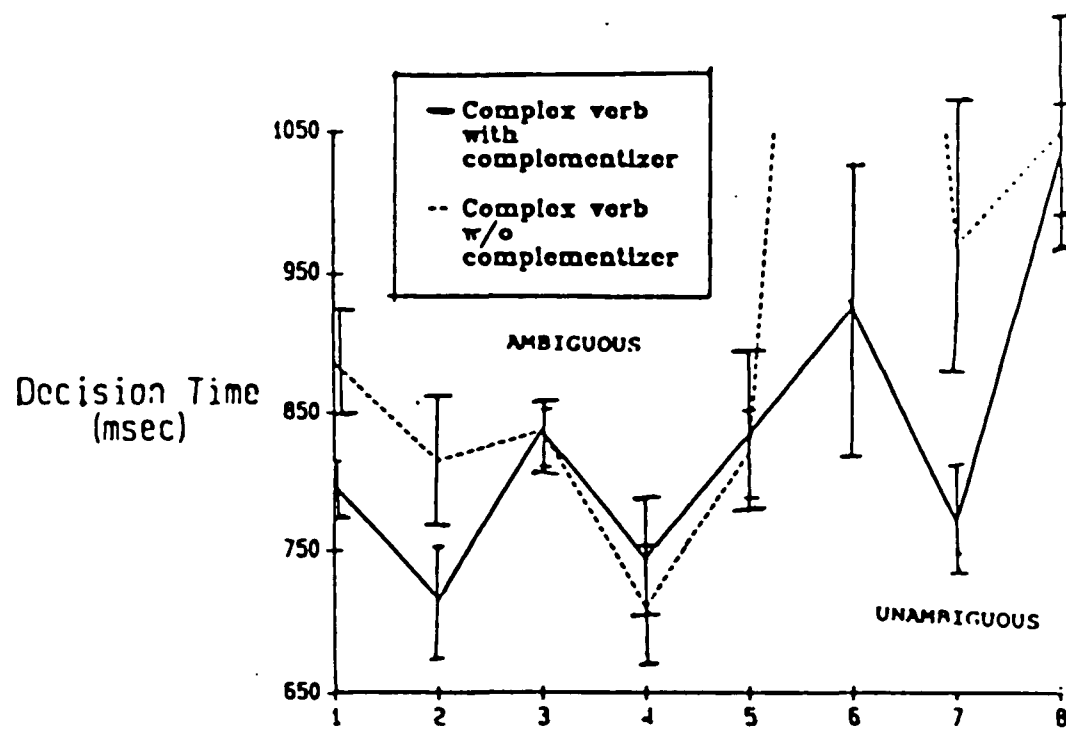
Mean response times across sentences and subjects for those positions selected in the two complex transitive sentence types

(complementized and uncomplementized) are shown in Figure 5.

Mean response times shown are from an item analysis with eleven sentences in complementized and uncomplementized versions.

Figure 5.

Experiment 2: Mean decision times for Complementized and
Uncomplementized transformed transitive sentences (taken from
an 11 sentence item analysis).



The helicopter crew discovered the wreckage in....mountains was on fire
(that)

It can readily be seen in Figure 5 from mean response time profiles of the two sentence types (complementized and uncomplementized transformed transitives) that the divergence and significant difference at position 6 (the disambiguating verb) is quite outstanding.

Discussion. The significantly longer response time at the disambiguating verb in the uncomplementized sentence strongly suggests that subjects employed serial processing, preferring the noun phrase (ex. "the wreckage in the mountains") as an object rather than the subject of a complement clause. Subjects were gardenpathed. Upon encountering the final verb phrase, subjects were surprized and/or had difficulty processing thus then having to reprocess.

Except as a consequence of the Minimal Attachment Principle (Frazier & Fodor, 1978), it is difficult to explain this finding of an apparent preference or set for processing these ambiguous uncomplementized complement clause sentences in this manner. In Experiment 2, over all the materials, fewer noun phrases appeared as objects of the main verb than as subjects of the complement clause due to the transformation of transitives from Experiment 1 into complement clause sentences. Thus, one might have expected a preferential set to have been established, albeit for subjects of complement clauses. Similarly, due to the lengthening of all sentences either by extension at the end or by added adjectival phrases within,

establishment of a set for the longer and therefore complement clause sentences (which were longer than direct object sentences) might also have been expected. In addition, it is difficult to explain the finding of a serial processing strategy employed with these transformed complex transitives given the finding in Experiment 1 which suggested, although weakly, either a parallel or delay parsing strategy for complex transitives as well as a parallel parsing strategy for uncomplementized complement clause sentences.

Furthermore, Kurtzman's (1984) finding of a parallel parsing for similar complement clause sentences also contrasts with the present transformed transitive findings. While it might be argued that the weak parallel/delay effect found for transitive sentences of Experiment 1 were quite marginal and therefore inconclusive, both Kurtzman's (1984) findings and complement sentence findings from Experiment 1 each suggest that a parallel parsing strategy might have been expected for the transformed transitives of Experiment 2. Perhaps some unsuspected systematic difference between the transitive sentence set of Experiment 1 (and by extension, the transformed transitives of Experiment 2) and the complement clause sentence set of Experiment 1 contributed to the weak parallel/delay effect in Experiment 1 transitives, the apparent serial effect in transformed transitives as well as the contrasting parallel processing shown for the complement sentences of Experiment 1.

I would argue that there appears to be such a systematic difference with respect to the animacy of the noun phrase (NP) following the main verb. That is, eleven of the twelve transitive sentences contain inanimate NPs compared with two such inanimate NPs in the complement clause sentence set. Thus, subjects may have been more inclined toward a direct object parse of the transitive and transformed transitive sentence sets without entertaining or pursuing an alternative. Subjects may not have required a parallel or delay parsing strategy since the sentences may have seemed more determined or less ambiguous. Such inanimate NPs may have seemed less likely to be the subject of a complement clause. Although one might therefore conclude that the animacy of NPs should be experimentally manipulated in future research to determine the possible biasing influence upon parsing, such biasing would not explain the disparate results found between the present transitive and complement sentence sets. This is because the parallel processing effect for the complement sentence set is suggested beginning with the determiner following the ambiguating verb. Any unsuspected systematic biasing would have to occur before the determiner, that is, in the first noun phrase or with respect to the ambiguating verb. One such possibility is a biasing toward a transitive or complement completion by the ambiguating verb, that is, lexical preference. Although lexical preferences have been demonstrated

for verbs in other studies (Ford et. al., 1982; Mitchell & Holmes, 1985), there is reason to infer from the work of Chodorow (1980) who examined the sentences from which the current set was derived that such lexical preferences did not exist in the current study. However, it must be considered that the current subject group was not examined with respect to such preferences. No unsuspected systematic biasing prior to the determiner within these sentences comparable to the biasing suggested following the determiner, could be detected by mere perusal of the materials and thus the explanation remains unsatisfying.

Complement Clause Sentences

Predictions and results. As followup to Experiment 1, it was proposed that use of the current task variant along with a lengthening of the ambiguous region in complement clause sentences might offer a more direct measure of parsing than did Kurtzman's (1984) methodology using similar materials. Complementary findings to his should be reflected in longer response times for uncomplementized sentences at the point of disambiguation on the assumption that commitment to a direct object parse would require reassignment of the noun phrase to a complement construction when the disambiguating verb is encountered, thus introducing additional processing complexity at that point. In addition, longer response times at earlier

points within the ambiguous region might be expected if commitment to a direct object parse does not take place early in the ambiguous region. If however a completely parallel parsing strategy is employed, then longer response times only throughout the region of ambiguity would be expected.

For complement clause sentences, the two way factorial design consists of the two sentence types (complementized and uncomplementized) x eleven positions crossed with the repeated measures variable. The positions consist of the verb introducing the complement clause through the word following the disambiguating verb of the complement clause plus the final word in the sentence (excluding the complementizer "that" in the complementized form). For example, response times were analyzed for the matched set of complement clause sentences in underlined positions as follows:

The mathematics teacher believed that the girl from the
slowest reading group would improve her grades.

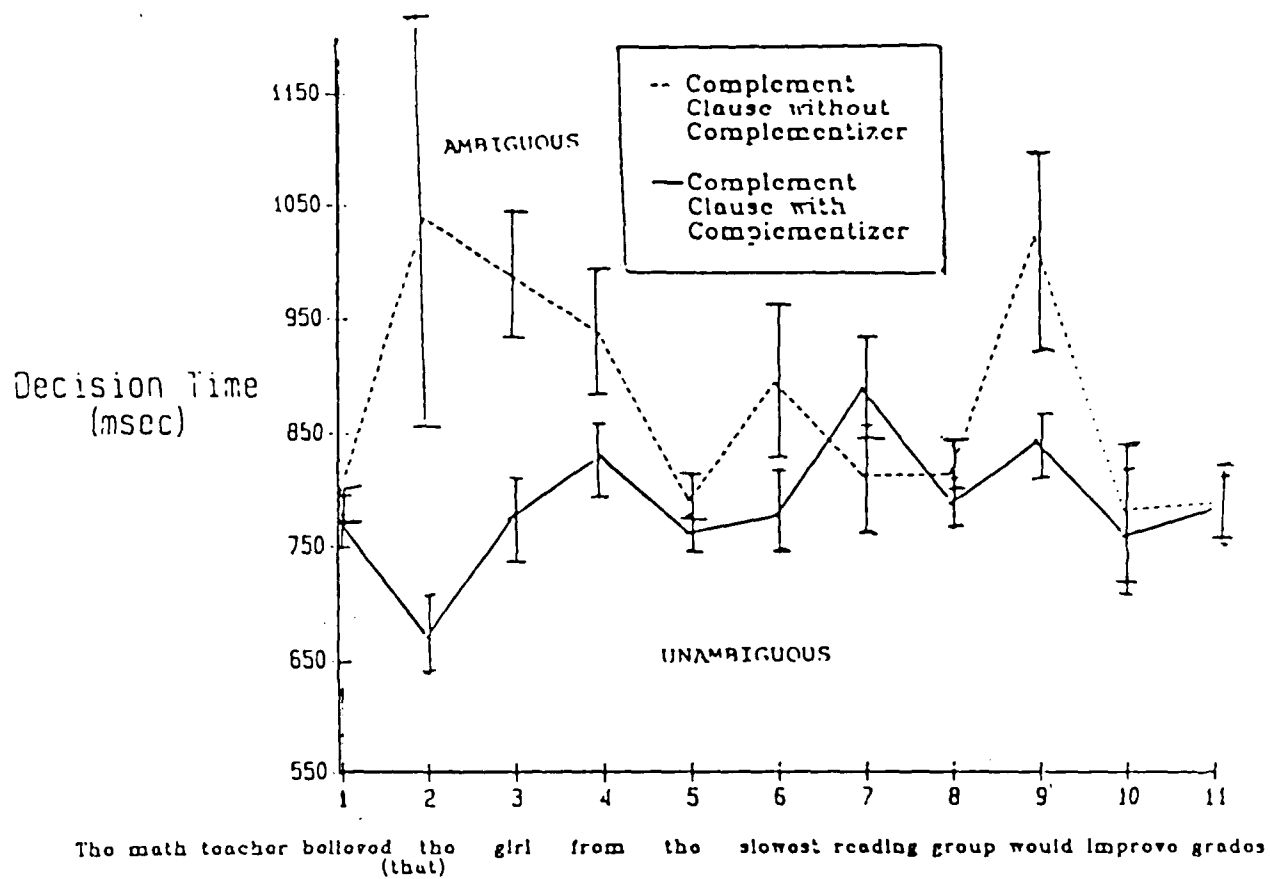
The mathematics teacher believed the girl from the slowest
reading group would improve her grades.

Mean response times across sentences and subjects for those

positions selected in the two complement clause sentence types (complementized and uncomplementized) are shown in Figure 6. Mean response times shown were averaged from subject and item analyses.

Figure 6.

Experiment 2: Mean decision times for lengthened Complementized and Uncomplementized verb complement sentences (averaged from subject and item analyses).



Significant main effects were found for sentence type in both the subject analysis, $F_1(1,190)=10.29$, $p<.01$ and the item analysis, $F_2(1,110)=11.48$, $p<.01$ as well as for the interaction of sentence type with position, $F_1(10,190)=3.91$, $p<.001$; $F_2(10,110)=2.94$, $p<.01$.

Orthogonal contrasts were performed to see which positions yielded significant differences between complementized and uncomplementized complement clause types. In the subject analysis as well as the item analysis, differences were significant at position 2 (the first word in the complement clause), $F_1(1,190)=34$, $p<.01$; $F_2(1,110)=21.11$, $p<.01$. The difference was significant at position 3 (the second word in the complement clause) in the subject analysis, $F_1(1,190)=11.07$, $p<.01$ as was the difference at position 6 (the third word of the adjectival phrase), $F_1(1,190)=4.23$, $p<.05$. The difference at position 9 (the auxiliary verb in the disambiguating verb phrase) was significant in the subject analysis, $F_1(1,190)=5.09$, $p<.05$ and the item analysis, $F_2(1,110)=6.90$, $p<.05$.

It can be seen in Figure 6 from mean response time profiles of the the two sentence types (complementized and uncomplementized complement clause) that the most outstanding positions of divergence and significant differences in both the subject and item analysis are located at position 3 and position 9.

Discussion. Greater processing difficulty for the uncomplementized complement clause sentences is suggested both at positions beginning the complement clause, that is just following the ambiguating verb and at the disambiguating auxiliary verb of the second clause. It thus appears that in these ambiguous sentences either a temporary parallel or temporary delay strategy is employed, this followed by some resolution or commitment, that is syntactic assignment in favor of a direct object structure, requiring reassignment of the noun phrase to a complement structure when the disambiguating auxiliary verb is encountered. Such a strategy is a mixed strategy, one of a number postulated by Kurtzman (1984). These results employing the current methodology lend support to Kurtzman's (1984) findings in which a direct object parse is chosen in sentences of this type with lengthened ambiguous regions. In addition, the continuous decision task permits examination of processing as it evolves even prior to the point of selection or commitment to a direct object parse, thus making the current task a more sensitive "on-line" measure than that of Kurtzman (1984).

General Discussion

Parallel Versus Mixed Strategies

It may be recalled that Gorrell (1987) criticized the earlier work of Chodorow (1979) in failing to differentiate parallel processing from possible mixed transitive and complement resolutions by a given subject or mixed strategies within a group of subjects. Such criticism could of course be applied to the present study as well as Gorrell's work per se. In an attempt to examine this possibility, ~~standard~~ errors were calculated and reflected in error bars representing the ranges of reaction time at all positions of ambiguous and unambiguous sentences. In addition, variances of reaction time ranges were compared. Significantly greater variances were found for ambiguous sentences at those positions formerly found to have significant mean reaction time differences between ambiguous and unambiguous sentences. Such post hoc findings suggest more varied processing of ambiguous than unambiguous sentence types by subject and item in the current study. The nature of such varied processing, be it mixed strategies or resolutions across subjects could not be definitively determined.

Influence of Lexical Preference

Reaction time differences between ambiguous and unambiguous sentences at the position of the disambiguating auxiliary verb

reflect the degree of complexity or difficulty created by the necessity for reassignment of the noun phrase to a complement construction. Longer reaction time differences at this position are suggestive of more complexity or difficulty than smaller reaction time differences. Reassignment is necessitated because of an initial parsing preference in favor of a transitive construction. Although such a preference appears to exist overall, perhaps as a consequence of the Minimal Attachment Principle (Frazier & Fodor, 1978), there may nevertheless be variation from sentence to sentence in parsing preferences related to verb bias (Ford et al, 1982; Chodorow, 1980; Mitchell & Holmes, 1985). Therefore, one might ask whether or not the degree of difficulty required to reassign the noun phrase from a transitive to a complement construction relates to the strength of lexical preference, that is, commitment to, or bias for a transitive construction demonstrated earlier in a given sentence. Put another way, one might ask, does the strength of lexical preference influence the strength of gardenpathing?

Lexical preferences that is, parsing preferences for particular constructions which may be associated with particular verbs have been found using presentations of whole sentences followed by a choice of interpretations from paraphrases (Ford et al, 1982), or using sentence completion/first occurring interpretation tasks (Mitchell &

Holmes, 1985). In these studies, merely changing the verb in structurally ambiguous unfinished sentence material produced a change in subjects' choices of the first occurring sentence interpretations (selected from amongst written alternatives). This in turn suggests that changing the verb changes parsing preferences. Lexical preferences associated with verbs have also been reflected in gardenpathing effects found in self paced reading tasks using reading time measures (Mitchell & Holmes, 1985). In their study using self paced visual presentation of sentences displayed in groups of words (segments), significantly longer reading times were found for sentence endings containing nonpreferred rather than preferred constructions. Construction preferences had been determined in advance through a questionnaire given to other subjects. No attempt was made to obtain two independent measures, that is, one for lexical preference and one for gardenpath effect. Lexical preference was inferred from the gardenpath effect (RT for nonpreferred endings - RT for preferred endings). Therefore, no attempt could be made to compare the magnitude (strength) of lexical preference with that of the gardenpath effect.

It might be inferred most directly from the work of Chodorow (1980) that the strength of lexical preference for a transitive construction would vary within the current sentence set for subjects participating in the current experiment.

Indeed, the current set of sentences was derived from one of the sentence sets used in that study. Lexical preferences were determined for incomplete fragments of those sentences. Ten subjects were required to complete the sentences which were truncated after the the main verb. Chodorow concluded that although there was a tendency toward transitive completions, the verbs of the sentences had functionally complex subcategorization features. Many of the verbs were considered relatively unbiased (a 50-50 or a 60-40 split) between transitive and complement completions. "At least some of the fragments in each set drew more complement completions than transitive ones and every fragment received some of each type". Percentages of the ten subjects showing a sentence completion preference for a transitive construction were thus determined for each sentence (see Appendix C). Such percentages can be considered an indication of lexical preference strength.

In an attempt to answer the question regarding the influence of lexical preference strength upon the strength of gardenpathing, these percentages were correlated with the reaction time differences found in the current experiment at the position of the disambiguating auxiliary verb (ambiguous - unambiguous). These correlations were non-significant for both the set of transformed transitives ($r(10) = -.461$) and for the lengthened complement clause sentences ($r(10) = .139$), thus suggesting no relation between the strength of lexical

preference and the strength of gardenpathing (the degree of complexity associated with reassignment of the noun phrase from a transitive to a complement construction).

Errors As a Counterpart to Larger Reaction Time Differences

It may be recalled that to one of the transformed complex transitive sentences, inordinately long response times by all subjects might have resulted in spuriously inflated reaction time differences found in that item ANOVA and thus the ANOVA was recomputed without that particular sentence. In fact three of five subjects went on to erroneously judge the sentence ungrammatical. While responses of this magnitude or kind by a majority of subjects were rare, errors made by individual or even several subjects at the same point in given sentences were by no means rare. It suggested that perhaps such erroneous judgments of sentences as ungrammatical may have been a counterpart of parsing complexity, and although it might not be reflected in greater reaction time differences nevertheless might correspond with or complement such differences.

Table 1. Number of Errors

<u>Experiment</u>	1		2	
	Transitive Complement		Transformed Complement	
Ambiguous	4	20	32	38
Unambiguous	1	2	4	11

Table 1 shows the distribution of errors amongst ambiguous and unambiguous sentences in each set from Experiment 1 and 2 without relation to position. It can be seen that as expected from design and selection of subjects, given the possibility of 120 errors, relatively few were made for either ambiguous or unambiguous sentences of any set, the least having been made with unambiguous Transitive sentences and the most having been made with ambiguous Complement sentences of Experiment 2. More errors were made amongst ambiguous versions of sentences. Eight times as many errors were made to ambiguous Transformed transitives than the original Transitives and roughly twice as many errors were made to ambiguous Complement sentences from Experiment 2 than those from Experiment 1. Increases in errors between Experiment 1 and 2 amongst unambiguous sentences were much smaller.

The relative amount of errors made amongst sentence sets is shown below.

Table 2. Comparison of Error Rates for the 12 Ambiguous and 12 Unambiguous Sentences of Experiment 1 and 2

	Number of ambiguous sentences (of 12) having...				Range of errors (maximum of 10 per sentence)	
	more errors	fewer errors	equal errors			
	..than unambiguous sentences					
Experiment					Ambiguous	Unambiguous
1						
Transitive	3	1	8		0-2	0-1
Complement	7	1	4		0-5	0-2
2						
Transformed	11	0	1	**	0-7	0-1
Complement	10	0	2	*	0-8	0-6

* Significant at .05 level by a two tailed sign test

** Significant at .01 level by a two tailed sign test

Table 2 compares ambiguous and unambiguous sentence versions within Experiments 1 and 2.

Table 3. Comparison of Error Rates for the 12 Unmodified Sentences of Experiment 1 and 12 Modified Sentences of Experiment 2

	Number of modified sentences (of 12) having...				Range of errors (maximum of 10 per sentence)	
	more errors	fewer errors	equal errors			
	...than unmodified sentences				Experiment 2 Unmodified	Experiment 1 Modified
<u>Transitive</u>						
Ambiguous	10	1	1	*	0-7	0-1
Unambiguous	3	0	9		0-2	0-1
<u>Complement</u>						
Ambiguous	10	1	1	*	0-5	0-8
Unambiguous	5	6	1		0-7	0-2

* Significant at .05 level by a two tailed sign test

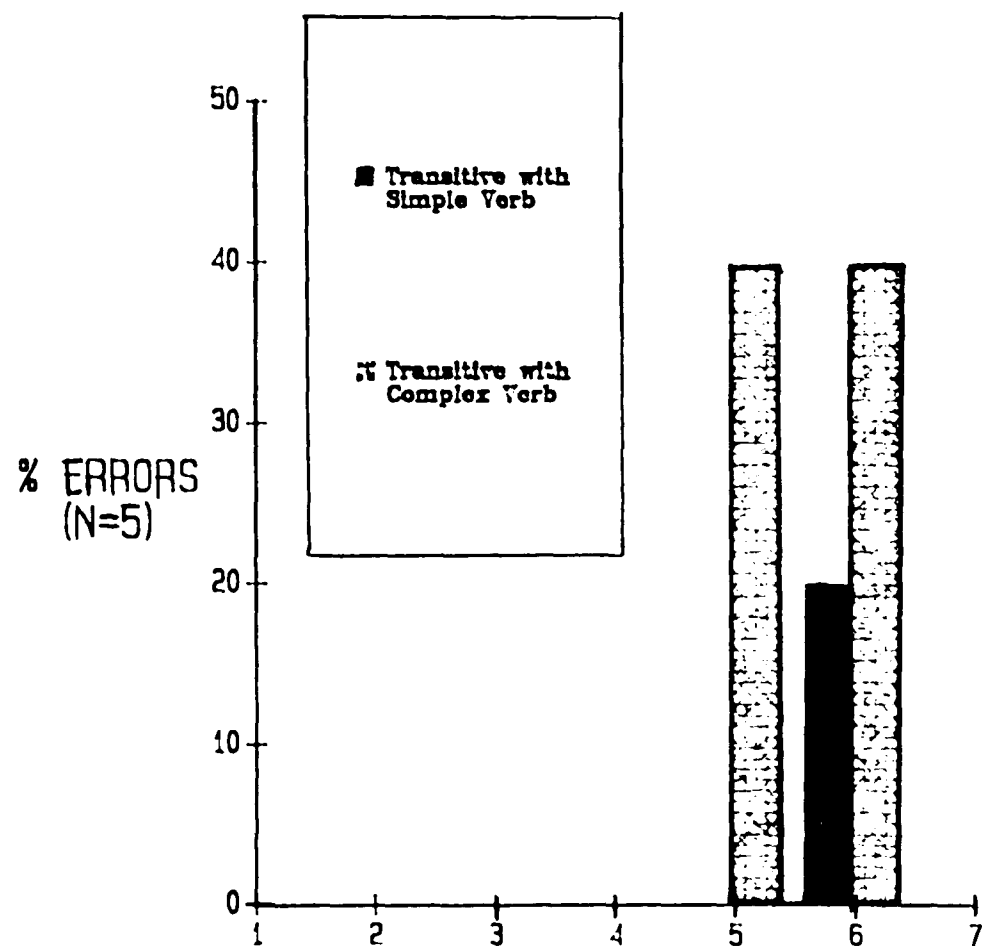
Table 3 compares the modified forms of Experiment 1 sentences used in Experiment 2 with the original (unmodified) Experiment 1 forms.

From Table 2, it can be seen that the error rate differences between ambiguous and unambiguous sentence versions are significant only amongst sentence sets from Experiment 2. Table 3 shows that the error rate differences between Experiment 1 and 2 are significant only amongst ambiguous versions of sentences. These results suggest that some interaction of ambiguity and lengthening or modifications of sentences between Experiment 1 and 2 contributed to significantly greater numbers of erroneous judgements of grammaticality by subjects in the current set of experiments.

Figures 7 through 10 show the percent of errors made at given locations (relative to ANOVA positions) within ambiguous and unambiguous versions of the sentences from Experiment 1 and 2. Full sample sentences from each of the sets accompany the graphs of the figure for illustrative purposes.

Figure 7.

Experiment 1: Error percent by location within ambiguous and unambiguous transitive sentences.

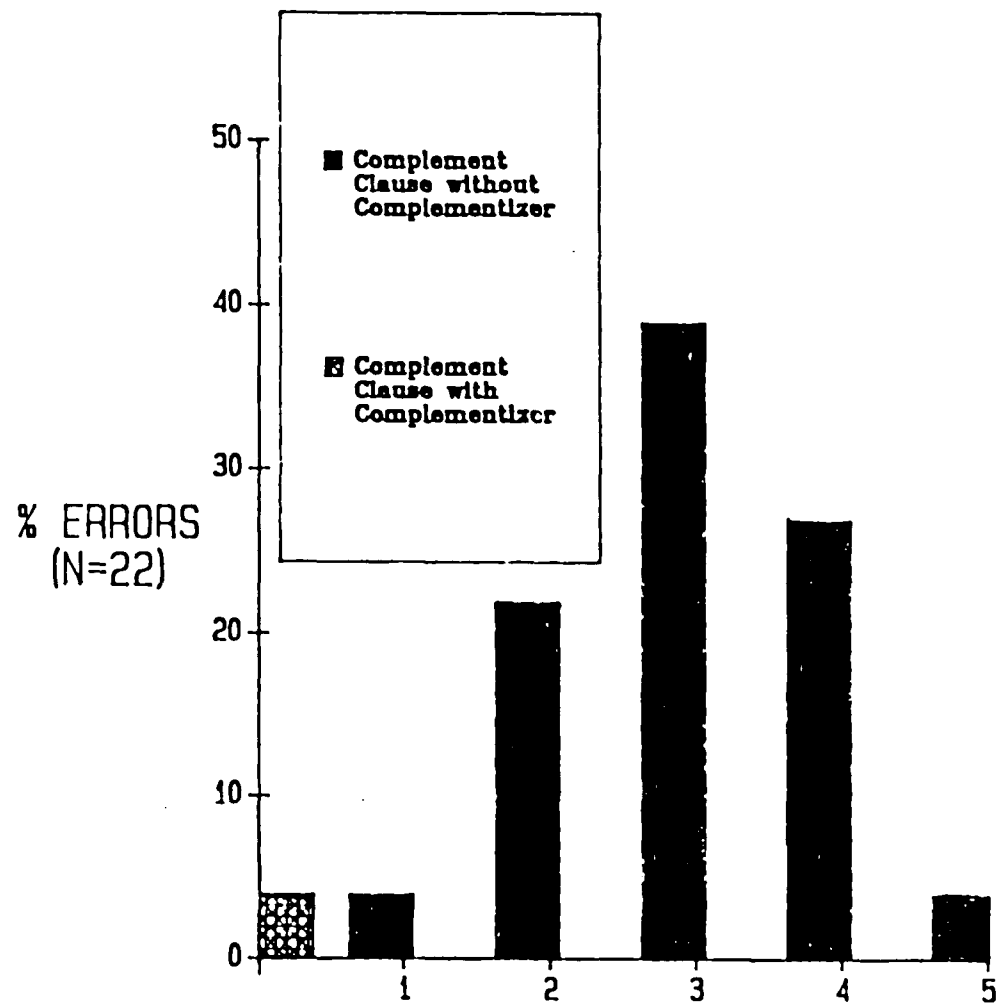


The helicopter crew located the wreckage in the mountains
discovered

It can be seen from Figure 7 that for the set of Transitive sentences from Experiment 1 all 5 errors were clustered near the end of sentences. Errors were made by subjects for both ambiguous and unambiguous sentences to the final word. This position was examined in previous reaction time analyses with no significant difference found in processing time between ambiguous and unambiguous versions. Errors were also made in ambiguous sentences on words presented prior to the final word. As previously discussed, the averaged reaction time analyses for these positions also did not yield significant processing time differences. No errors were made to words in the position following the ambiguating verb, a position for which there was a significant difference found in previous reaction time analyses. Thus, difficulty processing ambiguous transitive sentences as measured by reaction time differences does not appear to correspond to difficulties judging sentence grammaticality in the transitive sentences of Experiment 1.

Figure 8.

Experiment 1: Error percent by location within ambiguous and unambiguous verb complement sentences.

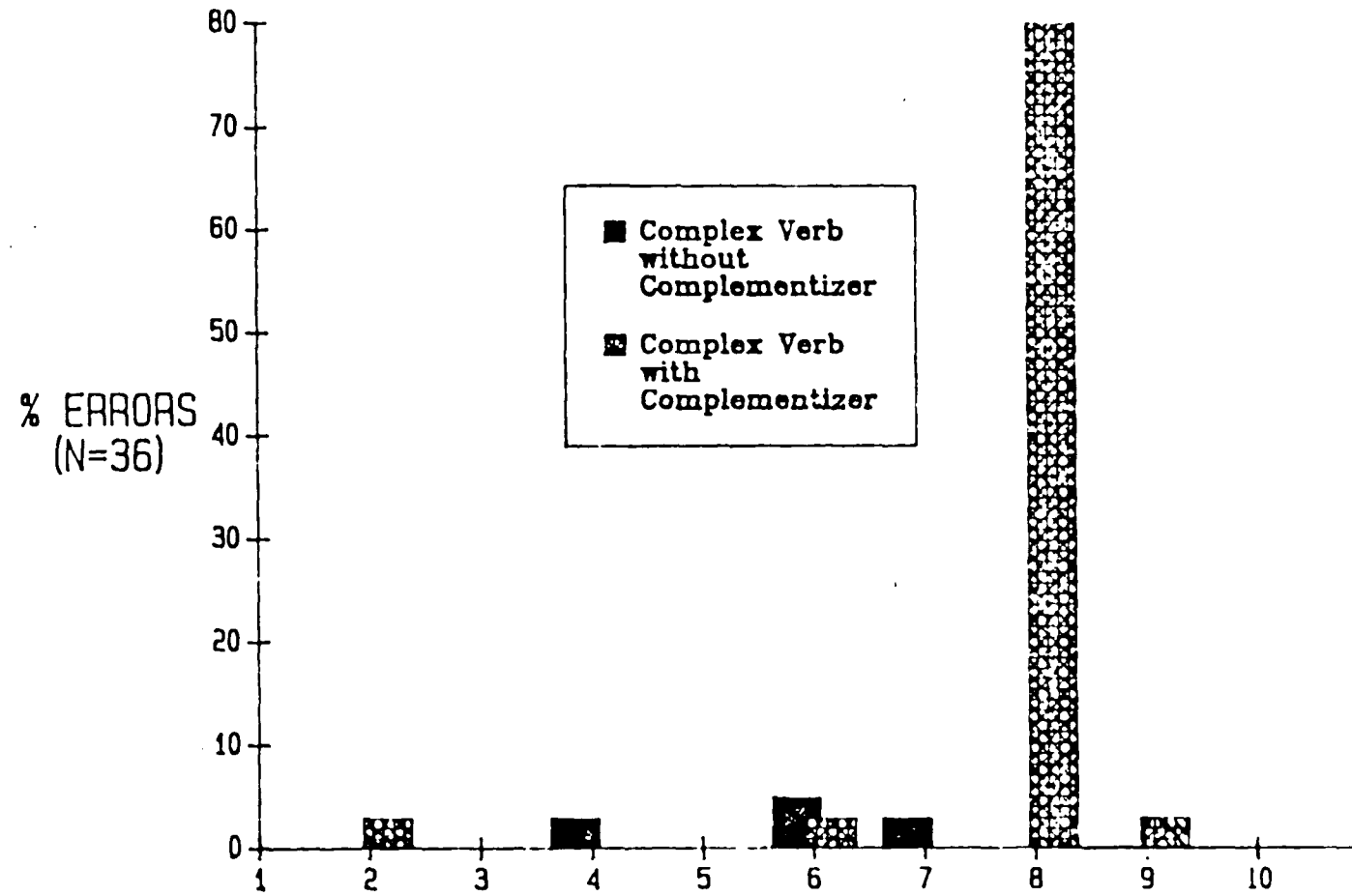


The math teacher believed
(that) the girl would improve grades

Figure 8 shows that for the set of Complement clause sentences, 2 of 22 errors were made on unambiguous sentences to the complementizer *per se*, a word for which reaction time difference data could not be obtained because complementizers existed only in unambiguous sentences. Of the total errors, the remainder were made to ambiguous sentences with the largest percent (39) made to the disambiguating auxiliary verb, with the next largest percent (27) made to the following verb and the next largest percent (22) made to the noun in the phrase immediately following the ambiguating verb. These percentages parallel the relative magnitude of significant reaction time differences found in the previous analyses. Thus, a correspondence between processing difficulty and difficulty judging grammaticality is strongly suggested.

Figure 9.

Experiment 2: Error percent by location within ambiguous and unambiguous transformed transitive sentences.

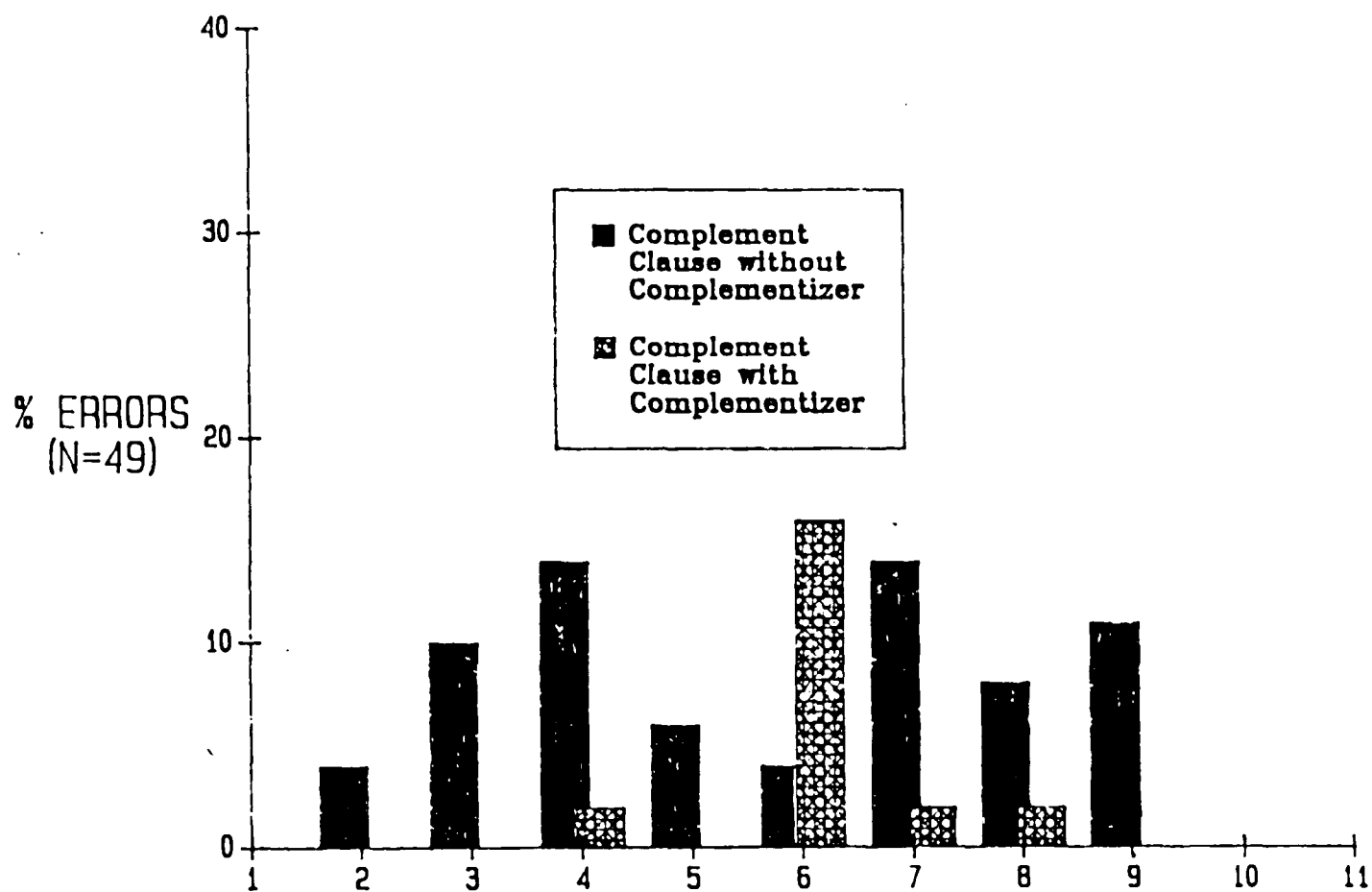


The helicopter
crew discovered (that) the wreckage in the mountains was on fire

For the set of transformed transitive sentences, Figure 9 shows that 80% of the total 36 errors were made on ambiguous sentences at the disambiguating auxiliary verb with a relatively even scattering of the remaining 20% of the errors throughout the sentences. This substantial percentage of errors at the auxiliary verb corresponds to the position of the one significant reaction time difference found in previous analyses and again suggests some correspondence between difficulty in processing sentences and difficulty in judging grammaticality.

Figure 10.

Experiment 2: Error percent by location within ambiguous and unambiguous lengthened verb complement sentences.



The math teacher
believed the
(that) girl from the
slowest reading group would improve grades

For the set of Complement clause sentences in Experiment 2, Figure 10 shows that of the total 49 errors, those made on ambiguous sentences are somewhat evenly scattered from the beginning of the third noun phrase to the auxiliary verb. This rather even distribution does not correspond with the location of significant reaction time differences found in former analyses at the position of the word immediately following the ambiguating verb and the position of the auxiliary verb.

Thus, in summary there appears to be a correspondence between processing difficulty and difficulty judging grammaticality for the Complement clause sentences of Experiment 1 and the Transformed transitives of Experiment 2.

Given that parallel processing of Complement sentences was suggested in reaction time profiles and serial processing was suggested for transformed transitives, then the difficulty judging grammaticality would not appear to be associated with a particular parsing strategy. The lack of correspondence between error distribution and reaction time difference profiles for the simple transitive sentences of Experiment 1 as well as for the lengthened Complement sentences of Experiment 2 cannot be readily or parsimoniously explained. Too low a ceiling on errors might suffice as an explanation for the simple transitives thus suggesting no competition for or need for sharing computational resources between judging grammaticality and parsing because one or both of these tasks is not

particularly difficult. However this explanation would not suffice for the Complement sentences of Experiment 2 which in form contain similarities to both the complements of Experiment 1 and Transformed transitives of Experiment 2, both of which show a correspondence between error and reaction time data. This inconsistency in correspondence raises questions as to the validity of correspondence where found. In turn, one must conclude that for these sentence sets errors in judging grammaticality cannot be used as a counterpart of reaction time differences to localize processing loads.

Summary and Conclusions

The current study was an extension of the work of Chodorow (1979), who attempted to determine which of serial, parallel or delay parsing strategies was employed in processing structurally ambiguous sentence material. A time-compressed speech methodology including post-sentential measures of processing load was employed by Chodorow (1979) in examining auditorily presented material. The current study presented visual material and employed a relatively new methodology, a self paced presentation of sentences with continuous word by word syntactic decision time measures taken throughout the sentences. This technique permitted an on-line examination of processing considered more sensitive than either the post-sentential measures of Chodorow (1979) or the single position mid-sentential decision time measures employed more recently by Kurtzman (1984).

The efficacy of the current study's methodology was established through a partial replication of Ford's (1983) work which examined processing differences between Subject and Object relative sentences using a similar continuous decision task from which the current technique was derived. Ford herself suggested using a syntactic rather than a lexical decision task

as a means to obtain greater sensitivity to differences in local parsing complexity. In fact, Ford later (1985) employed the syntactic decision task with other sentence materials. In addition, a successive rather than cumulative word by word presentation was employed for increased sensitivity.

Current findings indicated that as with Ford's (1983) task, the current task variant was sensitive to variations in local parsing complexity, having located a difference in difficulty of processing Subject and Object relative sentences. Object relatives were found to be harder to process at the position of the main verb, which is a more circumscribed location than that found by Ford (1983), a result which is more supportive of the Filler-gap parsing explanation originally proposed by Ford (1983) for her own work. In finding support for the Filler-gap parsing explanation, Ford (1983) contended that the HOLD model of parsing for Object relative sentences (Kaplan, 1974; Wanner & Maratsos, 1978) did not apply. That is, evidence for increased transient memory load which should have been reflected in increased processing difficulty throughout the region of the relative clause had not been found. It appeared to this author that Ford's (1983) own finding of greater difficulty with Object relative processing not only at the main clause verb and main clause determiner but also at the position of the relative clause verb served to weaken Ford's argument. A reconciliation of the two positions was offered, that being the possible

insensitivity of the current as well as Ford's task to transient memory load effects. Thus, a followup experiment was conducted as part of the present study in which the relative clause was lengthened in order to enhance possible transient memory load and/or Filler-gap effects. As a result, the greater processing difficulty was again found at the main clause verb of Object relatives and not found throughout the relative clause.

These followup findings tend to reaffirm Ford's conclusion that the greater difficulty in the processing of Object relatives lies in assignment of the head as filler of the gap rather than increased processing complexity throughout the relative clause. This of course assumes sensitivity of the current task variant to increased demands incurred by increased memory load.

Prerequisite to the central investigation of parsing strategies in the current study were those general findings indicating that the current task variant was sensitive not only to differences in local parsing complexity between Subject and Object relatives but also between ambiguous and unambiguous transitive and verb complement sentences. This was reflected and graphically depicted in profiles of decision time differences found between the sentence types.

Regarding serial vs. parallel vs. delay parsing strategies employed for the ambiguous sentences examined, it was found

that for ambiguous transitive sentences there was only weak support for either a parallel or delay parsing strategy (as opposed to a serial strategy). This was reflected in findings of greater processing difficulty for complex transitives found within the ambiguous region, albeit at only one position (the word following the complex verb). By nature the transitive sentences ended without a point of disambiguation, thus precluding differentiation of a parallel from a delay parsing strategy (which requires examination of sentences at and beyond such a point). Therefore as followup in a second experiment, transitive sentences were lengthened to include such a point of disambiguation beyond which to examine (in effect transforming them into complement clause sentences).

The greater difficulty processing the ambiguous sentences at the position of the disambiguating verb was quite outstanding and strongly suggested that subjects employed a serial parsing strategy in which they preferred to parse the noun phrase of these sentences as objects rather than subject of the complement clause. It was argued that except as a consequence of the Minimal Attachment Principle preference for an object parse with a serial parsing strategy would not have been expected, given the suggestion (albeit weak) of a parallel or delay parsing strategy employed with the original transitive sentences. In addition, the lengthening of the transitive sentences created a set of sentences not unlike the complement

verb sentence forms which were also examined in the first experiment of the present study. Findings for these sentences dramatically supported either a parallel or delay parsing strategy in which increased processing time differences occurred beginning with the ambiguous region created by a missing complementizer and terminated once the disambiguating verb phrase was encountered.

Further weighting expectations in favor of a parallel parsing strategy for the transformed materials was the reported work of Kurtzman (1984) whose findings with similar complement clause sentences were interpreted in favor of a parallel parsing strategy. By way of explanation, it was suggested that there perhaps was an unknown unsuspected systematic difference between transitive and complement clause sentences prior to the determiner (following the onset of ambiguity) with respect to the animacy of the noun phrase following the main verb. Such a bias could be ruled out, whereas biasing by lexical preferences seemed unlikely but could not be definitively ruled out. A more direct measure of lexical preferences in study subjects of future research could be helpful in this regard.

It was argued in the current study that Kurtzman's (1984) methodology, which required a single mid-sentence grammaticality judgment by subjects was not an on-line measure of processing throughout sentences as was the current methodology. Therefore, it seemed worthwhile to test out

Kurtzman's (1984) conclusions regarding complement clause sentences containing longer ambiguous regions, that is that they are resolved in favor of a direct object parse. Support for this conclusion was found in the followup experiment of the current study. In addition, the present methodology permitted examination of processing throughout these sentences, from which it was further concluded that a mixed parsing model was used. It appeared to be one in which a parallel or delay strategy was initially pursued, followed by some resolution in favor of a direct object structure, necessitating reassignment of the noun phrase to a complement structure when the disambiguating auxiliary verb was later encountered.

A post hoc analysis of standard errors with respect to syntactic decision times from ambiguous and unambiguous sentences was conducted in the current study. The analysis suggested that the current findings are subject to earlier criticism regarding difficulty differentiating parallel from mixed subject strategies which should be addressed more systematically in future research.

Earlier work demonstrated the existence of verbs biasing parsing toward particular constructions (lexical preference). Therefore, it was of interest to determine if the bias of individual verbs in the current sentence sets strengthened parsing in the direction of transitive constructions, possibly making reassignment from transitive to complement

constructions, which were required, more difficult (the garden path effect). A correlational analysis of lexical preference and garden pathing was not statistically significant although factors were discussed related to undetermined lexical preferences for the current subject group precluded certainty on this issue.

There were informal findings that some errors in making judgments of sentence grammaticality by some subjects coincided with increased decision time making correct judgments by other subjects. This was followed up with a more comprehensive examination of error rates and error distribution to determine if a correspondence existed between parsing complexity and grammaticality judgment errors which in turn might suggest that the latter be considered a counterpart to decision time measures of parsing complexity. An examination of the distribution of errors amongst sentences suggested a correspondence between processing difficulty and difficulty judging grammaticality for the complement clause sentences in the first experiment and the transformed transitives in the second experiment, neither of which appeared to be associated with a particular parsing strategy (i.e., serial or parallel). However a correspondence was not found for the lengthened complements of the second experiment which in form contain sufficient similarities to both the aforementioned sentence sets to raise questions as to the validity of those apparent

correspondences. Therefore, for the sentence sets of the current experiment, it appears that errors in judging grammaticality cannot be used as a counterpart of decision-time differences to localize processing load. A more formal correlational analysis of error rates suggested that an interaction between ambiguity and lengthening of sentences contributed to greater numbers of erroneous grammaticality judgments in the current set of experiments.

Appendix A

Stimulus File 1 for Half of the Subjects

Transitive Sentences

The helicopter crew discovered the wreckage in the mountains

The structural engineer explained the strength of the new
design

The birdwatcher observed a very rare species in the woods

The surveyor determined the length of the plot of land

The contestants guessed the number of jelly beans in the jar

The fireman noticed a potential fire hazard in the building

The students covered most of the material in their textbooks

The foreign diplomat discussed the provisions of the treaty
proposal

The astronomer checked the accuracy of his original
calculations

The waiter dropped a plate of cornbeef and cabbage

The physician studied some recent cases of the once-rare
disease

The manufacturer defended the superior quality of his product

Complement Clause Sentences

The mathematics teacher believed the girl would improve her
grades

The new law specifies taxpayers can take an extra deduction

The general assumed his men would fight bravely in battle

The meteorologist recommended people near the coast seek
shelter

The broker requested the company issue more stock

The banker recalled his friend repaid the loan on time

The college president promised that a committee would
investigate the scandal

The young minister hinted that his congregation should be more
charitable

The hijackers demanded that the airline follow their
instructions

The scientist predicted that his assistants would verify the
controversial experiment

The judge insisted that the experienced lawyer handle the case

The rookie patrolman feared that the sergeant would push him
around

Relative Clause Sentences

The ranger that the hunters invited donated the trophy

The managers that the designer praised examined the sketches

The author that the speaker opposed denied the comment

The driver that the soldier fought visited the lawyer

The singer that the actress adored mended the costume

The fighter that the referee fooled chewed the tobacco

The builder that the merchant disliked ignored the protest

The dancer that the crowd loved joined the ballet

The tourist that the cowboy accused avoided the rancher
The jockey that the winner hated blamed the owners
The client that greeted the porter forgot the package
The waiter that upset the actors ruined the supper
The sponsor that thanked the pianist rented the cottage
The composer that advised the musician altered the proposal
The expert that phoned the doctors solved the crimes
The reporter that attacked the senator admitted the mistake
The servant that kicked the guards escaped the sheriff
The editors that elected the judges awarded the prizes
The priest that admired the bishop revised the lecture
The worker that liked the artist signed the papers

Stimulus File 2 for Half of the Subjects

Transitive Sentences

The helicopter crew located the wreckage in the mountains
The structural engineer improved the strength of the new design
The birdwatcher spotted a very rare species in the woods
The surveyor measured the length of the plot of land
The contestants counted the number of jelly beans in the jar
The fireman removed a potential fire hazard from the building
The students learned most of the material in their textbooks
The foreign diplomat revealed the provisions of the treaty proposal
The astronomer doubted the accuracy of his original calculations

The waiter suggested a plate of cornbeef and cabbage

The physician reported some recent cases of the once-rare
disease

The manufacturer guaranteed the superior quality of his
product

Complement Clause Sentences

The mathematics teacher believed that the girl would improve
her grades

The new law specifies that taxpayers can take an extra
deduction

The general assumed that his men would fight bravely in battle
The meteorologist recommended that people near the coast seek
shelter

The broker requested that the company issue more stock

The banker recalled that his friend repaid the loan on time

The college president promised a committee would investigate
the scandal

The young minister hinted his congregation should be more
charitable

The hijackers demanded the airline follow their
instructions

The scientist predicted his assistants would verify the
controversial experiment

The judge insisted the experienced lawyer handle the case

The rookie patrolman feared the sargeant would push him
around

Relative Clause Sentences

The ranger that invited the hunters donated the trophy
 The managers that praised the designer examined the sketches
 The author that opposed the speaker denied the comment
 The driver that fought the soldier visited the lawyer
 The singer that adored the actress mended the costume
 The fighter that fooled the referee chewed the tobacco
 The builder that disliked the merchant ignored the protest
 The dancer that loved the crowd joined the ballet
 The tourist that accused the cowboy avoided the rancher
 The jockey that hated the winner blamed the owners
 The client that the porter greeted forgot the package
 The waiter that the actors upset ruined the supper
 The sponsor that the pianist thanked rented the cottage
 The composer that the musician advised altered the proposal
 The expert that the doctors phoned solved the crimes
 The reporter that the senator attacked admitted the mistake
 The servant that the guards kicked escaped the sheriff
 The editors that the judges elected awarded the prizes
 The priest that the bishop admired revised the lecture
 The worker that the artist liked signed the papers

Stimulus File 1 and 2

Filler Sentences and Fragments for All Subjects

The priest that if
 The before
 The mechanic that however

Before we tomorrow
The man that when
The only answer floor
The company that beside
It around
An enjoyable his
The dogs that is
The clamps that who
All of run
The scouts that why
The school that end
They sold the painting smile
Whoever finds the course too table
Some people believe that their best the
The singer recorded the song for with
Although the rewards were merely was
Two men rode quickly store
Near the arena was standing might
Little time has been door
Weary of the long drive them
Finishing the race was all some why
If all goes too while
The manager escorted the visitor think
The sheriff arrested the tell
The bitter cold forces people lose
Many trees were injured pipe

Each sheep had been died

The careful waiter that carried the salad was extremely
lettuce

The helpful caretaker carried the statue from the garden to
the under

The frustrated musician moved the piano from the basement to
the room sing

The fearful soldiers guarded the office near the translate

The cashier that the customer considered honest became was

The proud dancer that showed the director his studio with
under

The oldfashioned barber that the hairdresser brought the
liking

The chef cooked the roast on the include

The respectful nuns that watched the baby at laughed

The skilled jeweler made the bracelet with the asked

The newscaster that reported the information to about

The city worker met the district representative for seems

The diligent lawyer found the policy to be much never

The best guitarist playing acoustic jazz is undoubtedly were

Practice Sentences and Fragments for All Subjects

The resourceful teacher found that the children all and

Their slanderous comments annoy could

The detective questioned our neighbor after the

The impending nuclear teach

The hero leaped to the without

The cow that the butcher warned us about was the know

Too few cups us

Those clues that the people detected very errors

He believed someone was spying on

The coach insisted that the new when

The swimmers trained hard for the race

Within of

Appendix B
Instructions

"First I'll describe what you'll be expected to do and then you'll have a chance for some practice. On this screen in this box you'll be showing yourself a sentence or sentence fragment one word at a time. As each new word appears your task is to judge whether or not the word is grammatically acceptable. If the word is acceptable you should press this key marked 'yes'. If the word is not grammatically acceptable, you should press the key marked 'no'. For example, let's suppose you've already seen three words of a sentence. The three words are 'The child decided...' If the fourth word presented is the word 'could' C-O-U-L-D, it would not be acceptable because given the four words "The child decided could" a grammatically correct sentence can no longer be made no matter how it's completed. So as soon as you see the word 'could' you should press the 'no' key. Suppose instead the fourth word presented is 'that'. The word 'that' is acceptable because the four words "The child decided that..." can still be made into a grammatically correct sentence. So when you see the fourth word 'that' you should press the 'yes' key. The words that make sentences ungrammatical will appear almost anywhere in a sentence. So you may have to press the "no" key anywhere in a sentence..... toward the beginning, the middle or the end. If

you press 'no' to indicate that a word is not gramatically acceptable, a new sentence will be presented. Some sentences will be completely correct so you may have to press the 'yes' key for every word of those sentences. There will be no period to mark the end of any sentence. Instead, this box will disappear and then after a brief delay this **** symbol will be shown before the presentation of any new sentence. Since you'll actually be presenting the sentences to yourself, you should press the 'yes' key when you see this **** symbol to get rid of the symbol and to get the first word of the sentence. All first words in sentences are grammatically correct, so you should also press the 'yes' key so the second word will be shown for you to judge. Remember, each word will stay on the screen until you make your choice by pressing the 'yes' or "no" key. Use your thumbs to press the keys. Keep your hands like this (demonstrate). O.K. now you'll get some practice. The first twelve sentences or sentence fragments will be practice items. I'll stay with you during these items to answer any procedural questions and then the regular items will begin. You'll receive approximately forty regular sentences and then you'll get a brief break and then get the rest of the sentences. Make your choices as quickly as possible while trying not to make errors. It should be clear when a sentence becomes ungrammatical".

All subjects then proceed with the practice items following which they will be told to continue in the same manner for the test items and call the experimenter when signalled by the computer to do so at break time.

During the break, instructions for subjects who are to receive interword delays in the second half of the session are told:

"Now you are to continue as before. However, once you make your choice the next word will come on after a brief delay. As before a new word will stay on the screen until you make your choice".

Instructions for subjects who are to receive no interword delays in the second half of the session are told:

"Now you are to continue as before. However, once you make your choice, the next word will come on immediately without any delay. As before a new word will stay on the screen until you make your choice".

Appendix C

Stimulus File 1 for Half of the Subjects

Transformed Transitive Sentences

The helicopter crew discovered the wreckage in the mountains
was on fire

The structural engineer explained the strength of the new
design is very durable

The birdwatcher observed a very rare species in the woods
would die out

The surveyor determined the length of the plot of land was too
short

The contestants guessed the number of jelly beans in the jar
would be even

The fireman noticed a potential fire hazard in the building
had been removed

The students learned that most of the material in their
textbooks could be wrong

The foreign diplomat revealed that the provisions of the
treaty proposal would be upheld

The astronomer doubted that the accuracy of his original
calculations had been valid

The waiter suggested that a plate of cornbeef and cabbage
would be best

The physician reported that some recent cases of the once-rare
disease had been studied

The manufacturer guaranteed that the superior quality of his

product would be obvious

Complement Clause Sentences

The mathematics teacher believed the girl from the slowest reading group would improve her grades

The new law specifies the taxpayers with an elderly blind parent can take an extra deduction

The general assumed the men with the most combat training would fight bravely in battle

The meteorologist recommended the people with houses near the coast seek shelter

The broker requested the company with the most outstanding shares issue more stock

The banker recalled his friend with the most to lose repaid the loan on time

The college president promised that a committee from the student housing authority would investigate the scandal

The young minister hinted that a congregation with so many wealthy members should be more charitable

The hijackers demanded that the airline with the experienced flight attendants follow their instructions

The scientist predicted that the assistants most familiar with the test would verify the controversial experiment

The judge insisted that the experienced lawyer from the public defender's office handle the case

The rookie patrolman feared that the sergeant from the internal investigation squad would push him around

Relative Clause Sentences

The ranger that the avid bear hunters invited donated the trophy

The managers that the well known designer praised examined the sketches

The author that the very first speaker opposed denied the comment

The driver that the bad tempered soldier fought visited the lawyer

The singer that the poorly dressed actress adored mended the costume

The fighter that the easy going referee fooled chewed the tobacco

The builder that the hard working merchant disliked ignored the protest

The dancer that the mostly adoring crowd loved joined the ballet

The tourist that the mild mannered cowboy accused avoided the rancher

The jockey that the newly crowned winner hated blamed the owners

The client that greeted the long awaited porter forgot the package

The waiter that upset the well received actors ruined the supper

The sponsor that thanked the highly praised pianist rented the

cottage

The composer that advised the absent minded musician altered
the proposal

The expert that phoned the world famous doctors solved the
crimes

The reporter that attacked the newly elected senator admitted
the mistake

The servant that kicked the heavily armed guards escaped the
sheriff

The editors that elected the fair minded judges awarded the
prizes

The priest that admired the well meaning bishop revised the
lecture

The worker that liked the very popular artist signed the
papers

Stimulus File 2 for Half of the Subjects

Transformed Transitive Sentences

The helicopter crew discovered that the wreckage in the
mountains was on fire

The structural engineer explained that the strength of the new
design is very durable

The birdwatcher observed that a very rare species in the woods
would die out

The surveyor determined that the length of the plot of land
was too short

The contestants guessed that the number of jelly beans in the

jar would be even

The fireman noticed that a potential fire hazard from the building had been removed

The students learned most of the material in their textbooks could be wrong

The foreign diplomat revealed the provisions of the treaty proposal would be upheld

The astronomer doubted the accuracy of his original calculations had been valid

The waiter suggested a plate of cornbeef and cabbage would be best

The physician reported some recent cases of the once-rare disease had been studied

The manufacturer guaranteed the superior quality of his product would be obvious

Complement Clause Sentences

The mathematics teacher believed that the girl from the slowest reading group would improve her grades

The new law specifies that the taxpayers with an elderly blind parent can take an extra deduction

The general assumed that the men with the most combat training would fight bravely in battle

The meteorologist recommended that the people with houses near the coast seek shelter

The broker requested that the company with the most outstanding shares issue more stock

The banker recalled that his friend with the most to lose repaid the loan on time

The college president promised a committee from the student housing authority would investigate the scandal

The young minister hinted a congregation with so many wealthy members should be more charitable

The hijackers demanded the airline with the experienced flight attendants follow their instructions

The scientist predicted the assistants most familiar with the test would verify the controversial experiment

The judge insisted the experienced lawyer from the public defender's office handle the case

The rookie patrolman feared the sergeant from the internal investigation squad would push him around

Relative Clause Sentences

The ranger that invited the avid bear hunters donated the trophy

The managers that praised the well known designer examined the sketches

The author that opposed the very first speaker denied the comment

The driver that fought the bad tempered soldier visited the lawyer

The singer that adored the poorly dressed actress mended the costume

The fighter that fooled the easy going referee chewed the

tobacco

The builder that disliked the hard working merchant ignored
the protest

The dancer that loved the mostly adoring crowd joined the
ballet

The tourist that accused the mild mannered cowboy avoided the
rancher

The jockey that hated the newly crowned winner blamed the
owners

The client that the long awaited porter greeted forgot the
package

The waiter that the well received actors upset ruined the
supper

The sponsor that the highly praised pianist thanked rented the
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The composer that the absent minded musician advised altered
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The priest that the well meaning bishop admired revised the

lecture

The worker that the very popular artist liked signed the
papers

Appendix D

Sentence Completions for
Fragments Ending with Complex Verbs

<u>Fragment</u>	<u>Frequency of Response (%)</u>		
	Form of Completion		
	<u>Transitive*</u>	<u>Complement</u>	<u>Other**</u>
<u>Transitive Clause Sentences</u>			
1. The helicopter crew discovered...	70	30	
2. The structural engineer explained...	60	40	
3. The birdwatcher observrd...	90	10	
4. The surveyor determined...	50	50	
5. The contestants guessed...	50	10	40
6. The fireman noticed...	50	50	
7. The students learned...	50	50	
8. The foreign diplomat revealed...	60	40	
9. The astronomer doubted...	40	50	10
10. The waiter suggested...	70	30	
11. The physician reported...	70	30	
12. The manufacturer guaranteed	90	10	
<u>Complement Clause Sentences</u>			
1. The mathematics teacher believed...	30	70	
2. The new law specifies...	50	50	
3. The general assumed...	20	80	
4. The meteorologist recommended...	40	60	
5. The broker requested...	70	30	
6. The banker recalled...	80	20	
7. The college president promised...	50	50	
8. The young minister hinted...	30	70	
9. The highjackers demanded...	70	30	
10. The scientist predicted...	90	10	
11. The judge insisted...	40	60	
12. The rookie patrolman feared...	50	50	

* This category includes some transitive constructions involving verb + particle such as believed in the girl

** This category consists primarily of simple intransitives
The above table is an excerpt of a table from Chodorow (1980)

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