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6 Perceptual Mechanisms and Formal Properties of Main and Subordinate Clauses

Thomas G. Bever
Columbia University

David J. Townsend
Columbia University
and
Montclair State College

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INTRODUCTION

Language displays an awesome number of systematic phenomena. This is what makes it a favorite topic of those interested in the human mind. Here we see encapsulated a capacity that is uniquely human (on Earth) and one that draws on aspects of persona sapiens, ranging from the most concrete to the most abstract. If we could advance our understanding of language, we would make a major advance in understanding ourselves. The richness of structures in language has prompted many thinkers to despair of explaining their presence except by appeal to specific innate mechanisms. In this view language is the way it is for the same kind of reason that we have five fingers on each hand (not four or six): We are simply "programmed" genetically to be that way. In this regard linguistic science can be viewed as exploring the universals of language in order to specify what it is that constitutes our innate endowment that is specifically grammatical.

To many, this view seems stultifying—to claim that a structure is "innate" seems to leave no further reason for study: If a mental property is in fact innate, what else is there to say about it? An opposing point of view is that linguistic structures arise because of the function that language serves or because of the way it operates. Scholars in this school attempt to argue that language is the way it is because it is shaped by other mental systems, which are presumed to be general properties of the world or mind, as opposed to specifically linguistic properties.

If we now turn to other biological sciences, we find that opposition between these points of view can be quite healthy. For example, it is a dual rallying cry

of evolutionary theory that form precedes function and that function guides form. With respect to any particular structure, the question becomes empirical rather than philosophical: Which aspects are directly evolved from previous structures, and which aspects evolved because of the function they could assume? In the case of language, it is imperative to know which aspects are innate sui generis and which exist because of the functions that govern it.

As an analogy, consider the description of a home-shop drill press. Many of its functions are attributable to the ways it is employed; e.g., it must be usable at different speeds, have a table to which objects-to-be-drilled can be clamped, and a convenient lever for lowering the drill that can be used by hand. Hence, many of its features are the way they are because of what the machine is for and who will use it. Other aspects, however, have no such direct explanation. For example, the pulley could be made out of many materials; the motor has an arbitrary number of windings; the drill chock a certain number of tightening holes: in fact all the *function* of a chock requires is that it grip the drill bit, *how* it does it is arbitrary and determined by current technology. Thus, a description of an actual drill press is partially independent of the functions it serves; certain aspects may be convincingly guided by those functions, and others will be due to the nature of machines in general or to specific historical accidents in the evolution of shop tools. The description is initially independent of such considerations.

We argue that this description is analogous to the current study of language. The description of what language is must proceed independently of particular functional explanations of why it is that way. At a practical level, we cannot know what to explain until we have isolated and described it. At a theoretical level, many aspects of language may indeed have become autonomous mental structures, whatever their original functional explanation might be. Specifically, we demonstrate in this chapter that certain universal aspects of the relation between main and subordinate clauses are explicable as a function of the way language is used. The structure of our argument is the following. First, we show that the universal restrictions on word order in subordinate clauses are interpretable as a reflection of the different perceptual heuristics that apply to main and subordinate clauses. Then, we demonstrate that the differentiation of the heuristics may be characteristic of other perceptual phenomena. In the course of these investigations, we show that the processing of subordinate clauses is influenced strongly by the semantic relation set up by the subordinating conjunction—a prediction that appears to be true. Thus, we have explained an existing phenomenon and correctly predicted new data, the best of all possible theoretical worlds.

There is a broader moral to our discussion than the descriptive status of main and subordinate clauses alone. In recent linguistic discussions, researchers have argued that the complexity of facts about language requires

that semantic structures and syntactic structures be conflated: the so-called *generative semantics models* and their derivatives. The general argument underlying the specific research in this paper is that grammars that combine syntax and semantics strengthen the potential descriptive power of universal grammar and thereby weaken the psychological interest of any particular grammar. This paper serves as a case study in use of psychological theory and experimentation to relieve the grammar of formally powerful descriptive devices; if we can use experimental psychology in general for this purpose, we can maintain the study of syntax as distinct from semantics (and comprehension), thereby increasing the formal interest of universal grammar: The weaker it is descriptively (i.e., the more precise the distinction between what it could and could not describe), the greater the interest in it as the description of linguistic knowledge.

BRIEF HISTORY OF FUNCTIONAL EXPLANATIONS OF LANGUAGE

There have been two major kinds of attempts to explain linguistic structure as the result of speech functions. One we call the *behavioral context approach*, the other, the *interactionist approach*. The behavioral context approach argues that linguistic patterns exist because of general properties of the way language is used and general properties of the mind. The interactionist approach argues that particular mental mechanisms guide and form certain aspects of linguistic structure.

Behavioral Context Theories

Zipf (1949) offered one of the most noted attempts to explain language as a function of the context in which it is used. He proposed that language evolves so as best to serve the speaker and the listener in a communication situation. Both conversational participants set constraints so that conversations can proceed with the *least mental effort*. This proposal explains why frequently-used utterances become short (e.g., "television" becomes "TV"), and it led to the discovery of "Zipf's law": The frequency of a word in ordinary use is logarithmically related to its length. This striking observation was a focus for much concern until it was demonstrated that it would follow from the assumption that word boundaries are *randomly* assigned. That is, the law of least effort applied to the speaker/listener interaction does not constrain possible linguistic structures. Zipf's law turns out to be a demonstration that word length is not itself a function of linguistic structure: Some words are shorter than others for nonstructural reasons.

We are left with Zipf's (1949) plausible claim that one reason that frequent words are shortened is that this reduces the average effort needed by speakers and listeners. This observation is an acceptable hypothesis as far as it goes. However, it is not clear how to test it critically. A theory of least mental effort presupposes an independently motivated theory of mental function that can specify which utterances are relatively complex. The ultimate difficulty with the law of least effort is not that it is wrong. In a sense, it must always be circularly true if we discover which utterances are easy by looking for the ones that are uttered frequently. In Zipf's formulation, the "law" is too unconstrained to predict the particular linguistic structures that occur.

Zipf's (1949) considerations were rooted in the context of language being used by humans who actively apply a principle of least effort: Language is assumed to strike a balance between the functional needs of the listener (for the speaker to be explicit) and the speaker (to utter as little as possible to convey an idea). Martinet (1962) and his followers have offered a more abstract context in which to examine linguistic structure. The nature of each language unit is assessed in the context of the "functional information" that it conveys, relative to other language units. This view often focuses arguments on historical pressures to reduce the ambiguity of specific sounds or words. When a particular phonetic sequence carries too many potential meanings, its "functional load" is out of balance and provides pressure to change the language. This principle can apply to single sounds (e.g., in English the initial phoneme /t has a higher frequency and, hence, different functional load from the initial phoneme /dj/; this may result in a historical divergence of initial *t* into two separate phonemes if the functional load becomes too great, or a dropping of initial *dj* from the language if its functional load becomes too small). Martinet attempted to show that such pressures have determined the evolution of languages and, thereby, determine their apparent momentary structure.

The difficulty with this general proposal is that the notion of functional load *does not rest on a theory of speech function*; the only relevant facts are differences in abstracted frequencies in the units of a language and the notion that listeners and speakers pressure the language units so as to be uniformly "informative." Like Zipf's views, this notion may explain some of what speakers do with their language but not the structure of the language itself. As before, the difficulty remains that the functional theory does not constrain the possible language structures in a unique or motivated way.

The final attempt to explain language as a function of a general performance context is current in psychology and linguistics under the rubric of *computational models*. Because this development is just beginning, its inadequacies have not been fully displayed, although gloomy prognosis is clearly indicated. These models attempt to describe regularities in language behavior as a function of computationally adequate representations of language use (e.g., Lakoff & Thompson, 1974; Norman & Rumelhart, 1975; Winograd, 1972). That is, language behavior is interpreted as arising in the context of a general set of computational mechanisms that can be used to simulate any behavior. In this view the goal of research on language is to provide an empirically adequate simulation of such behaviors as speech perception, production, question answering, and sentence-picture verification. Because such simulations can (in principle) represent data obtained in all language behavior, they can be taken as representing an exhaustive account of why language is the way it is.

This approach surely is a refinement over Zipf's (1949) behavioral principle of least effort and Martinet's (1962) notion of functional load. But it shares the same defect: a lack of a psychological theory of speech mechanisms. As in previous cases, there are no psychologically relevant constraints; rather, we must refer to general computational formalisms. Here too, the formalisms do not motivate any particular representation over many others. Different simulations are available to "account" for any pattern of results.

Therefore, one must be cautious not to condemn a priori all such computational models of speech behavior. It is certainly the case that such investigators might hit upon the correct behavioral model: Formal descriptive devices of general power must surely be able to describe the correct model as well as many incorrect ones. The point here is that isolation of the correct model would be a matter of descriptive luck, not a consequence of specific universal assumption.

One must also be cautious in claiming that, in principle, computational models lack explanatory force. After all, it certainly would be possible to represent a correct psycholinguistic theory in *some* computer program. Conversely, it might turn out to be the case that the elementary formal operations of a simulation program are just those of the universal psychology of grammar. Although possible, this is extremely unlikely in the present computational models, for several reasons. First, the current models are constrained by the characteristics of current computers and available programming languages: There is no reason to believe that the human mind is constrained in similar ways. Second, the computational models are directed at simulating aspects of human language performance, not at representing the mechanisms that carry out the performance. Finally, by focusing on performance, such models eschew formal constraints on language. Because behavioral simulations are doomed to represent only part of the data, they are in danger of representing even that part incorrectly.

Behavioral Context Theories: Summary

These theories share the same virtues and limitations: They purport to describe specific features of language by reference to the behavioral context in which language exists. One could hope that such investigations can clarify the extent to which grammatical properties of language are due to behavioral

systems. However, the behavioral context theories are so general that they do not effectively predict specific properties of grammar. In any case, they characteristically do not consider grammar (e.g., Zipf, 1949), or they view synchronic grammar as nonexistent (e.g., Martinet, 1962), or they hold that "grammar" is a "convenient abstraction" (e.g., Lakoff & Thompson, 1964). In any of these views, there are no properties of language that are specifically "grammatical"; therefore, there is nothing to be accounted for by a functionalist explanation.

Interactionist Explanations

The previous models are reductionist in the sense that they seek to describe regularities of language behavior as a function of "lower-level" microstructures and constraints. An alternative form of explanation is to refer to the mental systems that *use* language rather than elements out of which the language is constructed. These approaches assume that a grammar exists as a psychologically real structure; the quest is to show that certain aspects of grammar are due to the way it interacts with other mental systems. There have been three investigations of this type during the last few decades.

Osgood has claimed for many years that the hierarchical nature of many grammatical structures is due to the way that the mechanism of learning operates in general, rather than to innate grammatical structures. Expanding on Hull's studies of habit family hierarchies, Osgood (1963) argued that laws of learning in animals provide a direct precedent for the acquisition of hierarchies in humans. Consequently, phrase structure in language is not due to some specific linguistic property but is simply an extension of learning mechanisms that govern the acquisition of behavior in mammals. In this sense, phrase-structure hierarchies are not unique to language but are characteristic of the structure that the mechanism of learning imposes on all complex behavior.

As a student of Hull, and as a committed behaviorist, Osgood has been careful to maintain the empiricist position that all psychologically real "abstract" entities are rooted directly in observable behavior and stimuli; i.e., that abstractions are subsets of overtly describable events. Consequently, Osgood has attempted to reject any term (e.g., *space, time*) that cannot be shown to be grounded in observable data. This limits the possible grammars to those that are taxonomic. The specific theory of grammar that he chose to "explain" as a function of mechanisms of learning was essentially a phrase-structure model, a model that is inadequate in a number of ways. Thus, Osgood's enterprise was exactly correct: to explain aspects of grammatical structure as due to general psychological laws governing learning. However, he was working with a limited theory of learning and an incorrect theory of linguistic structure. Thus, the enterprise was correct but limited both by its theory of language and its theory of behavior.

A second specific model has been provided by Yngve (1960), who focused primarily on the influence of speech production on grammatical structure. His main hypothesis is that the needs of the speaker restrict the amount of phrase-structure left-branching. This, in turn, "motivates" the existence of rules that reduce the amount of left-branching in any given surface phrase structure. Transformations are such rules, because many transformations appear to reduce the amount of left-branching in the surface phrase-structure tree. Yngve suggested that (at least part of) the motivation for transformation is to reduce the psychological strain on the speaker. He argued that left-branching places an inordinate processing load on the speaker, for every initial constituent in a left-branching structure is related to what follows on at least two levels (see Fig. 6.1). That is, "a" is simultaneously the initial terminal member of (a,b) and of (AB). Thus, when uttering "a", the speaker must keep both "b" and "c" in mind, until they are uttered. This is not the case with a right-branching structure, as follows in Fig. 6.2. Thus, the needs of the speaker pressure the language to form right-branching structures, which, Yngve (1960) claimed is the overall function of transformations.

Yngve's (1960) proposals are intuitive and attractive, as far as they go. Their limitation is inherent to the fact that he was not clear as to whether they were intended as synchronic or historical explanations and whether transformations were to be viewed as current psychological structures or as psychologically motivated relics. Despite this obscurity, Yngve's proposals remain a landmark in the series of attempts to explain language as a function of specific properties of how it is used. Recently, Bever, Carroll, and Hurtig (1976) have used an extended theory of speech production to account for specific universals, in particular, the role of analogy and its behavioral basis as the source for linguistic neologisms.

TREE DIAGRAMS

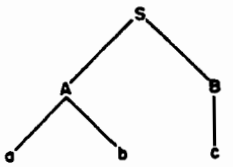

FIG. 6.1. Left-branching structure.

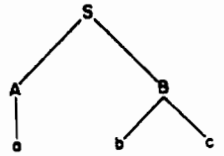

FIG. 6.2. Right-branching structure.

Yngve's (1960) proposals did not explain why left-branching does not *facilitate* sentence perception, although it increases the predictability of the latter parts of a sequence. This paradox directs the discussion to the third attempt to explain structures of language as a function of a mechanism for its use: by reference to speech perception. We discuss examples of this view in greater detail in the next section. The main features that have been explored so far involve the limitations on short-term memory: These limitations pressure listeners to segment incoming sentences into major syntactic units, which in turn, constrains the way in which certain sequences are interpreted and explains grammatical and behavioral restrictions that correspond to those constraints.

Interactionist Explanations: Summary

These models presuppose that grammar is a psychologically real entity. They attempt to explain certain properties of grammar as a function of one of the behavioral systems with which the grammar interacts. Taken together, the three specific interactionist proposals define the major systems of language behavior that could constrain grammatical structure: language learning (Osgood), speech production (Yngve) and speech perception (Bever). As these systems emerge in children, they constrain the kinds of speech neologisms and linguistic restructurings that the children will create. Thus, certain types of linguistic structures never appear, not because they are incompatible with *grammatical* universals, but because they are unusable or unlearnable. The importance of the interactionist program is that it allows us to state which observed facts about languages are due to behavioral systems and which are due to formal grammatical universals. This increase in predictive clarity makes the claims concerning innate linguistic structure more precise and, thereby, makes those claims more testable.

The Penthouse Principle

There are several formal differences between main and subordinate clauses (see Bever, 1974, 1975; Townsend & Bever, 1977a). First, Ross (1973, 1974) has noted that when there is a difference on constraints in the application of a syntactic rule that reorders words, the difference is always such that the rule applies less freely in subordinate clauses than in main clauses (see also Green, 1974; Hooper & Thompson, 1973). Differences in rule application are greater when the clause in question is the initial clause of the sentence:

(1a) *That tomorrow we will hire a new person is unlikely.
(1b) ?It is unlikely that tomorrow we will hire a new person.

(1c) Tomorrow we will hire a new person.
(2a) *Though off went the alarm Bill kept sleeping.
(2b) *Bill kept sleeping though off went the alarm.
(2c) Off went the alarm.

These constraints on word order in subordinate clauses may exist because of a comprehension strategy to interpret a subordinate clause less deeply in the immediate processing of a sentence. The listener may do so because the main clause is "more important" and, hence, serves as the basis for integration of the two clauses. The use of such a strategy would entail that the subordinate clause be retained relatively longer in superficial form, which may be easier for clauses having canonical word order (e.g., Mehler, 1963; but see Bock, 1977).

Second, a subject pronoun in an initial main or coordinate clause cannot refer to a noun phrase in a following clause, but a subject pronoun in an initial subordinate clause can refer to a noun phrase in the following main clause (Chapin, 1970; Dik, 1968; Gleitman, 1965; Lakoff, 1968):

(3) {(a)*He / (b) John} will buy a car though {(a) John / (b) he} doesn't have enough money.

(4) {(a)*He / (b) John} will buy a car and {(a) John / (b) he} will get married.

Third, deletion of a coreferential verb-phase is permissable in an initial subordinate clause but not in an initial main clause (Lakoff, 1968):

(5a) If Max does Sally will buy a car.
(5b) *Sally will if Max buys a car.

The latter two types of syntactic constraints disallow "functionally incomplete" initial main clauses, but do allow functionally incomplete initial subordinate clauses (cf. Tanenhaus & Carroll, 1975). These differences in the form of main and subordinate clauses can also be attributed to the comprehension strategy of interpreting the main clause deeply during immediate processing, for if functionally incomplete initial main clauses did occur, the listener would not be able to obtain a complete propositional representation of the clause until after the following subordinate clause had been heard.

Why are main clauses processed more deeply in the initial phases of listening? We assumed above that the main clause contains more important information. Admittedly, this term is somewhat vague. It could be more useful to say that main clauses convey assertions or new information, and

ıbordinate clauses convey presuppositions or old information.[1] Thus, we ıight say that listeners are sensitive to assertions and presuppositions in nmediate processing and that it is this difference that accounts for the ifference in syntactic constraints described above. However, it is clear that ıe information in a subordinate clause does not always carry a presupposi-ıon, as in, for example, *if* clauses and nonfactive complement clauses, and hat a subordinate clause can convey assertions, as when a speaker reports an ssertion that someone else made. It is noteworthy in this regard that D. W. Green (1975) and Hooper and Thompson (1973) have shown that word-order onstraints in subordinate clauses are relaxed when the subordinate clause is mphasized or when it reports an assertion. Whether the difference in mmediate processing of main and subordinate clauses is actually a difference n processing assertions (new) and presuppositions (given) is at present an pen question, although this distinction does have psychological validity utside the context of clausal differences (see, e.g., Haviland & Clark, 1974; Hornby, 1972, 1974; Just & Clark, 1973).

SPEECH PERCEPTION

Before demonstrating how the interactionist model can explain such facts as those about main/subordinate clauses, it is necessary for us to review what is known about speech perception.

For several decades, psychologists have been investigating the problem of speech perception as defined by Miller in the early 1950s. Miller and his colleagues showed that listening to speech involves simultaneous reference to a number of linguistic levels, including the level of the sentence and meaning. A sample demonstration of this is the fact that a sequence of random words is harder to *hear* than the same words ordered into a sentence. The most striking aspect of this phenomenon is the fact that the words themselves seem to be acoustically clearer as a function of their role in the sentence, which suggests that the sentential structure is providing information that can guide the acoustic analysis of the signal. The question was, How does this kind of interaction in speech perception occur?

That question is with us today, still unanswered. However, it has stimulated a considerable body of research that has advanced our understanding of how to answer it. There are several principles guiding virtually every kind of research program on speech perception. (a) The amount of information that can be stored in immediate memory in a single form is extremely limited. (b) The structure of language specifies a number of forms in which speech information can be simultaneously represented. These forms are structurally ordered in a hierarchy of levels. (c) The way to study the perception of a representation at a particular linguistic level is to vary the stimulus at another level and observe the changes in reports about the representation.

The linguistic levels applicable to an utterance include (at least) the following (ordered roughly according to a traditional and intuitive notion of increasing "abstractness"):

Psychoacoustics: a physiological specification of the speech waveform as transmitted by the ear.
Phonetics: a segmentation of the signal into discrete categories of speech sounds, using universal features.
Phonemes: a segmentation in terms of the categories of sounds and features used in the particular language.
Syllables: a segmentation of the sequence in terms of canonical acoustic forms that could be uttered in isolation (e.g., consonant-vowel-consonant [CVC], CV, VC).
Morphemes: a segmentation in terms of the (memorized) meaning-bearing units of the language.
Words: the minimal units, that could be uttered in isolation, in universal categories (noun [N], verb [V], etc.)
Phrases: hierarchical groupings of adjacent words into universal categories (noun phrase, verb phrase, ...).
Clauses: Groupings of adjacent phrases in terms of the canonical external relations they bear to each other (e.g., subject, verb, object).
Sentoids: groupings of the phrases (not necessarily adjacent) in terms of the canonical internal grammatical relations they bear to each other (agent, action, object, modifier).
Semantics: interpretation (usually of a sentoid) in terms of relations to other utterances with which it is synonymous, contradictory, etc.
Speech act: analysis of the utterance in terms of the act it performs (promise, request, inform, etc.).
Intention: an analysis of what the utterance indicates to be the speaker's state of mind (often in universal terms: supportive, critical, assertive, submissive, etc.).

This list is by no means complete, nor is it the case that every school of linguistics claims that all of these levels are properly included within the domain of a formal grammar. The fact remains that we can analyze even the simplest utterance simultaneously in terms of a large number of different

[1]The concept of presupposition has been given many names and definitions, and its linguistic usefulness has been questioned (see Garner, 1971; Harnish, 1976; Haviland & Clark, 1974; Kartunnen, 1973; Kempson, 1975; Wilson, 1972; and others.) We tentatively adopt the definition that the presupposition of a sentence retains its truth value when the sentence is negated, but that the assertion does not.

kinds of knowledge. For example, (5) can be represented in ways varying from an acoustic specification to a (possible) description of an act by a speaker who intends to indicate that he/she feels unwell.

(5) Can you take out the garbage tonight dear?

In a logical sense, it might appear that each of the lower levels of representations *must* be present before the more abstract levels can be fully specified; e.g., how can one isolate the phonetic segments without first having fully analyzed the acoustic structure?

The answer is that *some* acoustic analysis must be available, but not necessarily a complete one, only one that renders those specific parameters that are criterial for phonetic analysis. Furthermore, the number of choices at a lower level are restricted by the representations at *higher* levels of analysis. For example, lexical and sentential information renders almost completely predictable the phonetic segment following the fragment in (6).

(6) Can you take out the garba—

Almost *any* acoustic parameter of /ĵ/ will be sufficient for its perception at that point. Thus, perception at each level can facilitate the perception at the others. The availability of such a large number of interacting forms of simultaneous representation can reduce the limiting effect of immediate memory. In this view, speech perception is at least not magic; but how does it in fact occur?

This also raises an issue about the distinction between "top-down," "active," "bottom-up," and "passive" models of speech perception (cf. Marslen-Wilson, 1975). Obviously, perception must be passive, in part, or else it would be the equivalent of hallucination. As long as research is confined to individual clause perception, this issue can remain latent. Our present concern, however, is explicitly the perception of the relationship between clauses, which requires us to at least outline a theory of the way in which different levels of information can interact during speech perception.

Clausal Processing in Isolation

Much of the work on adult psycholinguistics has examined the processes the listener conducts while hearing a single sentence with minimal contextual cues. This research provides a useful framework for examining complex sentence processing.

The clausal-processing theory (Bever, 1970a; Fodor, Bever, & Garrett, 1974) maintains that the end of the first surface-structure clause in a complex sentence defines the major break in the structural description of the sentence.

The surface-structure clause functions as a unit during comprehension in at least three ways. (a) The listener determines the location of major surface-structure breaks during listening. This segmentation process is shown by experiments demonstrating that detection of a nonspeech noise is poorer when it occurs within a clause than when it occurs between clauses (Abrams & Bever, 1969; Fodor & Bever, 1965; Garrett, 1965; Garrett, Bever, & Fodor, 1966; Holmes, 1970; Holmes & Forster, 1970; see also Berry, 1970; Bever & Hurtig, 1975; Bever, Hurtig, & Handel, 1977; Bever, Lackner, & Kirk, 1969; Chapin, Smith, & Abrahamson, 1972; Dalrymple-Alford, 1976; Forster, 1970; Scholes, 1969; Seitz, 1972; Wingfield & Klein, 1971). (b) The listener applies perceptual mapping rules to assign the words of a clause to their semantic roles. Strategies for this mapping operation may include the use of semantic constraints that suggest the more plausible logical subject (Bever, 1970a; Slobin, 1966; Walker, Gough, & Wall, 1968; but see Forster & Olbrei, 1973; Glucksberg, Trabasso, & Wald, 1973, for instances where semantics is irrelevant), direct mapping of words onto underlying structure on the basis of the order of elements in underlying structure (Baird & Koslick, 1974; Bever & Mehler, 1967; Tanenhaus, 1977; Walker, 1969; Wanner & Maratsos, 1971; but see also Holmes & Watson, 1976; Sheldon, 1974, 1975), and mapping on the basis of syntactic properties of individual words occurring within the clause (Fodor & Garrett, 1967; Hakes & Cairns, 1970; Holmes & Forster, 1972). (c) As the listener determines a set of underlying logical relations within a clause and an interpretation for the clause, the exact word sequence of the clause fades. This process of "erasure" of words from immediate memory is shown by experiments that demonstrate abrupt shifts in verbatim recall and word-recognition performance at clause boundaries (Caplan, 1972; Jarvella, 1970; Jarvella & Herman, 1972; Marslen-Wilson & Tyler, 1976; Perfetti & Goldman, 1976). The process of deciding about an underlying structure for a clause and removal of the exact wording from immediate memory has typically been assumed to occur at the clause boundary (Bever, Garrett, & Hurtig, 1973).

Underlying Clauses as Units

The picture of sentence processing that emerges is that the listeners formulate hypotheses about underlying clauses as they hear the surface manifestations of them and make a decision about the intended underlying structure as they hear the last words of the clause, which suggests that it is the underlying clause, and not the surface clause, that is the unit of perception. Bever et al. (1969; see also Fodor, Fodor, Garrett, & Lackner, 1974) made the claim explicitly that the underlying clause functions as a better segmentation unit than does the surface clause and supported the claim by showing that click mislocations were greater into the position following the main verb

hen that position coincided with an underlying clause boundary. That is, the ick effect was greater following *desired* in (7) than it was following *defied* in):

(7) John desired Bill to resign.
(8) John defied Bill to resign.

The conclusions of Bever et al. (1969) have been questioned, however, by hapin et al. (1972), who presented evidence that clicks are subjectively isplaced towards major surface boundaries, in particular, the main ubject–predicate break. The issue has not been resolved at present because of ie difficulty of devising materials that adequately test the two positions and lso because of problems with the click paradigm itself. (For a review of the sues involved in the interpretation of click effects, see Bever, 1973; Bever et l., 1969; Chapin et al., 1972; Carroll & Bever, 1976; Fodor et al., 1974; reund, 1975; Johnson-Laird, 1974; Olson & Clark, 1976; Reber & nderson, 1970; Wanner, 1973.)

It seems apparent, nevertheless, that the underlying clauses cannot always e segmentation units, because, for example, in conventional linguistic nalyses *tall* in (9) is derived from the underlying clause S_2 in (10):

(9) The tall lady requested a table for two.
(10) (The lady (the lady is tall) requested a table for two.)
S_1 S_2

f underlying clauses are segmentation units, segmentation should occur after *all* in (9), and clicks should be attracted toward the boundary after *tall* in (9). or the present purposes, we can note that most of the evidence indicates that egmentation certainly occurs at those points where major surface structure reaks and underlying clause boundaries coincide.

With regard to the claim that the listener seeks to determine the underlying tructure of sentences during listening, three additional areas of research are elevant and are considered briefly. These areas of research deal with the "cue-eletion" hypothesis, the effects of verb complexity, and the effects of nderlying ambiguities.

Cue Deletion

The cue-deletion hypothesis states that a rule that deletes a cue to nderlying structure increases complexity in sentence comprehension. Fodor nd Garrett (1967) and Hakes and Cairns (1970) showed that sentences ontaining center-embedded relative clauses are easier to paraphrase when he relative pronouns are present, as in (11) than when the pronouns have een deleted, as in (12).

(11) The cow that the horse that the boy rode chased likes grass.
(12) The cow the horse the boy rode chased likes grass.

These results suggest that comprehension is easier when the underlying structure is more "transparent." Other studies have produced similar results with the phoneme-monitor task (Hakes, 1972; Hakes & Foss, 1970; Hakes & Cairns, 1970).

Verb Complexity

If listeners do entertain several hypotheses about underlying structure as they hear a surface clause, processing should be more difficult when there are more potential underlying structures. Fodor, Garrett, and Bever (1968) showed that paraphrasing a sentence containing a purely transitive verb, such as *slap*, is easier than paraphrasing one containing a verb that may take a simple direct object or a complement, such as *know*. This result was replicated by Hakes (1971), who also found, however, that phoneme-monitoring difficulty did not differ for sentences containing one or the other type of verb. On the other hand, Holmes and Forster (1972) found poorer performance for sentences containing complex verbs using the rapid serial-visual presentation task. For some tasks, at least, verbal complexity is related to processing difficulty, which suggests that listeners do compute several potential underlying structures when a complex verb is present.

Ambiguity

Research on the effect of ambiguities on sentence processing also suggests that listeners formulate hypotheses about underlying structure while hearing a clause and make a decision about the intended meaning at the clause boundary. Studies on ambiguities can be roughly divided into two groups: those finding that ambiguity increases processing difficulty and those finding no effect of ambiguity. Studies in the first group typically require the subjects to respond before they hear the end of the clause, i.e., before closure (Bever et al., 1973; Foss, 1970; Hurtig, 1978; Lackner & Garrett, 1973; MacKay, 1966), whereas those in the second group require the response after closure (Bever et al., 1973; Cairns, 1970; Carey, Mehler, & Bever, 1970; Foss, Bever, & Silver, 1968; Foss & Jenkins, 1973; Hurtig, 1978). The fact that ambiguity generally has its effect only before the hypothesized closure point strongly supports the clausal processing view. (We have not, however, considered here the effects of different types of ambiguity or the role of disambiguating context. See, for example, Bever, Garrett, & Hurtig, 1976; Cairns, 1971, 1973; Cairns & Kamerman, 1975; Conrad, 1974; Foss & Jenkins, 1973; Garcia, 1976; Holmes, Arwas, & Garrett, 1977; Hurtig, 1978; Tyler & Marslen-Wilson, 1977.)

ıement of Clausal-Processing Theory

ough the clausal-processing theory outlined previously has an appealing licity, other considerations indicate that certain aspects of it cannot be ct even for single sentence processing. These considerations include the rability of the three major processes, surface properties of clauses, and rlying and semantic properties of clauses.

ıparability of Processes

arslen-Wilson and his colleagues (Marslen-Wilson, 1973, 1975; Marslen-on & Tyler, 1975, 1976; Marslen-Wilson, Tyler, & Seidenberg, 1978; r & Marslen-Wilson, 1977) have shown that listeners make lexical, actic, and semantic decisions about words within a clause while they hear vords of the clause. The view that listeners have available to them several s of representations of sentence information while hearing a clause is istent with recent views of memory maintaining that immediate memory include simultaneous analysis at several levels (Craik & Jacoby, 1975; k & Lockhart, 1972; Lockhart, Craik, & Jacoby, 1976) and that listeners focus on one or another of these analyses or their products (Green, 1975). ı a view is inconsistent with the hypothesis that listeners passively ımulate lexical information during the early part of a clause, although it is inconsistent with the hypothesis that a decision between alternative erlying structural hypotheses is made at the end of the clause.

he major evidence for the on-line interactive hypothesis is that rhyme and gory-monitor times are a linear function of target position within a simple ence. This evidence suggests that there is no discontinuity in the lability of lexical and semantic information within the sentence, a direct radiction of the clausal-processing hypothesis, that the listener passively ımulates lexical information during a clause and determines the erlying structure at the end of the clause (Fodor et al., 1974). More recent k by Marslen-Wilson and his colleagues (Marslen-Wilson et al., 1978), ever, has shown a discontinuity in rhyme-monitoring in some cases. The cal cases are the following:

13a) Even though they are quite small *cats*, they need a lot of space.
13b) Even though they are quite small, *cats* need a lot of space.
14a) Although Mary rarely cooks *trout*, when she does it is delicious.
14b) Although Mary rarely cooks, *trout* is one thing she prepares well.

subject monitors the sentence for a word that rhymes with *bats* in ence (13), or with *doubt* in sentence (14). Rhyme-monitor times were ger when the target occurred after the clause boundary in (14b) than when

it occurred before the clause boundary in (14a), but there was no difference between (13a) and (13b). The presence of a clause-boundary effect in (14) suggests that information from the first clause is less accessible just after the clause boundary, so that it is not used as effectively to constrain the next word. The results for sentences like (14), then, appear to suggest a discontinuity in access to clausal information. But the results for sentences like (13) indicate that these initial clauses are relatively poor processing units and that segmentation and closure do not occur at the clause boundary.

Functional Clauses

A variety of surface properties of clauses may modify the processes of segmentation and erasure. One such property is the length of the clause (Carroll & Bever, 1976; Carroll, Tanenhaus, & Bever, 1977; Tanenhaus & Carroll, 1975). For example, it might be expected that segmentation and erasure would not be as compelling after a very short clause as compared to after a longer clause, because a very short clause would not make strong demands on processing capacity. A second surface property that may affect initial processing is the "completeness" of the clause. Tanenhaus and Carroll (1975) proposed a hierarchy of functional clauses that vary in their semantic explicitness, ranging from simple sentences and main clauses to nominalizations and showed that the more complete clauses serve as better segmentation units. For example, using a tone-location paradigm, they showed that tones are mislocated more often around the clause break (indicated by slash below) in sentences with adverbial subordinate clauses, as in (15), than they are around the clause break in sentences with headless nominalizations, as in (16):

(15) The crook ran for safety/after he stole the young woman's bag.
(16) Meeting the pretty young girl/was the highlight of Peter's trip.

In their view, this difference is due to the fact that the logical subject of the initial clause in (16) is not explicitly stated in the surface clause, making it difficult to represent as a complete proposition at the end of the clause. A further example of an incomplete clause is one containing a pronoun whose referent is unspecified, as in sentences such as (13).

Causal Relations

The clauses of a sentence may also differ in their underlying syntactic and semantic properties. To the extent that underlying structure and semantic properties are psychologically real in sentence processing, these differences can be expected to modify the processes described by the clausal-processing theory.

Main vs. Subordinate. A major difference in underlying structure tween clauses is the main-subordinate distinction: A main clause ominates a subordinate clause in the structural description of a sentence. If rt of the process of sentence comprehension involves reconstruction of the rface tree from the top-down and from left-to-right (Kimball, 1973; ornfeld, 1973; Osgood, 1963; Yngve, 1960), comprehension would be licker for clauses higher and to the left. Expressed in terms of the clausal ocessing theory, the dominant structure view would predict the segmenta- on and erasure processes to be more pronounced at the end of a main clause an at the end of a subordinate clause, all other factors constant.

A second formal difference between main and subordinate clauses that ight suggest modification of the clausal-processing theory concerns their rface properties. There are generally greater constraints on the application f syntactic rules that reorder words when they are applied to subordinate auses than when they are applied to main clauses (Ross, 1973, 1974, but see lso Green, 1974; Hooper & Thompson, 1973), but constraints on the pplication of deletion rules and pronominalization are greater in main lauses than in subordinate clauses (Chapin, 1970; Dik, 1968; Gleitman, 1965; akoff, 1968). One interpretation of these formal differences is that they are a esult of differences in the initial processing of main and subordinate clauses: ord order in subordinate clauses is more like underlying word order because is word order is easier to retain for later integration with the meaning of the ain clause (Bever, 1974; 1975),[2] and words may not be deleted as freely in ain clauses because such deletions would prohibit a more complete terpretation while hearing the clause (Townsend & Bever, 1977a). ccording to this interpretation of the surface differences between main and ubordinate clauses, the main clause is more readily interpreted.

There is considerable evidence that adults and children have better access o the meaning of a main clause, but better access to the verbatim form of a ubordinate clause immediately or shortly after hearing a sentence (Amidon & Carey, 1972; Flores d'Arcais, 1978; Harris, 1976; Shedletsky, 1974; Singer, 976b; Singer & Rosenberg, 1973; Smith & McMahon, 1970 in two of three xperiments; Townsend, 1974; Townsend & Erb, 1975; Townsend, Otta- iano, & Bever, in press; but see Johnson, 1975, Kornfeld, 1973). The ifferential accessibility to different levels of representation follows directly rom the hypothesis that main clauses are encoded more deeply during istening. In addition, several previous studies show that perception,

[2]Bock (1977, see also Bock & Brewer, 1974) has recently provided evidence that the use of alternate word order (e.g., use of passive, dative, particle movement) within a sentence depends on given-new relations, that reordering rules have the function of placing given information earlier in the sentence. How these functions of rules that are equally permissible in main and subordinate clauses interact with clause type has not been examined systematically.

comprehension, and long-term retention are easier with sentences with the main-subordinate order (Clark & Clark, 1968, for *before* sentences but not for *after* sentences; Foss & Lynch, 1969; Holmes, 1973; Hoosain, 1974), but immediate verbatim recall is easier with sentences with subordinate-main order (Jarvella & Herman, 1972). Finally, tone mislocations are more frequent at the end of a subordinate clause than at the end of a main clause (Carroll, Tanenhaus, & Bever, 1977, 1978; see also Flores d'Arcais, 1978). All of these differences are consistent with the view that a dominant strategy in sentence comprehension is an initially deeper interpretation of a main clause. Such a strategy would predict that main-subordinate sentences are easier to comprehend because the strategy can be applied to the first clause, which may result in deeper comprehension and, hence, better long-term retention of the main-subordinate sentence. An alternative interpretation of the long-term recall differences appeals to a preference for producing sentences with main-subordinate order, but even this presupposes that such a preference exists without explaining it.

All of these studies, however, tested performance after a complete sentence had been presented, and so they are subject to the criticism that the initial processing of main and subordinate clauses may not differ, but the organization of the two types in memory may. Following, we show that listeners had better access to the semantic form of main clauses than to that of subordinate clauses *while* they were hearing the sentences. This trend, however, varied considerably depending on the semantic role of the clause in the sentence.

Given vs. New. Clauses differ in terms of level of emphasis. Some clauses convey information that is emphasized, and others convey information which is deemphasized. This property of clauses has been given many different labels. The deemphasized portion of a sentence has been called *given information, old information, presupposition, presumption, background, topic, psychological subject, theme,* etc., whereas the emphasized portion has been called *new information, focus, assertion, foreground, comment, psychological predicate,* and *theme* (Chafe, 1970; Halliday, 1967, 1970; Haviland & Clark, 1974; Hornby, 1972, 1974; Katz, 1972; Kuno, 1972, 1975). Although various authors make distinctions between some of these terms (e.g., Halliday), other authors use a single term in two different ways, and different authors use the same term for different properties. Kartunnen (1973), for example, has defined *presupposition* as information that the speaker assumes the listener already knows, which is the "speaker-based" or the "pragmatic" definition; and Katz (1972), for example, as a condition under which the proposition expressed by a sentence can make a statement. The status of these concepts is, at present, quite unclear, for some authors have questioned the usefulness of the concept of presupposition for semantic

theory and whether presupposition is distinct from entailment (Boer & Lycan, 1976; Harnish, 1976; Kempson, 1975; Wilson, 1972; for further discussion of this issue see Garner, 1971; Hornby, 1972; Jackendoff, 1972; Kartunnen, 1971, 1973, 1974a, 1974b; Katz, 1972; Katz & Langendoen, 1976; Keenan, 1971; Lakoff, 1970; Morgan, 1969; Peters, 1975).

In any case, it appears that certain syntactically identifiable parts of sentences convey information that the listener is more likely to assume is true, to assume that the speaker believes to be true, or to assume that the speaker believes the listener already knows. Whether these parts of sentences are labeled *entailments* or *presuppositions* may be largely irrelevant for the purpose of studying sentence comprehension. The following examples contain some clauses whose validity the listener is less likely to question. The deemphasized clause is identified by applying the negation test that has typically been used to identify logical presupposition: The information in the underlined clause normally is taken to be true, even when "It is not the case that..." precedes the sentence, although the nonunderlined clause is normally taken to be false in this case.

(17a) Harry got sick although he ate the apple.
(17b) Harry got sick while he ate the apple.[3]
(17c) Harry got sick when he ate the apple.
(17d) Harry got sick before he ate the apple.
(17e) Harry got sick after he ate the apple.
(17f) John knows that Harry ate the apple.
(17g) John knows the man that ate the apple.

Applying the same test to the sentences with other types of clauses shows that neither clause is relatively deemphasized, as in:

(18a) Harry got sick because he ate the apple.[4]
(18b) Harry got sick if he ate the apple.
(18c) Harry ate the apple and John ate the orange.
(18d) Harry ate the apple but John ate the orange.

What seems to be denied when "It is not the case that..." precedes (18a through 18d) is the semantic relation between the clauses, not just one or the other clause.

[3]Stress pattern and clause position sometimes affect judgments of relative deemphasis.

[4]Some readers may feel that this sentence preceded by "It is not the case that..." tends to negate the event in the *because*-clause rather than that of the main clause.

The given-new (or emphasis vs. deemphasis) dimension may modify "normal" clausal processing in such a way that segmentation and erasure occur more readily at the end of an emphasized clause because the listener adopts the strategy of focusing greater attention on emphasized clauses. Another way of saying this is that emphasized clauses may be more deeply encoded while the listener hears them. Because of the correlation of the given-new dimension with the main-subordinate structural distinction, many of the studies in the previous section can be taken as support for the claim that emphasized clauses are more deeply encoded. Both Hornby (1974) and Just and Clark (1973) have suggested that presupposed information is less likely to be questioned than is asserted or implied information (see also Clark & Haviland, 1974, 1977; Harris, 1974a, 1974b; Haviland & Clark, 1974; Hupet & Le Bouedec, 1977; Offir, 1973; Singer, 1976b.)

Causal Relations. A complex sentence does not simply express a series of unrelated propositions. Rather, the propositions are related to one another in a variety of ways. To the extent that listeners are concerned with obtaining these higher order semantic relations between propositions while they hear sentences, it might be expected that clausal processing is modified (as Bever [1970a, 1970b] suggested might be the case for complex sentences). Many studies of memory show that higher order integration of propositions occurs beyond the simple grasp of propositional content (e.g., Bransford & Franks, 1971). This section describes some relations between clauses and how these relations might affect on-line processing. We deal here only marginally with implications and inferences of the sort studied by Bransford, Barclay, and Franks (1972), Just and Clark (1973), Clark and Lucy (1975), Brewer (1977), Johnson, Bransford, and Solomon (1973), Thorndyke (1976), and others, for at least some of these types of inferences are apparently derived after sentence closure (see Jenkins, 1972; Singer, 1976a).

Structurally, there are five major complex sentence types in English (Burt, 1971; Stockwell, Schachter, & Partee, 1973) containing coordinate clauses, complement clauses, adverbial clauses, relative clauses, and clefted clauses. The range of semantic relations between clauses, however, is much larger than this. Complement clauses bear a subject or object relation to the verb in the main clause, relative and clefted clauses generally have a modification, attribution, or identification relation to some element in the main clause, but coordinate and adverbial clauses express a variety of logical, causal, and temporal relations. A major concern of our research program is to examine the influence of the latter set of semantic relations on the on-line processing of clauses and sentences.

The nature of the semantic relation between clauses depends, to some extent, on the individual meanings of the clauses being related (see, e.g., Fillenbaum, 1971, 1974b, 1975, 1976; Johnson-Laird, 1969; Lakoff, 1971; Staal, 1968). Nevertheless, there is some regularity in the kinds of relations

TABLE 6.1
Some Semantic Relations Cued by Conjunctions

1. Cause: because, if, for, since, (after), (when)		
	EFFECT	CAUSE
a.	the glass melted	because Floyd heated it
b.	the glass will melt	if Floyd heats it
c.	the glass melted	since Floyd heated it
d.	the glass melted	for Floyd heated it
(e.	the glass melted	after Floyd heated it)
(f.	the glass melted	when Floyd heated it)
2. + Prior: since, after (when), (and)		
	- Prior	+ Prior
a.	Harry ate 12 apples	since Mary came home
b.	Harry ate 12 apples	after Mary came home
(c.	Harry filled the tank	when Mary ran out of gas)
(d.	Harry died	and he ate 12 apples)
3. Simultaneous: when, while, and		
a.	Harry got sick	when he was eating the apple
b.	Harry got sick	while he was eating the apple
c.	Harry ate some cheese	and he ate an apple
4. - Prior: before, until, and, (so), (while)		
	+ Prior	- Prior
a.	Harry was sick	before he ate the apple
b.	Harry was sick	until he ate the apple
c.	Harry threw the stick	and the dog retrieved it
(d.	Harry was sick	so he took some medicine)
(e.	Harry ate 12 apples	while Mary cleaned up the mess)
5. Effect: so, (before), (and), (while)		
	CAUSE	EFFECT
a.	Floyd heated the glass	so it melted
(b.	Floyd heated the glass	before it melted)
(c.	Floyd heated the glass	and it melted)
(d.	Floyd ate 12 apples	while Mary cleaned up the mess)
6. Adversative: while, although, but, (and)		
	CAUSE	UNEXPECTED EFFECT
a.	While Harry was sick	he ate an apple
b.	Although Harry was sick	he ate an apple
c.	Harry was sick	but he ate an apple
(d.	Harry was sick	and he ate an apple)

cued by different conjunctions. A partial list of the possible relations between the clause following the conjunction with respect to the other clause of the sentence includes the following: cause, + prior in time, simultaneous in time, - prior in time, effect, and adversative. Table 6.1 lists some examples of these relations. Sentences that seem to imply a given relation are parenthesized. The table ignores certain distinctions, for example, the specific cause–generic cause distinction and the distinction between evidentiary and causal relations (see Fillenbaum, 1975, 1976; Miller & Johnson-Laird, 1976), but these distinctions are not critical for the present purpose. (These semantic relations and various refinements are further discussed in Ballard, Conrad, and Longacre, 1971; Dakin, 1970; Dik, 1968; Gleitman, 1965; Heinamaki, 1972; Rips and Marcus, 1977; Simon and Rescher, 1966; Taplin and Staudenmeyer, 1973; and Wason and Johnson-Laird, 1972, as well as in the references cited previously in this paragraph.)

The relations illustrated in Table 6.1 can be summarized as follows. A subordinate clause (or coordinate clause in the case of *for*; cf. Dik, 1968) may express an event that causes the event described in the adjoined clause. The subordinate or coordinate clause may occur either *prior* in time to the adjoined clause, or late in time (- prior) than the adjoined clause. A clause may describe an event that is the *effect* of the event in the adjoined clause. Finally, the clauses of a sentence may be related in an *adverse* way: One clause may state an event that is unexpected based on the event in the adjoined clause. In Dakin's (1970) analysis, the causative and adversative relations are opposites. Both statements make two assertions, but the assertions in causative statements are compatible, whereas those in adversative statements are incompatible. For example, Sentence 1a of Table 6.1 asserts "the glass melted" and "the fact that Floyd heated the glass demanded that the glass melt," but Sentence 6b asserts "Harry ate an apple" and "the fact that Harry was sick demanded that Harry *not* eat an apple."

Several conjunctions take on two or more semantic relations. The relations that the various conjunctions listed in Table 6.1 can have are summarized in Table 6.2. What is striking about this table is the continuity of the meanings of the conjunctions. For example, a given conjunction may not express both a causal relation and a simultaneous relation unless it also expresses the + prior relation. The continuous meanings of the conjunctions suggest a single underlying dimension. An event that occurs prior in time to another event may be the cause of the later event, but not vice versa. Similarly an event that occurs later in time than another may be the effect of the earlier event, and not vice versa. In other words, causes are associated with earlier events and effects and adverse effects are generally associated with later events. Such an association is neither surprising nor newly discovered (see e.g., Miller & Johnson-Laird, 1976).

Another notable aspect of Tables 6.1 and 6.2 is that causes and prior events tend to occur in initial clause positions. For example, *so-*, *but-*, and *and-*clauses only occur in final position, and these may express some type of effect. Table 6.1 shows an *and-* clause expressing a prior event (Sentence 2d), but this sentence sounds strange. (This sentence may be interpreted as stating that the initial clause is an unexpected effect of the final clause; Fillenbaum [1971] has shown that such sentences are extremely hard to recall.) The only exception among coordinate clauses to the generalization of "cause and first event first, effect and second event second" is the *for-* clause.

TABLE 6.2
Semantic Relations Between Clauses

Conjunction	*Cause*	*+ Prior*	*Simultaneous*	*- Prior*	*Effect*	*Unexpected Effect*	*Presuppositions in Conjoined Classes*
Because	x						?
If	x						No[a]
For	x						?
Since	x	x					Yes
After	(x)	x					Yes
When	(x)	(x)	x				Yes
And			x	(x)	(x)	(x)	No
While			x	(x)	(x)	x	Yes
Until				x			Yes
Before				x	(x)		Yes
So				(x)	x		?
Although						x	Yes
But						x	No

[a] The "presuppositions" of an *if*-sentence interact with the mood of the verb in the *if*-clause (Morgan, 1969). *If*-sentences differ from other types of sentences in this respect.

Perceptual Implications. What role do these semantic relations play in clausal processing, sentence integration, and recall? We can speculate that a semantic processing strategy exists that emphasizes early interpretation of underlying causes or potential causes. That is, a clause marked by a conjunction that signals a causal connection to another clause is more deeply processed during listening and more basic in the listener's postsentence organization. Table 6.2 ranks the various conjunctions according to their "causal efficiency": *because-* and *if-* clauses are the most causally efficient and *although-* and *but-* clauses are least causally efficient. We might further speculate that this strategy applies to clauses that could be causes by implication or inference. Thus, although *after* does not literally relate clauses in a causal way, the listener may, depending on the meanings of the clauses themselves, infer that the event in the *after-* clause is the cause of the event in the main clause, but not that the main clause event causes the *after-* clause event. The later inference is ruled out for the epistemological reasons noted earlier: An event cannot cause something to happen before the causal event occurs. The semantic processing strategy proposed here encompasses the order of mention strategy described previously (e.g., Bever, 1970b; Clark & Clark, 1968, 1977).

Most of the previous work dealing with conjunctions like those in Table 6.2 have been concerned with postsentence organization and memory, or with production, rather than on-line processing. To our knowledge, however, no work has examined the role of the more general causal-temporal dimension in either processing or memory. For example, Clark & Clark (1968; see also Smith & McMahon, 1970) showed that *before* and *after* sentences that present the events in their actual order of occurrence are easier to remember. Similarly, children perform better on acting out *before* and *after* sentences that present the events in their actual order of occurrence (Barrie-Blackley, 1973; Clark, 1971; Johnson, 1975), and such sentences appear relatively early in the child's speech (Clark, 1970; see also Osgood, 1971). The question "what happened first?" following a *before* or *after* sentence is answered more quickly than the question "what happened second?" (Smith & McMahon, 1970; see also Townsend & Ravelo, 1978). Other studies have considered the mental representation and use of *if* (Carpenter, 1973; Fillenbaum, 1975, 1976), *unless* (Clark & Lucy, 1975), and *or* (Fillenbaum, 1974a, 1974b; Springston & Clark, 1973), the inherent negativity of *but* with respect to *and* (Fillenbaum, 1971; Hoosain, 1973; Osgood & Richards, 1973), and the relative difficulty of *although* with respect to *because* and the preference for ordering events as "cause, effect" (Katz & Brent, 1968). Many of these studies provide data supporting the use of the causal-temporal dimension in organization and memory, but none has examined on-line processing of clauses nor have any examined a wide range of conjunctions.

EXPERIMENTS 1 AND 2—MEANING VS. LITERAL REPRESENTATION

Both intuition and the studies cited suggest that main clauses are more immediately interpreted than subordinate clauses. Our first goal was to confirm this with a set of tasks that tap on-line perceptual processing, rather than short-term memory. In our tasks, the subjects hear only a fragment of a sentence, ending before either the last word of the initial clause or the last word of the final clause. The interrupted clause in either position is either main or subordinate (introduced by *if, since, when, while,* or *though*). After hearing the fragment, the subjects determine whether a visually-presented verb–object phrase is similar in meaning to what they have heard (Experiment 1) or they determine whether a probe-word had occurred in the fragment (Experiment 2). Reaction times (RTs) in the former task provide an index of the listeners' on-line accessibility to the meaning of the clause they had been hearing. In the latter task, we assume that the subjects have maintained the interrupted clause in more superficial form to the extent that their RTs are longer for target-words that had occurred later in the clause. This assumption is based on the view that a superficial representation is searched word-by-word from left-to-right, but that such a search process is impossible in an abstract representation, which, in the extreme case, does not contain information about word order, or even specific words. These tasks differ from those of many previous studies primarily in that they involve a test before the complete clause has been heard. Thus, any differences we find can be attributed to processing that occurs while the clause is being heard. The tasks provide a means of determining whether listeners process clauses with different properties in different ways. The properties under consideration here are the structural, presuppositional, and semantic roles of various clauses.

The conjunctions in this study display a variety of meanings on a causal–temporal dimension. The possible meanings of the conjunctions we used with respect to the causal–temporal dimension are excerpted from Table 6.1 in Table 6.3. Occupying one end of this dimension is the *if*-clause, which often states a cause for the event in the main clause, as shown in, "If Harry

TABLE 6.3
Semantic Relations Between Subordinate and Main Clauses

Conjunction	*Cause*	*+ Prior*	*Simultaneous*	*- Prior*	*Adversative*
If	X				
Since	X	X			
When	X	X	X		
While			X	X	X
Though					X

takes the arsenic, he'll die." At the other end of the causal–temporal dimension is a *though*-clause, which expresses an adversative relation, i.e., a denial of an expected cause–effect relation. A *though*-clause states an event that ordinarily would lead one to expect a certain effect, but it indicates that the expected effect did not occur (Dakin, 1970). For example, in "Though Harry took the arsenic, he didn't die," the speaker believes that taking arsenic ordinarily causes death.

Many conjunctions have meanings that fall between the causal and adversative extremes, and some conjunctions have multiple meanings. For example, in "Since Harry wrecked his car, he's been taking the bus," the *since*-clause may indicate an event that causes the main clause event, or it may simply indicate an event that occurs prior in time to the main clause event. *When*-clauses may have three meanings. A *when*-clause may indicate, by inference, a cause, as in "When Harry heated the glass, it melted," an event prior in time, as in "When Harry wrecked the car, Bill fixed it," or an event occurring simultaneously with the main clause event, as in "When Harry was raking the leaves, Bill was fixing the car." A *while*-clause also expresses several meanings; among these are a simultaneous event, as in "While Harry was raking the leaves, Bill was fixing the car," an event occurring later in time than the main clause event, as in "Harry threw the stick, while the dog retrieved it," or it may express an adversative relation, as in "While Harry did take the arsenic, he didn't die."

The particular meaning that is dominant depends on several factors, such as the meanings of the individual clauses, stress, and the order of the clauses. The meanings of the conjunctions, however, are orderly in that there are no discontinuities on the causal–temporal dimension, as shown in Table 6.1. Furthermore, causal and temporal meanings are associated: Those conjunctions that indicate prior events may, by inference, indicate causal events.

The question we address in these two experiments is whether listeners are sensitive to these differences in causal–temporal meanings during immediate processing. It is well known that postsentence performance is superior for temporal sentences that present the events in their actual order of occurrence and that questions about first events are answered more quickly than are questions about second events (Clark & Clark, 1968; Fillenbaum, 1971; Smith & McMahon, 1970; see also Katz & Brent, 1968). These results suggest that temporal sentences are organized in memory in terms of the temporal order of events. Experiment 1 was designed to determine whether listeners conduct this type of organization as they hear the sentence and whether the organization of temporally related events is part of a more general strategy of organizing causally related events. We refer to the prediction that causes and first events are more directly interpreted as the *causal–temporal hypothesis.*

Other types of relations between clauses may be the basis for modifying on-line processing. Structurally, main clauses dominate subordinate clauses in the surface-structure tree, and main clauses are more complete in that they

can stand alone as a sentence. To the extent that listeners reconstruct the surface tree from the top-down (Kimball, 1973) or to the extent that more complete clauses serve as better processing units (Tanenhaus & Carroll, 1975), main clauses should be interpreted more directly than should subordinate clauses. We refer to this prediction as the *structural hypothesis.*

Main and subordinate clauses also differ in the types of information they convey. Main clauses often express an assertion, but subordinate clauses often express a presupposition (Keenan, 1971; but see also Boer & Lycan, 1976). For example, denying a sentence with a *though-*, *while-*, *when-* or *since-*clause appears to deny only the main clause and not the subordinate; hence, these subordinate clauses are said to convey a presupposition. The presuppositions of *if-*sentences, however, are more complex, and it is difficult to associate any simple presupposition with the *if-*clause (cf. Morgan, 1969). The presupposition–assertion distinction, at least for the clear cases, may serve as the listeners' basis for the organization of the two clauses of a sentence. That is, the assertion may be interpreted more directly, because it contains the "new" information, while the presupposition may simply be used to indicate where the new information is to be integrated into memory once it has been understood (cf. Haviland & Clark, 1974; Hornby, 1974). We refer to the prediction that presuppositions are less directly interpreted as they are being heard as the *presuppositional hypothesis.*

In Experiment 1, we examined the listeners' on-line accessibility to the semantic form of a clause. Subjects listened to two-clause sentences but were interrupted either before the last word of the first clause or the last word of the second clause. At the interruption point, they read and classified a verb–object phrase as being consistent or inconsistent with the meaning of what they had just heard. The interrupted clause varied in its causal-temporal, structural, and presuppositional role in the sentence. The causal-temporal hypothesis predicts that classification time is relatively faster for subordinate clauses that are more explicitly causal. The structural hypothesis predicts that classification time is faster for main clauses than for subordinate clauses. The presuppositional hypothesis predicts that classification time is faster for assertions than for presuppositions, more specifically, that times are faster for main clauses in *though-*, *while-*, *when-*, and *since-*sentences.

Experiment 1

Method

Procedure. The subjects were tested individually, one subject for each of 16 lists. They were instructed to listen to a sentence fragment. Upon hearing a tone, a verb–object phrase in lowercase elite letters was projected onto a ground-glass screen. The subjects were instructed to read the phrase and decide whether it was similar in meaning to any part of the fragment. They were instructed to say, as quickly as possible, yes if they felt the phrase was consistent in meaning with the fragment, or no if they felt it was not consistent in meaning. The sentence fragments were presented with a Sony TC280 tape deck through headphones into the subject's right ear. The tone started a Hunter msec timer and simultaneously activated a shutter that allowed the phrase to be projected onto a screen. The subject's vocal response stopped the timer.

Sentence Fragments. Sentences for positive and negative trials were constructed with similar constraints. The actual form of each positive sentence varied across lists, but the form of negative sentences was constant across lists. There were 16 positive sentences (4 with *while* and 3 each with *if, since, when,* and *though*); and 12 negative sentences (3 with *when,* and 2 each with *if, since, while,* and *though*). Excluding the conjunction, one clause (the probed clause) contained 10 or 11 monosyllabic words, and the other contained 12 or 13 syllables. The probed clause contained a word that appeared in one of two positions without changing meaning (see Experiment 2). Across lists, each positive sentence appeared in eight forms, depending on the position of the movable word, the position of the probed clause, and the structural role of the probed clause. A complete set of eight versions of one sentence fragment is shown in (19a through d):

(19a) Initial Main: Good jobs are (now) quite scarce (now) in most large...
(19b) Initial Subordinate: Though good jobs are (now) quite scarce (now) in most large...
(19c) Final Main: Though there is little danger of a major depression, good jobs are (now) quite scarce (now) in most large...
(19d) Final Subordinate: There is little danger of a major depression though good jobs are (now) quite scarce (now) in most large...

The positive sentences were arranged into a single random order, as were the combinations of the independent variables (position of movable word, clause structure, clause position) within each block of eight sentences. Eight lists were generated by partially counterbalancing within blocks the combinations of variables across the single random order of positive sentences. Eight additional lists were generated by using the complement of clause position and clause structure for each positive sentence in the first list and again partially counterbalancing.

The 12 negative sentences were randomly placed among the 16 positive sentences and occupied the same relative position in each list. Half of the negative sentences had an initial main clause. Six practice sentences (3 with an

initial main clause) were placed at the beginning of each list; half of these constituted positive trials.

A male speaker recorded the intact sentences with normal intonation. Fragments were produced by cutting out the last word of the initial clause and the remainder of the sentence for trials in which the initial clause was interrupted and by cutting out the last word of the final clause for trials in which the final clause was interrupted. A 50 msec, 500 Hz tone and blank tape were spliced onto the end of each fragment.

Phrases. Phrases that were consistent with the meaning of one of the clauses of the sentences used for positive trials were obtained by administering a questionnaire to students in a psycholinguistics class at Montclair State College. The students were shown the 19 intact positive sentences as they appeared in one of the lists. In each sentence the probed clause was underlined. For some sentences the underlined clause was initial main; for some initial subordinate, etc. The students were asked to generate a 2- to 4-word verb–object phrase that was related to or consistent with the meaning of the underlined clause. They were instructed to produce phrases that did not repeat any of the content words in the sentence. From the pool of verb–object phrases obtained in this manner, the phrase generated most frequently for each sentence was selected for use in the experiment; for Sentence 1 through 4, for example, the phrase was *finding employment*. For negative trials verb–object phrases judged to be totally unrelated to the meaning of either clause were selected.

Subjects. Sixteen undergraduate volunteers (8 males) at Montclair State College served in the experiment. All were right-handed native speakers of English.

Results

The error rate for trials in which the phrase was consistent with one of the clauses was 4.3%, whereas the error rate for trials in which the phrase was not consistent with either of the clauses was 7.8%. The percentage of errors and mean response times for correct responses in different clause types and positions are shown in Table 6.4. To simplify the statistical analysis of RT data, the RTs for positive trials on which errors were made were replaced by the mean RT for correct responses in the appropriate Clause Type × Clause Position × lexical content cell. For negative trials, error RTs were replaced by the means for correct responses in the appropriate Clause Type × Clause Position cell.

Positive Trials. The initial statistical analysis of RTs for positive trials used analysis of variance with clause type, clause position, word order, block,

TABLE 6.4
Response Time (Msec) for Judgments of Consistency of Meaning
(Percentage of Errors in Parenthesis)

	Initial Clause		*Final Clause*	
Type of Trial	*Main*	*Subordinate*	*Main*	*Subordinate*
Positive trials[a]	1224(1.6)	1282(4.7)	1214(3.1)	1359(7.8)
Negative trial[b]	1224(8.3)	1306(12.5)	1302(6.3)	1295(4.2)
Overall	1224	1292	1252	1332

[a]The average standard error was 64.0 msec, ranging from 49.8 to 77.8.
[b]The average standard error was 68.1 msec, ranging from 56.7 to 81.9.

and lists as variables, the first four treated as within-subject variables. Because each subject was tested on a given lexical content with different combinations of independent variables, Lexical Contents × Treatments were nested within subjects. The analysis of variance, therefore, treats both subjects and lexical contents by treatments as random effects, and the statistical tests are generalizable to the larger population of subjects and materials (see Clark, 1973).

The means in Table 6.4 suggest that response times on positive trials were shorter when main clauses were interrupted. This conclusion was supported by the analysis of variance, $F(1, 16) = 4.58$, $p < .05$. The Clause Type × Clause Position interaction fell short of significance, $F(1, 16) = 3.14$, $p < .10$, and no other interactions approached significance, although there was a large effect of block, $F(1, 16) = 13.9$, $p < .01$, with the mean response time of Block 2 (1169 msec) much faster than that of Block 1 (1302 msec). Although there was a large practice effect, the major variable affecting overall response times was the type of interrupted clause: Subjects had much better access to the meaning of main clauses.

The relative effects of subordination did vary with conjunctions, however. Table 6.5 shows the difference in mean response time between subordinate and main clauses (mean RT for subordinate clauses minus mean RT for main clauses) for fragments using different conjunctions. The effect of subordination was opposite in initial *if*- and *though*-fragments: Response times were 136 msec faster on subordinate clauses in *if*-fragments, and 340 msec slower on subordinate clauses in *though*-fragments. Performance on initial clause fragments introduced by *since*, *when*, and *while* fell between these extremes, and followed the causal–temporal dimension illustrated in Table 6.1. On final clause fragments, there was also wide variation depending on the conjunction introducing the final clause; but in this case, response times were 295 msec slower on *if*-clauses than on the corresponding main clauses and response times for *though*-clauses and main clauses were about equal (a 21-msec difference).

TABLE 6.5
Effects of Clause Type on Judgments of Consistency of Meaning in Fragments with Various Conjunctions: (Response Time for Subordinate) - (Response Time for Main)

Conjunction	*Initial Clause*	*Final Clause*
If	-136	+295
Since	+9	+143
When	+19	+117
While	+68	+169
Though	+340	+21

Note. The critical difference ($p < .05$, $df = 216$) in (S-M) between conjunctions is 192. In initial clausees, relative response time for *though*-clauses differs from all other subordinate clauses, and *while* differs from *if*.

Negative Trials. For negative trials, Table 6.4 shows that response times were faster for main clauses when the initial clause was interrupted. Response times for negative trials were examined by analysis of variance with clause type, clause position, and blocks as variables. This analysis showed a trend toward an interaction between clause type and clause position, $F'(1, 151) = 3.48$, $p < .10$. There were no other significant main effects or interactions in the analysis by subjects or by lexical contents. A comparison of main and subordinate response times for initial clauses indicated a marginal effect, $F'(1, 121) = 2.92$, $p < .10$. A similar comparison for final clauses showed no difference between response times to main and subordinate clauses, $F' < 1$. Subjects were faster at deciding that a phrase was inconsistent with the meaning of an initial main clause than they were at doing so for initial subordinate clauses. However, they did not differ in the speed with which they decided that a phrase was inconsistent with the meaning of the sentence when final main or subordinate clauses were interrupted.

Discussion

Overall, on-line accessibility to meaning was faster in main clauses than in subordinate clauses. Although this result favors the structural hypothesis, the considerable variation in the size and even direction of subordinate-main differences across fragments using different conjunctions casts doubt on both the structural and presuppositional hypotheses as explanations for the data. The size of the subordinate-main differences in initial clause position, did, however, follow the causal-temporal dimension described in the introduction. The data suggest that initial clauses that are more explicitly marked as stating a cause for the event in the following clause are more directly interpreted and that initial *though*-clauses, which explicitly state that the event in the initial clause is *not* a cause for the following event, are less directly interpreted. An initial *though*-clause may be held in superficial form so that it can be interpreted in light of the meaning of the following main clause. The relative effects of *if*- and *though*-clauses in final clause position, however, were reversed. We return to this reversal in performance after considering whether the causal-temporal dimension is also related to the listener's accessibility to the literal form of a clause.

Experiment 2

In the second experiment, we presented subjects the same lists used in Experiment 1, but after each fragment we presented a probe word rather than a verb-object phrase. The subject's task was to say as quickly as possible whether or not the probe word was mentioned in the fragment. The critical variable was whether the target word occurred relatively early or relatively late in the interrupted clause. A notable aspect of our design was that the same word served as the target both early and late; such a design controls the effects of semantic and grammatical characteristics of the target words.

The central problem was whether the listeners search their representation of a clause differently depending on whether the representation is in relatively semantic form vs. relatively literal form. We suggest that semantic representations are searched by an essentially parallel process that is relatively insensitive to literal form, i.e., word order. That such a process operates on propositional representations is indirectly suggested, although not demanded by, several previous studies (Green, 1975; Kennedy & Wilkes, 1969, 1970). On the other hand, we suggest that literal representations are searched by a word-by-word, left-to-right scan that is sensitive to word order. Evidence for item-by-item scans has been found in previous studies that require retention of order information (Kennedy & Wilkes, 1969, 1970; Sternberg, 1967; see also Green, 1975).

This analysis suggests that target-position effects should be greater for those clauses that produced rather slow accessibility to meaning in Experiment 1. That is, target words occurring late in a subordinate clause should take longer to classify than target words occurring early in a subordinate clause, but there should be little difference between early and late targets in main clauses. Furthermore, the difference in response times between late targets and early targets in initial subordinate clauses, relative to main clauses, should decrease as the subordinate clause states more explicitly that it is a cause for the event in the main clause. This prediction follows from the results of Experiment 1, that the relative advantage of main clauses over subordinate clauses in accessibility to meaning decreased with the explicitness with which a subordinate clause states a causal relation.

Method

Procedure. The subjects were tested individually, one subject for each list. All subjects heard the sentences and probe words in the right ear. A tone signalled the end of the sentence fragment and activated a msec timer that was stopped by the subject's vocal response. Subjects were instructed to respond as quickly as possible to the word occurring after the tone, saying yes if the probe had occurred in the fragment and no if it had not. In order to induce comprehension of the fragments, subjects were instructed to generate a sentence that paraphrased the sentence fragment after they had responded to the probe. This requirement was effective in that all paraphrases were judged to be accurate.

Materials. The tape recordings used in Experiment 1 were modified for a word-probe experiment. For each fragment a monosyllabic target word was selected. For positive trials, which consisted of the same set of fragments used in positive trials in Experiment 1, the target was the movable word. Target words classified as early in the clause occurred 6 to 8 words from the end of the clause, with a mean of 7, whereas late targets occurred 3 to 5 words from the end, with a mean of 4. The early and late positions of a particular target word were separated by 2 to 5 words. The grammatical class of the target was distributed evenly across nouns, verbs, adverbs, and particles in positive trials as well as in negative and practice trials. The target word for negative trials did not occur in the fragments, nor was it similar in sound or meaning to any word occurring in the fragment. For half of the practice fragments, a word appearing in the fragment was selected as a target.

Tape recordings of the 34 probe words were made, and copies of these were spliced onto the tape containing the fragments. The probe was placed so that it began 333 msec after the end of the tone.

Subjects. Sixteen undergraduates (8 males) at Montclair State College were paid $2 for their participation. They were right-handed native speakers of English.

Results

The error rate was 0.4% when the target was in the sentence fragment and 3.1% when it was not. To simplify the statistical analysis, RTs for errors were replaced in a fashion similar to that used in Experiment 1.

Positive Trials. For positive trials overall, there was no RT difference between main and subordinate clauses, $F(1, 16) = 1.93$, $p > .05$, nor was

TABLE 6.6
Mean Response Time (Msec) for Recognition of Early and Late Target Words (Percentage of Errors in Parenthesis)

	Initial Clause				*Final Clause*			
	Main		*Subordinate*		*Main*		*Subordinate*	
Type of Trial	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*
Positive[a]	1098	1125	1085	1181	1117	1207	1157	1057
Mean positive	1112(0)		1134(1.6)		1162(0)		1107(0)	
Negative[b]	1157(4.2)		1280(2.1)		1352(2.1)		1342(4.2)	

[a]The average standard error was 53.3 msec, ranging from 33.8 to 65.3.
[b]The average standard error was 46.6 msec, ranging from 34.9 to 64.6.

there a difference between initial and final clauses, $F(1, 16) < 1$, as suggested by Table 6.6. That is, the average accessibility of the actual words did not differ by clause type or by clause position. The overall mean RTs by clause type, clause position, and target position, however, did vary. Target position had its strongest effects in subordinate clauses and its weakest effect in initial main clauses. Target position had opposite effects in initial and final subordinate clauses and larger effects in final main clauses than in initial main clauses. These conclusions were supported by a Clause Type × Clause Position × Target Position interaction, $F(1, 16) = 9.44$, $p < .01$. These variables together did not interact with list or block. Response times were slower for late targets than for early targets in initial subordinate clauses, $F(1, 16) = 6.35$, $p < .05$, and in final main clauses, $F(1, 16) = 5.58$, $p < .05$, but not in initial main clauses, $F(1, 16) < 1$, or in final subordinate clauses, which showed a large recency effect, $F(1, 16) = 6.89$, $p < .05$. The location of the target word had large effects on response time in all clauses except initial main clauses, where the position effects were negligible.

Table 6.7 presents the target position effects for fragments using different conjunctions. The table shows the effects of target position in subordinate clauses relative to its effect in the corresponding main clauses. That is, for each fragment we calculated the difference (mean RT late [L] minus mean RT early [E]) for the subordinate clause (S) and subtracted from that the difference (mean RT late minus mean RT early) for the main clause (M). The resulting score provides some control for differences between fragments in within-clause lexical items and structural complexity. The $(L-E)_S - (L-E)_M$ score is highly positive when response times are slower to late targets than to early targets in a subordinate clause but faster to late targets than to early targets in the corresonding main clause; a highly positive $(L-E)_S - (L-E)_M$ score indicates a "primacy" effect in subordinate clauses relative to main clauses.

TABLE 6.7
Effects of Clause Type on Word Recognition in Sentences with Various Conjunctions: $(\bar{R}\bar{T}_L - \bar{R}\bar{T}_E)_S - (\bar{R}\bar{T}_L - \bar{R}\bar{T}_E)_M$[a]

Conjunction	*Initial Clause*[b]	*Final Clause*[b]
If	-159	+86
Since	-106	-329
When	-67	-125
While	+77	-34
Though	+399	-267

[a](Response times for late targets in subordinate clauses minus response times for early targets in subordinate clauses) - (response times for late targets in main clauses minus response times for early targets in main clauses).

[b]The critical difference ($p < .05$, $df = 216$) in derived scores between conjunctions is 143. In initial clauses relative target position effects in *though* and *while* differ from all other subordinate clauses.

The relative target-position effects varied widely depending on the conjunction in the fragment. In initial-clause position the relative primacy effects were strongest in *though*-clauses, and they became weaker as the subordinate clause became more causal. The primacy effect was actually weaker in initial *if*-clauses as compared to the corresponding main clauses. The relative primacy effects for other initial subordinate clauses fell between these extremes and followed the causal-temporal dimension of Table 6.3. In final-clause position the ordering of relative primacy effects was roughly opposite that in initial clause position: Subjects were most sensitive to the literal form of final *if*-clauses and (nearly) least sensitive to the literal form of final *though*-clauses.

Negative Trials. Those clause types that showed large overall effects of target position also showed a large difference between response times to positive and negative trials (see Table 6.6). The differences between positive and negative trials were assessed in a between-subject and between-lexical content analysis of variance with trial type, clause type, clause position, block, and list as variables. The type of trial interacted with the type and position of the interrupted clause, $F(1, 383) = 4.17$, $p < .05$. The slower response times for negative trials than for positive trials in initial subordinate clauses, $t(383) = 2.83$, $p < .01$, final subordinate clauses, $t(383) = 4.56$, $p < .01$, and final main clauses, $t(383) = 3.69$, $p < .01$, suggest that subjects examined every word of these fragments before responding only in the case of negative trials. On the other hand, the fact that response times for negative and positive trials did not differ in initial main clauses, $t(383) = 0.87$, $p > .10$, suggests either that subjects did not compare the probe with every word individually or that they did do so for both positive and negative trials. These comparisons of positive and negative trials are only suggestive however, because different sets of words were used in the two types of trials.

Discussion of Experiments 1 and 2

Overall, the target-position effects were much smaller in initial main clauses than in other types of clauses. This suggests that the literal form of an initial main clause is more quickly lost in immediate processing, supporting a structural or presuppositional hypothesis. However, the target-position effects were strongly influenced by the particular conjunction contained in the fragment. Among initial clauses, primacy effects in subordinate clauses were weakest in *if*-clauses, but these effects became progressively stronge in *since*-, *while*-, and *though*-clauses. These results indicate that on-line accessibility to superficial form in initial clauses increases in the order: *if*-clause, *since*-clause, *when*-clause, *while*-clause, and *though*-clause.

The results by conjunctions were quite similar in the two experiments. In initial clauses, the size of the subordinate–main differences were ordered identically in the two experiments; relative accessibility to meaning was poorest in *though*-clauses, but relative sensitivity to literal form was best in *though*-clauses. The results for final clauses were roughly opposite those for initial clauses in both experiments. The parallel results for conjunctions within clause positions strongly suggest that the underlying factor affecting performance is not the structural or presuppositional properties of the clauses but, instead, is the meanings of the conjunctions and the kinds of organizing strategies they elicit.

The two experiments also gave similar results across the 16 sentences from which the positive fragments were derived. For each of the 16 sentences, we calculated a total (subordinate–main) score as described previously, but now summed over initial and final clauses. These scores were highly correlated, $rs = +.57$, $t(14) = 2.59$, $p < .05$. This correlation indicates that those sentences that produced slower synonymy-judgment times in subordinate clauses relative to main clauses also produced greater sensitivity to superficial form in subordinate clauses relative to main clauses. It follows that listeners' accessibility to semantic form is related to their word-recognition processes.

The first two experiments converge on the following conclusion: Listeners are sensitive to the possible semantic relations between clauses that are cued by conjunctions while they hear a two-clause sentence and modify their comprehension processes in terms of these semantic relations. Although the overall performance differences between main and subordinate clauses support structural and presuppositional hypotheses about clausal-processing differences, the variations in performance within different subordinate

clauses do not support either of these hypotheses. Instead, the performance differences followed the causal-temporal dimension described in Table 6.3.

Initial subordinate clauses that more explicitly signalled a causal relation to the following clause were more deeply processed. Of the clauses studied here, the *if*-clause is most explicit in indicating a causal relation: It describes a generic set of conditions that either cause the main-clause event or constitute evidence for it. *Since* has a more specific causal sense than *if*, but it may also have the temporal sense of *after*. *When* may have, by inference, the causal or temporal meanings of *since*, but it more directly indicates an event occurring at the same time as the event in the main clause. *While* may have the temporal cooccurrence meaning of *when*, but it may also have an adversative reading of "contrary to the fact that the event in this clause would ordinarily cause, or lead one to expect, a certain event, some event other than the expected event has occurred." This contrary-to-expectation relation is strongest in *though*, where it is an explicit denial of the relation indicated by *if*.

Our results for initial clauses indicate that, relative to main clauses, more explicitly causal subordinate clauses are processed more deeply during listening, and less explicitly causal subordinate clauses are held in more literal form during listening. For example, listeners had easy access to the meaning of initial *if*-clauses. An initial *if*-clause is processed deeply as it is heard because it is important for evaluating the event in the final clause: an *if*-clause describes the conditions in which the event in the following clause will occur. On the other hand, initial *though*-clauses, indicating a denial of a causal relation, were held in very superficial form. This may be the case because, at the time listeners hear the initial *though*-clause, they cannot know which cause-effect relation the speaker is denying. For example, on hearing "Though Harry ate the apple...," listeners know that the speaker believes that "Harry ate an apple" would normally be a cause for some event or evidence for some belief, but listeners do not know what cause-effect or evidence-belief relationship the speaker has in mind. On hearing the main clause "... he got sick," the listeners now know that the speaker has denied the cause-effect relation of "eating an apple causes one to be healthy." But on hearing the main clause "... he wanted a steak," the listeners know that the speaker has denied the evidence-belief relation of "X ate an apple is evidence that X wanted to eat an apple." Listeners may hold initial *though*-clauses in relatively superficial form until they have interpreted the main clause so that they can determine which cause-expected effect relation has not been fulfilled.

The results for final clauses showed a strong reversal from the pattern found in initial clauses. In final-clause position, the meanings of *though*-clauses and of the corresponding main clauses were about equally accessible, but the meanings of *if*-clauses were much less accessible than the meanings of the corresponding main clauses. A similar shift occurred in relative sensitivity to literal form in word recognition. These shifts must be taken seriously, for the relative ordering of differences by conjunctions in final clause position

were highly correlated ($rs = 0.7$) across the two experiments. The results, therefore, suggest that listeners do not process on-line for meaning in a final *if*-clause as much as they do for other clauses. This may be the case because the *if*-clause sets up a generic condition on the previously heard main clause. As such, the listener must interpret the final *if*-clause "as a whole" and perhaps reorganize the events of the sentence into their proper cause-effect relationship. Listeners may readily interpret a final *though*-clause because they can determine on-line the specific cause-effect relation that is being denied and because they already know the "unexpected effect" stated in the previous clause.

EXPERIMENT 3—WORD ORDER IN MAIN AND SUBORDINATE CLAUSES

Experiments 1 and 2 "converge" on the claim that the dominant representation of main clauses is immediately more meaning-based and less literal than that of subordinate clauses. We also showed that the size and direction of the difference in accessibility to meaning between main and subordinate clauses followed the causal-efficiency dimension. We interpreted these results to show that a subordinate clause that is less causally related to the main clause is less deeply interpreted in immediate processing. Thus, the previously observed differences in processing main and subordinate clauses may be due to the different causal and temporal roles that these clause types have in a sentence, rather than being due to structural or presuppositional differences.

In Experiment 3 we were concerned with the question of how listeners organize a two-clause sentence. We examined the effects of word order within main and subordinate clauses on listeners' accessibility to the words of a sentence immediately after they hear it. We used the identical word-probe task (see Caplan, 1972; Green, 1975; Kennedy & Wilkes, 1969; and others). We varied word order within clauses by using active vs. passive form, which occur without constraint in both types of clauses (e.g., Burt, 1971). The hypotheses that an initial main clause is interpreted more directly while hearing the sentence and that it serves as the basis for integration of the meanings of the two clauses, predict that word order within an initial main clause should have a smaller effect on word-recognition times than it has when varied within an initial subordiante clause. This prediction is based on the notion that once a clause or single sentence has been encoded, performance is generally less affected by the original form of the sentence (Anderson, 1974; Gough, 1966, but see Glucksberg, Trabasso, & Wald, 1973). We also examined word-order effects in sentences with different clausal relations: *since*, *when*, *while*, and *though*.

Method

Procedure

Subjects were tested individually. On each trial, they heard a sentence through the right channel of a set of headphones. Immediately after the sentence, they heard a 50 msec, 500 Hz blip in the left channel; and 333 msec later, a probe word in the right ear. Their instructions were to say as quickly as possible whether or not the probe word had occurred in the sentence. Response times were recorded by a Hunter msec timer. After responding to the probe, they turned over an index card and answered aloud a question that was printed on the card. Subjects received a total of 41 trials (25 positive).

Materials

Each subject heard 41 two-clause sentences. Twenty-four of these were used for critical trials in the current study; the remainder were filler sentences modified from a previous study (Townsend & Bever, 1977b). Of the 24 new sentences, 8 were used for negative trials for all subjects; these sentences had six to seven syllables in each clause in active voice (4 contained a passive clause) and contained either *since, when, while,* or *though* (two of each). The remaining 16 new sentences were used for positive trials. In half of these positive trials, the clauses contained six to seven syllables in active form, and in half they contained eight to nine syllables in active form, excluding subordinating conjunctions. Within each clause length, there were 2 sentences containing each of the conjunctions *since, when, while,* and *though.* Aside from these constraints on length and conjunction, the form of the critical positive sentences varied across eight groups of subjects. Each sentence appeared in different form for the eight groups, depending on whether the probed clause was active or passive, main or subordinate, initial or final. The eight forms of one sentence are as follows:

Initial, Main Active: The cat killed the parrot, when Sam left the house for a week.
Initial, Main Passive: The parrot was killed by the cat, when Sam left the house for a week.
Initial, Subordinate Active: When the cat killed the parrot, Sam left the house for a week.
Initial, Subordinate Passive: When the parrot was killed by the cat, Sam left the house for a week.
Final, Main Active: When Sam left the house for a week, the cat killed the parrot.
Final, Main Passive: When Sam left the house for a week, the parrot was killed by the cat.

Final, Subordinate Active: Sam left the house for a week, when the cat killed the parrot.
Final, Subordinate Passive: Sam left the house for a week, when the parrot was killed by the cat.

In all critical sentences, the target word was a verb (*killed* in the above sentences) having the same form in active and passive voice. The filler sentences were used to reduce bias toward verb targets.

Eight lists were prepared such that each list contained 2 critical positive sentences of each form (voice, clause type, clause positive). Counterbalancing ensured that each form appeared in all trial positions across the eight lists.

Subjects

Thirty-two right-handed undergraduate native English speakers at Columbia University and Montclair State College participated. Four subjects were assigned to each of the eight lists.

Results

The primary data were recognition times for trials on which correct responses were obtained for both recognition and the comprehension question following the word probe. On the 512 test trials, there were 16 word-recognition errors (3.1%) and 12 comprehension errors (2.3%). The distribution of word-recognition errors is shown in Table 6.8 and that of comprehension errors is shown in Fig. 6.3. For the statistical analysis, recognition times on error trials were replaced by the mean recognition times from the appropriate List × Length × Clause Type × Clause Position × Word-Order cell. The last four of these were within-subject variables in the statistical analysis; the last three were within-lexical content variables. Because different subjects received different combinations of clause type, clause position, and word order on a given lexical content, the statistical tests treat Subjects and Lexical Contents × Clause Type × Clause Position × Word Order as random effects (Clark, 1973). All statistical tests used a rejection level of .05.

TABLE 6.8
Percentage of Word-Recognition Errors in Experiment 3

	First Clause		*Second Clause*	
	Main	*Subordinate*	*Main*	*Subordinate*
Active	4.7	6.3	0	0
Passive	1.6	7.8	1.6	3.1

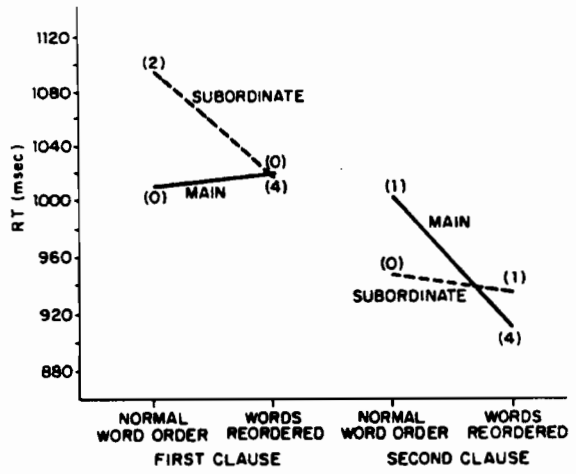

FIG. 6.3. Recognition times to different clauses with normal and reordered word orders. Number of errors in parentheses.

The major recognition-time results are shown in Fig. 6.3. This figure suggests (a) that recognition times were faster for words in final clauses than for words in initial clauses, (b) that recognition times were faster when the words of the probed clause were not in the normal active word order, (c) that word order had a larger effect on recognition times in initial subordinate clauses than in initial main clauses, and (d) that word order had a larger effect in final main clauses than in final subordinate clauses. Each of these impressions was confirmed by the statistical analysis. Recognition times were faster in final clauses than in initial clauses (means = 949 msec and 1035 msec, respectively, $F[1, 24] = 38.3$), faster in reordered clauses than in clauses with normal word order (means = 970 msec and 1014 msec, respectively, $F[1, 24] = 7.09$), and the clause type, clause position, and word-order variables interacted, $F(1, 24) = 8.23$. Further analysis of the three-way interaction showed that word order interacted with clause type in initial clause position, $F(1, 24) = 5.23$, and in final clause position, $F(1, 24) = 4.10$.

The overall results supported the prediction that word order within initial clauses has a relatively greater effect on accessibility to subordinate-clause information. For final clauses, however, the opposite result was obtained. One interpretation of the latter result is that a final subordinate clause can be interpreted directly because the basis for integrating the clauses has already been established. Processing a final main clause, however, is more difficult because the literal form of the preceding subordinate clause must be retained if it is to be interpreted in terms of the meaning of the main clause. Two additional results support the view that main-subordinate sentences are processed more directly than are subordinate-main sentences. First, of the 12

comprehension errors, 11 occurred on sentences with the subordinate-main order. Second, on negative trials response times were faster on main-subordinate sentences than subordinate-main sentences (means = 972 msec and 1038 msec, respectively, $F[1, 223] = 5.81$). On positive trials with comparable sentence length, however, mean response times were identical for main-subordinate and subordinate-main sentences (both means = 975 msec). These results suggest that the word-recognition process in subordinate-main sentences is a slower word-by-word scan based on a more literal representation of the sentence.

The main recognition times in active and passive clauses for positive trials, however, did vary in sentences with different conjunctions. The effects of word order in sentences containing *since, when, while,* or *though* are shown in Table 6.9. Because the various conjunctions were associated with different lexical items that may contribute to differences in absolute recognition times, and for the sake of brevity, this table simply presents the difference between mean recognition times in active and passive clauses (recognition time active minus recognition passive). The column headed "Sub-Main" presents the effect of word order in subordinate clauses relative to the effect in main clauses. It is clear that none of the sentence types shows the overall pattern of Fig. 6.3, because, for example, no sentence type showed a negligible effect of word order in initial main and faster times for passive than for active in initial subordinate. Thus, listeners do not organize sentences with different conjunctions in identical ways. In fact, for initial clauses there appear to be two groups of sentences: Three sentence types showed positive effects of passive in subordinate relative to main (i.e., passive is relatively faster in *since, when,* and *while* clauses), and one (*though*) showed a negative effect of passive in subordinate relative to main. For final clauses, there are also two groups: One sentence type (*since*) showed a positive or negligible effect of passive in subordinate relative to main, and three showed negative effects of passive in subordinate relative to main (*when, while,* and *though*). Thus, passive had positive effects in *since*-clauses in both positions, reversed its

TABLE 6.9
Effects of Word Order by Conjunction

	First Clause			*Second Clause*			
Conjunction	*Main*	*Subordinate*	*Sub[a]-Main*	*Main*	*Subordinate*	*Sub[a]-Main*	*Total*
Since	+91	+268	+177	+70	+95	+25	+202
When	70	+10	+80	+138	+53	-85	-5
While	-69	+155	+224	+41	95	136	+88
Though	33	154	121	+77	+7	-70	-257

Note. Entries are mean-active mean-passive scores.
[a]Subordinate.

TABLE 6.10
Word-Recognition Times (Msec) in Clauses of Different Lengths

	First Clause		*Second Clause*	
Length	*Main*	*Subordinate*	*Main*	*Subordinate*
Long	1352	1406	1336	1276
Short	1342	1374	1243	1274

effects in *when-* and *while*-clauses in initial and final position, and had negative effects in *though*-clauses in both positions.

We also found that the length of the probed clause had an effect on recognition times. Recognition times were faster on short clauses than on long clauses (means = 975 msec and 1010 msec, respectively, $F[1, 24] = 9.44$). Table 6.10 shows the mean recognition times by length, clause type, and clause position. This interaction fell short of significance, $F(1, 24) = 2.7$, $p = .11$, but it is interesting to note that the direction of the differences between long and short clauses is parallel to that found with active and passive word order. In initial position, length had a larger effect in subordinate clauses than in main clauses; but in final position, length had a larger effect in main clauses. These near differences might suggest that the number of words in the original clause has little effect on recognition times when the clause is represented internally in abstract form.

Discussion

Over all sentence types in Experiment 3, word order had greater effects on accessibility to literal form in initial subordinate clauses than in initial main clauses. This pattern was reversed in final-clause position. Overall, there was evidence that sentences with initial subordinate clauses are represented in more literal form, confirming previous results obtained by Jarvella and Herman (1972) and Townsend, Ottaviano, and Bever (in press).

The word-order effects in main and subordinate clauses, however, varied considerably depending on the subordinating conjunction in the sentence. Word recognition in initial *though*-clauses was relatively longer in passive form than in active form, but in initial *since-*, *when-* and *while*-clauses, it was shorter in passive form than in active form. These patterns shifted when final clauses were tested, the *since*-clauses being the only ones that showed any tendency at all for passive form to produce relatively faster word-recognition times. It is apparent that sentences with different subordinating conjunctions are not processed and organized in identical ways.

The interpretation of these differences depends on the interpretation of the relation between active vs. passive form and word-recognition times. Overall,

recognition times were faster for passive than for active clauses (see also Cairns & Blank, 1974). Yet, active sentences are usually found to be more quickly interpreted (e.g., Slobin, 1966), suggesting, in general, that the faster recognition times for passive clauses are due to rather shallow comprehension of the passive form. But in *though*-clauses, we found that recognition times were slower for passive than for active clauses. Such an outcome suggests that "normal" processing has not occurred. What kind of process would produce slower times for passive than for active? One possibility is that passives are more deeply comprehended than actives, but this seems unlikely, because it has almost never been obtained in previous work (but cf. Olson & Filby, 1972). A second possibility is that the literal form of the passive is simply harder to retrieve than is the literal form of the active, not because the passive has been represented more abstractly, but instead, because neither active nor passive has been actively attended to. The passive literal form is harder to retrieve because it does not correspond to the canonical underlying form. The latter explanation could account for the relatively longer recognition times for passive in initial *though*-clauses. In this interpretation, initial *though*-clauses are not analyzed for meaning, whereas all other initial clauses in this study do tend to be processed directly. This interpretation is consistent with the previous finding that relative accessibility to meaning is poorer for initial *though*-clauses than for other types of clauses (Townsend & Bever, 1977b).

As shown in Table 6.1, the semantic relations between the clauses of *since-*, *when-*, *while-*, and *though*-sentences differ. A *since*-clause may either state a cause or evidence for the main-clause event, or it may state an event prior in time to the main clause. *When* and *while* clauses also have a temporal sense, but *while*, like *though*, may have what has been called an adversative sense (Dik, 1968; Grimes, 1975). The adversative relation is opposite that of a causative relation. Both the causative and adversative relations involve two statements that are compatible in positive/negative value in the case of the causative, but incompatible in positive/negative value in the case of the adversative (Dakin, 1970). For example, "Since the lights were red John stopped" makes the statements "I state the fact that John stopped" and "I state that the fact that the lights were red demanded that John stop," both of which are positive in value. On the other hand, "Though John was late he stopped" makes the statements "I state the fact that John stopped" and "I state the fact that John was late demanded that he not stop," which are positive and negative in value, respectively. Thus, a *though*-clause is used to deny that an expected causal relation has been fulfilled, but a *since*-clause in its causative meaning asserts that the expected causal relation did occur. In their temporal senses, *when* and *while* differ from *though* in that they do not deny an expected event.

Our results suggest that listeners are aware of these differences in relations between clauses. Listeners hold an initial *though*-clause in relatively unanalyzed form while they hear it because they know that an opposite of the

expected consequence of the subordinate event is going to be asserted in the following main clause. As a result, the effects of word order on word recognition differ in initial *though*-clauses as compared to other types of clauses.

Experiments 1, 2, and 3—General Discussion

These experiments suggest that subordinate clauses are held in relatively uninterpreted form, just insofar as their full interpretation depends on information within the main clause. Thus, in all three experiments *if*-clauses (or *since*-clauses in Experiment 3) tended to act most like independent clauses and *though*-clauses least like them. These results follow from the fact that the semantic material within an *if*-clause can be processed largely independently of the main clause; in *though*-clauses the adversative relation requires processing of the main-clause information in relation to the subordinate clause, in order to understand the respect in which the relation is "unexpected."

EXPERIMENT 4

Experiments 1 through 3 suggest that listeners can switch their mode of access of a clause on the basis of very quick decisions. However, some of this flexibility might be unique to language; indeed, it might be restricted to main vs. subordinate clauses because of the linguistic universals that differentiate them (i.e., the penthouse principle might cause the differentiation of the strategies rather than the reverse). To test for this possibility, we conducted an experiment using a standard nonlinguistic serial-search task to see if we could manipulate the kind of search strategies in ways that reflect the different approaches to main vs. subordinate clauses.

In the well-known Sternberg (1966, 1969) paradigm, a subject is presented with a memory set consisting of one to six digits, letters, or words. After seeing the memory set, the subject is shown a probe item from the same class as the items in the set and is instructed to indicate as quickly as possible whether the probe was contained in the set. Sternberg's results show that RT increases with the size of the memory set and that the slope of this RT function is similar for positive and negative trials. In addition, Sternberg reported that RT does not vary with the serial position of the target item within the memory set. The fact that RT increases with set size rules out a parallel scan, in which the subject simultaneously compares all memory-set items with the probe. The lack of serial-position effects, the similar slopes for positive and negative trials, and the equality of RTs to positive and negative trials all rule out a self-terminating scan, in which the subject compares the memory-set items with

the probe one at a time and responds as soon as a match occurs. Instead, the data indicate that subjects conduct a serial exhaustive scan in which items are compared one at a time with the probe, but a response is not made until all items have been compared with the probe.

Although the exhaustive model has received broad support, several investigators have found reason to doubt the generality of the exhaustive model (see Sternberg [1975] for a review). One source of doubt is the frequent presence of serial-position effects in memory-scanning experiments. Recency effects have been found in several experiments (Baddeley & Ecob, 1973; Burrows & Okada, 1971; Clifton & Birenbaum, 1970; Corballis, 1967; Corballis, Kirby, & Miller, 1972; Corballis & Miller, 1973; Juola & Atkinson, 1971; Kennedy & Hamilton, 1969; Morin, DeRosa, & Stultz, 1967), although some of these effects could be explained in terms of a sensory store that retains the final items of the memory set. Even more problematical for the exhaustive model are those studies finding that RTs increase with the serial position of the target (Burrows & Okada, 1971; Corballis et al., 1972; Kennedy & Hamilton, 1969; Klatzky & Atkinson, 1970; Klatzky, Juola, & Atkinson, 1971; Sternberg, 1967). These increasing serial-position curves suggest a self-terminating scan and certainly cannot be explained in terms of a sensory store. In addition, two of these studies (Corballis et al., 1972; Klatzky & Atkinson, 1970) obtained greater slopes for negative trials than for positive trials, which also suggests the self-terminating scan.

A second source of doubt about the generality of the exhaustive model is evidence showing that scanning can be limited to a part of the memory set. Several studies (Clifton & Gutschera, 1971; Darley, Klatzky, & Atkinson, 1972; Naus, 1974; Naus, Glucksberg, & Ornstein, 1972; Williams, 1971) indicate that one portion of the memory set can be omitted from a subject's exhaustive scan. Other studies suggest that subjects use a self-terminating scan within sets of letters partitioned by a pause (Wilkes & Kennedy, 1970b) or within different constituents of a sentence (Kennedy & Wilkes, 1969; Shedletsky, 1974; Wilkes & Kennedy, 1969, 1970a). The evidence for the self-terminating scan in these studies is that RTs increase with the serial position of the target.

Experiment 4 is concerned with the question of whether a subject can use different scanning strategies, indicated by different serial-position effects and by different relations between RT for positive and negative trials, on different portions of a memory set. The studies reviewed in this section provide substantial evidence that the exhaustive and self-terminating scans can be used in different experimental situations and that scanning can be directed toward only one part of the memory set. However, only one study (Shedletsky, 1974), using a sentence as the memory set and testing only two serial positions within different portions of the set, found different serial-position effects in different portions of the memory set.

We examined the hypothesis that different scanning strategies can be used on different portions of a memory set by providing subjects with incentives for responding accurately to only one portion of the set. Although previous researchers (Banks, cited in Atkinson, Hermann, & Wescourt, 1974; Swanson & Briggs, 1969) have found that subjects do not use substantially different scanning strategies when given incentives for accuracy vs. speed on different memory sets, these studies have not shown the effect of incentives on scanning strategy within a memory set.

Method

Subjects

Eight undergraduates (four males, four females) at Columbia University were paid $3.50 to $4.50 for their participation. All subjects were right-handed.

Materials

Ninety 10-item sequences were generated. Half the sequences contained five letters followed by five digits, and half contained five digits followed by five letters. The letters were drawn from the first 10 letters of the alphabet; the digits were drawn from the 10 digits 0, 1, 2, ... 8, 9. Letters and digits were randomly assigned to sequences with the following constraints. Each letter and digit appeared approximately the same number of times within each block of 15 sequences. A single letter or digit never occurred in three consecutive sequences. Within a sequence there was never a run of three items in their normal order; e.g., a portion of a sequence never had "abc ..." or "123 ..." Each item occurred approximately the same number of times in each position of the sequences.

Probe items were randomly assigned to the sequences such that each letter or digit appeared as a probe in approximately equal numbers in the 90 sequences and that, in each block of 15 sequences, there were approximately the same number of digit and letter probes. Each block contained 10 positive trials and 5 negative trials.

The sequences were tape recorded at a rate of 3½ items per second. A 50 msec, 500 Hz tone, a 333 msec blank tape, and the probe item were spliced onto the end of each sequence.

Procedure

The subjects were tested individually. They were randomly assigned to a letter-paid vs. digits-paid group such that each group contained two males. Subjects in the letters-paid group were told that they would be paid 10¢ for

every letter probe they correctly recognized and nothing for correct recognition of digit probes. These instructions were reversed for the digits-paid group. Although the subjects were asked to respond to probes as quickly as possible, they were also encouraged to be as accurate as possible for both types of probes. Subjects were given feedback at the end of each block of 15 sequences and were paid the appropriate amount at the end of the experiment.

Sequences were presented to the subjects through binaural headphones. The tone signalled the end of a sequence and started a Hunter msec timer. The subjects stopped the timer by pressing one of two buttons, one on their right indicating a positive response and one on their left indicating a negative response.

Results

The hit rate for paid targets was 88.8%, whereas the false-alarm rate for paid targets was 10.0%. The unbiased measure of memory strength for paid targets was $d' = 2.51$ (Elliot, 1964). The hit rate for unpaid targets was somewhat lower, 77.9%, whereas the false-alarm rate for unpaid targets was higher, 15.8%. As a result, the estimate of memory strength for unpaid targets, $d' = 1.76$, was somewhat lower than for paid targets. The values of these measures of memory strength, however, suggest that subjects were not responding randomly for either paid or unpaid targets. The fact that the subjects' d's did not differ for paid vs. unpaid probes, $F(1, 7) = 1.01, p > .05$ (significance levels of .05 are used throughout this experiment), suggests that the average memory strengths of paid and unpaid items were not substantially different. The proposition of "new" responses was slightly higher to unpaid probes (.43) than to paid probes (.38), although this difference was not reliable, $F(1, 7) = 2.55$. Assuming that the proportion of new responses provides an estimate of the criterion the subject uses for deciding whether an item was in the set or not, subjects adopted a slightly higher criterion for unpaid probes.

The percentage of misses for each target position in paid and unpaid sequences is shown in the lower portion of Fig. 6.4. Misses were relatively stable in paid sequences, but, with the exception of the final target position, misses increased with target position in unpaid sequences. Analysis of variance on the frequency of misses indicated that subjects had more misses in unpaid sequences, $F(1, 7) = 6.76$, and that payoff condition interacted with target position, $F(4, 28) = 4.2$.

The statistical analysis of RTs includes only data for correct responses. The mean RTs for positive trials as a function of target position and payoff condition are shown in the upper portion of Fig. 6.4. Except for the relatively slow RT in the second target position, the RT curve for unpaid targets is flat. In contrast, the RT curve for paid targets increases with target position,

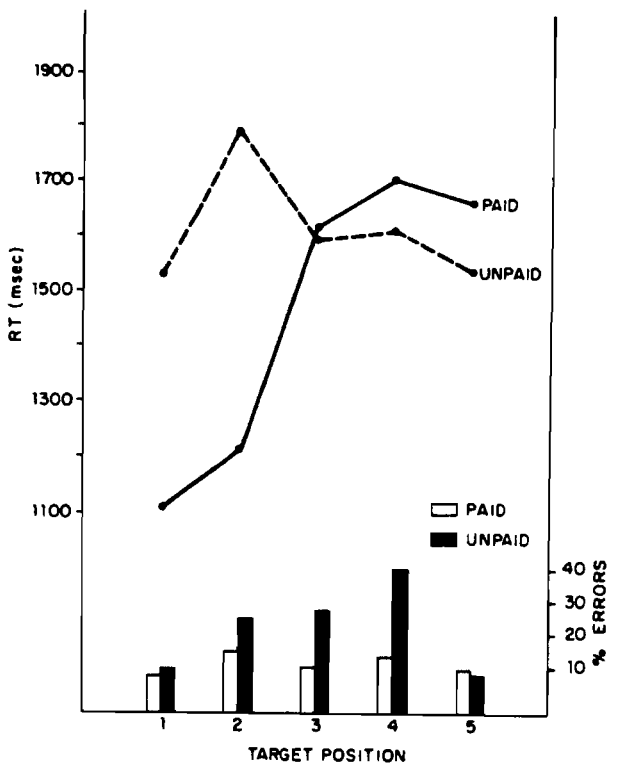

FIG. 6.4. Recognition times by target position for paid and unpaid portions of the memory set.

except for a slight recency effect. The effect of target position in paid and unpaid sequences was assessed by analysis of variance with payoff condition, sequence position (target in the first five items vs. second five items), target position within a sequence, and blocks as variables. This analysis revealed a significant Payoff Condition × Target Position interaction, $F(4, 28) = 6.73$. These variables did not interact with either sequence position or blocks. Comparison of Target Positions 1 and 2 showed that RTs for paid items were faster than RTs for unpaid items, $F(1, 42) = 95.03$, whereas a comparison of Target Positions 4 and 5 showed that RTs for unpaid items were faster, $F(1, 42) = 4.49$.

Best-fitting straight lines were established by the least-squares method. This line for paid targets was RT = 1034 + 113.4(target position), whereas the line for unpaid targets was RT = 1630 - 13.6(target position). The relation between target position and RT was significant for paid targets, $F(1, 238) = 28.95$. The corresponding relation for unpaid targets was nonsignificant, $F(1, 238) < 1$. These results show that RT increases with target position in the paid portion but is unrelated to target position in unpaid sequences.

Reaction times for positive and negative trials were compared using payoff condition, trial type (positive vs. negative), sequence position, and block position as variables. This analysis showed a significant Payoff Condition × Trial Type interaction, $F(1, 694) = 6.11$, indicating different effects of trial type on RT to paid and unpaid probes. For paid probes mean RTs were longer for negative trials than for positive trials (1564 and 1388 msec respectively, $t[694] = 3.25$). For unpaid probes mean RTs were actually shorter for negative trials (1591 msec) than for positive trials (1591 and 1615 msec respectively), although this difference was nonsignificant, $t(694) = 0.44$. Thus, negative trials took longer than did positive trials for paid probes but did not differ from positive trials for unpaid probes.

Discussion

The RT results for serial position of target and for positive vs. negative trials suggest that different incentives for correct response can induce subjects to apply different memory-scanning strategies to different parts of a list. When subjects are motivated to respond accurately to a certain type of memory-set items they scan that portion of the stimulus in a self-terminating fashion. The evidence for this type of scan is the presence of serial-position effects in RT and differences in RT to positive and negative trials. When subjects are not provided monetary incentive for accurate responses to a certain category, their scan of items in that category is either parallel or serial exhaustive. The evidence for this second type of scan is the absence of serial position effects in RT and the absence of a difference in RT to positive and negative trials. In order to distinguish the serial exhaustive and parallel scans in the unpaid sequences, a minimal requirement would be to determine whether RT increased linearly or remained constant as the size of the unpaid set increased (but cf. Murdock, 1971; Theios, Smith, Haviland, Traupmann, & Moy, 1973; Townsend, 1971).

The overall error rate was much higher than that of previous scanning studies. This was true for both paid and unpaid sequences. The higher error rate can be partially attributed to the rapid rate of presentation of the memory-set items and to the relatively large size of the memory set. The high estimates of memory strength, however, suggest that there was substantial encoding of both types of sequences. Given the high degree of encoding and the fact that RT data were obtained only for correct responses, the RT data indicate that scanning procedures differ for the two types of sequences.

The implication of this study for scanning strategies requires further research, in particular to lower the error rate and to vary the set size. But the results do suggest that listeners can change their processing strategies outside of a linguistic context. The potential generalization that cuts across both the language and nonlanguage tasks is the following:

(20) *"Easy" material is encoded (and/or accessed) in parallel. "Hard" material is encoded (and/or accessed) serially.*

In a recently completed master's thesis, Jeffra (1978) provided further general support for (20). In this study subjects listened to a sequence of 10 letters. Either the first 5 letters or the last 5 letters spelled a word; the remaining 5 letters were random. After hearing the 10 letters, subjects heard a probe letter, determined whether the probe was present in the sequence, and reported the word that had been spelled out within the 10-letter sequence. The serial-position effects for targets within word vs. nonword sequences differed radically: RTs increased sharply with ordinal position of the target in nonwords but decreased slightly with ordinal position of the target in words. These results suggest different modes of accessing words and nonwords for a specific letter.

These studies suggest that main clauses are treated like "unpaid" material (or "words") because their perceptual analysis is overdetermined; it is subordinate clauses that cause a processing load insofar as they must be held in memory for a time without a complete semantic analysis. We do not want to claim that listeners represent digit and letter information, or letters spelling words and nonwords, in just the same way as they represent sentence information. The results do, however, suggest that a recognition curve that increases with ordinal position of the target is due to a focus of attention on the literal form of memorized information. The results also suggest that different parts of both sentential and nonsentential stimuli can be represented in immediate memory in different ways and that the different types of representation lead to different memory search procedures.

THE NONLINGUISTIC BASIS OF THE PENTHOUSE PRINCIPLE

The general allocation of different parts of a stimulus to different memory systems may be the basis for two types of differences in the form of main and subordinate clauses. In particular, the fact that subordinate-clause information is retained relatively longer in unanalyzed form in immediate memory provides an explanation for the observation that word order is more constrained in presupposed subordinate clauses than in asserted main clauses. We noted that other linguists (e.g., Hooper & Thompson, 1973) have pointed out that there is a difference in acceptability of sentences in which movement rules have applied in a subordinate clause, depending on whether the subordinate clause contains a reported assertion or a presupposition. For example, the rule that moves the verb phrase to the front of the first subordinate clause in "Sally plans for Gary to marry her and he vows that

marry her he will" produces an unacceptable sentence when it is applied to a subordinate clause containing a presupposition as in "Sally plans for Gary to marry her and it bothers me that marry her he will."

The fact that the listener maintains the presupposed or less important information of subordinate clauses longer in unanalyzed verbatim form suggests that these differences in constraints on word order have a perceptual basis. Word order in a presupposed subordinate clause may be more like the canonical deep-structure order because this order is easier to retain in unanalyzed form. Word order is not as constrained in asserted clauses because these are interpreted as they are being heard and are not retained in unanalyzed form.

The fact that movement rules are more constrained in an initial subordinate clause than in a final subordinate clause is consistent with our results that initial subordinate clauses show the self-terminating memory search but final subordinate clauses do not. The listeners' dominant strategy is to postpone interpretation of an initial subordinate clause; the result of this is that word order is constrained in initial subordinate clauses. However, listeners interpret a final subordinate clause as they hear it because the main clause has already been interpreted and word order need not be as constrained.

A second type of difference in the form of main and subordinate clauses may be attributed to the listener's attempt to interpret as soon as possible the asserted information of the main clause. As we mentioned previously, Lakoff (1968) has noted that verb-phrase deletion is permissible in a sentence-final main clause as in "If Max buys a car Sally will" but is unacceptable in a sentence-initial main clause as in "Sally will if Max buys a car." On the other hand, verb-phrase deletion is equally acceptable in subordinate clauses in both positions. Lakoff has also noted that there are constraints on coreferential pronouns: A sentence with a final main clause containing a pronoun that refers to a noun in the preceding subordinate clause is acceptable, as in "Before John left town he ate supper," but a sentence with an initial main clause containing a pronoun that refers to a noun in the following subordinate clause is unacceptable, as in "*He ate supper before John left town." On the other hand, these constraints are not found with pronouns that occur in subordinate clauses.

The constraints on verb-phrase deletion and coreferential pronouns in initial main clauses follow directly from listeners' attempts to represent asserted main clauses in semantic form as quickly as possible. Application of these syntactic rules in initial main clauses would prevent the use of normal perceptual strategies because the new, important information of the initial main clause could not be recoded into semantic form until after the following subordinate clause had been interpreted. Verb-phrase deletion and coreferential pronouns in initial subordinate clauses, however, do not interfere with normal perceptual strategies because these strategies include postponing

interpretation of the less important information of the initial subordinate clause until after the new information of the main clause has been interpreted.

These conclusions suggest that there may be different constraints on word order within different types of subordinate clauses, depending on how closely the main clause follows from the subordinate clause. The following examples indicate that there are subtle differences of this sort, noncanonical word order being somewhat more acceptable in more "causally efficient" clauses:

(21a) Because tomorrow we are hiring a new person we're having a party.
(21b) ?Since tomorrow we are hiring a new person we're having a party.
(21c) *Though tomorrow we are hiring a new person we're having a party.
(22a) It's time to get up because off went the alarm.
(22b) ?It's time to get up since off went the alarm.
(22c) *Bill kept sleeping though off went the alarm.

These differences may be due to differences in "assertiveness" of the various subordinate clauses, as suggested by G. M. Green (1974), but they may also be attributed to the listeners' strategies for interpreting and integrating sentences having different causal relations between clauses. Whether such differences are attributed to presuppositional or causal differences, they may be interpreted as the product of the processing mechanisms listeners use as they hear a sentence. Thus, our analysis of the behavioral basis of the penthouse principle predicts *new* facts, which a purely structural description could only "post-dict."

We started this chapter with the view that universal grammar is made more complex if it must account for phenomena that are actually due to behavioral systems of language use. The penthouse principle is a good case in point. It traditionally has two parts (23a, b):

(23a) Reordering rules are more restricted in subordinate clauses.
(23b) This effect is weaker when the surface order places the subordinate clause second.

We have added a third part:

(23c) This effect is stronger for *though*-clauses than for *if*-clauses; in general, stronger for subordinate clauses whose interpretation depends on their main clause and is not a cause.

Even the first two parts are "global" constraints in the sense that they are not restrictions on possible transformations but, rather, are restrictions on the relative domain of transformations that result in certain types of deep-

structure/surface-structure pairs. The third part is simply a description, extremely hard to interpret as part of universal grammar because it is, in fact, a statement about processing.

We are arguing that an independently motivated distinction in the way main and subordinate clauses are processed predicts the original penthouse principle; i.e., it predicts that if there is an asymmetry in the extent to which word order can be flexible, it will be in favor of main clauses. Furthermore, our interpretation brings to light a new set of predictions that were originally unnoticed. So not only is universal grammar relieved of this need for global rules, we can explain new facts as well.

INTERACTIONISM AND THE POWER OF GRAMMARS

We have given examples in which a linguistic phenomenon is due to the way language is perceived and have intentionally addressed the discussions to a phenomenon that has been raised in the past decade as part of a reason to abandon transformational grammar in favor of a more powerful model. We have argued that independently motivated aspects of speech perception explain the phenomenon: This relieves the grammar of the descriptive responsibility and potentially reduces the descriptive power of grammatical universals.

There are several aspects of this research that are worth noting. First, our preoccupation with speech perception should not be taken as intended to exclude the interaction of language structure with other behavioral systems—most notably that of speech production. The role of perception has dominated our discussions because more is known about how perception operates; i.e., to some extent, we have an independently motivated perceptual theory. However, our general view is that there is a dynamic interaction between the grammar and both the systems of speech production and perception in children and adults.

Second, we have taken care to argue that each specific linguistic phenomenon is interpreted as due to independently motivated aspects of speech perception. We have attempted to avoid vague reference to properties such as "mental effort," "informativeness," "importance," "focus," "empathy," and so on. We do not mean that these terms are empty in principle; however, they are empty at the moment and, consequently, can have no clear explanatory force. This is a stolid, but necessary, methodological stance. Because of it, the rapidity of linguistic theorizing may often seem to outrun our behavioral explanations. But ultimate explanatory correctness requires that we base our claims on reasonably verified principles, not unconstrained theorizing. Remember the tortoise and the hare.

The final point concerns the claim that a grammar is psychologically real. For the past two decades, linguists have accepted that the goal of linguistic description is to account for a speaker's knowledge. This was in marked contrast with the position of linguists of the previous decades who emphasized that "regularities in linguistic data" are to be accounted for, leaving open the question of whether those regularities reflect knowledge. The claim that a grammar is a representation of knowledge is crucial to making linguistic science a contributer to the understanding of the human mind. Insofar as the grammatical descriptions are correct for adult speakers, they specify mental structures that underlie both linguistic behavior and linguistic knowledge. These structures, in turn, constrain our hypotheses about the structures in the infant's mind: clearly, structure that is possible in an adult language must either be learned by the child or must be innate. Hence, only if linguistic structures represent knowledge can we use linguistic science to increase our understanding of ourselves.

What is at issue in modern linguistics is the notion of the descriptive power of grammars. Confusion about this problem lies at the heart of many continuing controversies in the study of language. The term *descriptive power* refers to two kinds of questions concerning the status of grammar and the linguist's goal in constructing grammars: Are the formal devices in a grammar general or limited? Individual answers to these questions tend to coincide; i.e., those who argue that grammars are made up of an assemblage of specific descriptive devices also accept circumscribed goals for the domain of grammatical investigation.

The answers to the two questions are not logically linked even though they occur together; however, they are related methodologically. Consider first the generalist's view. We can feel impelled as scientists searching for general truths to find the most general formalisms to describe language. The reason for this is intuitively clear: The more general the mechanisms are, the less specific any given claim about their representation in the mind is and, therefore, the less radical appearing the claim that they are learned or innate. This goal would appear to accommodate the scientific method in the best sense: namely, to keep to a minimum the number of different kinds of formal devices that are postulated to exist, thereby increasing the plausibility and generality of the descriptions. Coupled with this is the desire to treat *all* systematic properties of language as due to the grammar; i.e., the domain of grammatical description is intended to be as broad as possible. This goal, too, appears to follow the requirements of good scientific practice: namely, it appeals to our desire to have one single theory account for many superficially different kinds of facts. We characterize this position as the "pan-theoretical" approach: the attempt to reduce all linguistic phenomena to a single theory that itself includes a single formal device.

We have noted that pan-theoretists tend also to be formal generalists. It is clear why the decisions to describe *all* linguistic phenomena in a grammar and

to use a single formal device are mutually reinforcing. If every regular fact about language is ipso facto relevant to a grammar, then the researcher must try to find a common formal thread. Otherwise every new kind of fact forces a revision of the theory, thus reducing its significance. After all, to treat all linguistic phenomena within a "grammar" is of interest only insofar as it does not require a distinct theoretical mechanism for every kind of fact. Accordingly, the more kinds of facts about speech a grammar describes, the more pressure to find some common theoretical denominator. The danger is that such pressure impels theorists to resort to the common theoretical denominator that is *least*.

The pressures are bilateral: If one pretheoretically accepts the goal of using the smallest and most generally applicable number of formalisms, then one is under pressure to show that the formal devices have wide applicability; after all, to show that a single formal device is adequate to describe language is of interest only insofar as the notion of "language" is broad and superficially heterogeneous. Thus, the simpler the formal devices, the more pressure to find a wide variety of facts they describe. The danger here is that such pressure impels theorists to ignore real distinctions between different kinds of facts about language.

The individual cases discussed in this paper highlight the dangers of this dual dynamic for linguistic description. Too often, current linguistic practice appears to be at the mercy of this force, resorting to theoretically vacuous generalizations and obscuring the distinctions that must be maintained if we are to understand language at all. There are two kinds of pressures that make this position attractive, despite the fact that it stultifies theoretical understanding. First, the smaller the number of formal mechanisms is, the weaker appears the claim that such mechanisms are "innate" or "learned." That is, psychologists and philosophers who maintain that language (and all other mental faculties) are learned are comforted by the apparent formal simplicity of what there is to be learned. Those who view human beings in terms of "general purpose computational mechanisms" are charmed by the possibility that there may be only one elementary kind of mental operation involved in language.

This question comes into sharp focus over the need for "global rules" of the kind needed to state the penthouse principle, rules that are sensitive to nonadjacent trees in a derivation. Some researchers have argued that transformations are simply special cases of such general rules. The question now is, what is wrong with viewing all grammatical rules as different kinds of global rules and thereby reducing universal grammar to one formal structure? The answer lies in the descriptive power of a universal grammar that includes both "transformations" between adjacent trees and "derivational constraints" between nonadjacent trees. Such a universal grammar has more ways of describing any particular phenomenon than does a universal grammar consisting of only "transformations." The more powerful the formal

mechanisms, the more solutions are available and theoretically plausible for any finite set of facts.

Such multiplicity of solutions quickly becomes a plethora. Recall that the goal of linguistic analysis is to use a set of universal formalisms that are adequate for the description of known language and, therefore, are candidates for psychologically innate or learned structures. However, this line of inquiry can proceed only if the grammatical solution for any set of linguistic facts *is reasonably* unique. If a variety of solutions is possible, the psychological pertinence of any particular solution is reduced: Whether it is empirically valid or not is of little interest because its nonuniqueness means its validity can neither uniquely confirm nor disconfirm the universal formalisms. The less unique a particular solution is, the less its validity confirms the explanatory power of the proposed universal formalisms. Finally, the less subject to confirmation the formal universals, the less of an empirical science is linguistics. For this reason, the invention of formal grammatical structures of increased descriptive power is to be avoided.

This argument highlights the complementary approach to linguistic research that ordinarily accompanies attempts to increase the formal power of universal grammar—the attempt to embrace all facts about language as necessarily "grammatical." Suppose that phenomena such as the penthouse principle are true. What makes them *grammatical* facts? Is their existence as generalizations only *truly* represented if they are represented within the grammar, among the many rules and structures that generate sentences? After all, (24) is a true generalization about language, but it is not ordinarily included as a grammatical universal.

(24) Speech power 1 cm. from the mouth is louder than 5 db (ref. - dyne = 0 db) and softer than 150 db.

The reason for not including (24) as a universal of grammar is two-fold. First, to include acoustic sensitivity within grammar would introduce new formal power and conceivably multiply possible grammatical solutions for any data set (in this case, perhaps multiplying the possible solutions for stress phenomena). Second, there is a plausible, independently motivated explanation for (24) to be found in the mechanisms of speech perception and production. Less than 5 dB at the mouth would not be sufficient for ordinary listening, and the vocal system cannot produce more than 150 dB. Thus, the constraints of the mechanisms of perception and production predict that (24) is a true generalization about language, albeit an extra-grammatical one.

The question now concerns the facts about main and subordinate clauses. Are they grammatical or extra-grammatical phenomena? We have reviewed the theoretical disadvantages of admitting them as *grammatical* phenomena, but if there are no alternative solutions, then we must accept them. After all, the argument that transformations are needed beyond phrase structure rules

involved increasing the formal mechanisms in a grammar and weakening the specificity of any grammatical solution. Transformations had to be accepted because there was no (known) way of accounting for the accepted facts with the existing formalisms (phrase structures). However, we argued that there are independently motivated descriptions for the phenomena; thus, we are not forced to accept the less constrained universal formalisms to describe those particular facts.

Of course, all such questions are empirical. It remains to be seen if all the phenomena that are referred to as motivating global constraints can be explained as due to independently motivated extra-grammatical mechanisms. It is our working hypothesis that all formalisms that constrain the structure of relations between basic and surface trees will be shown to be due to nongrammatical structures: If that turns out to be false, so be it. Our main motivation here is to explain why it is that such formalisms must be accepted reluctantly rather than apocalyptically embraced.

To put it briefly: If we can exclude such formalisms as global rules and maintain the notion of discrete grammaticality,

1. For any data set, the number of available grammatical solutions of equal complexity decreases.
2. This increases the uniqueness and power of a particular grammatical solution.
3. This in turn increases the interest of the possible grammatical universals underlying that grammatical solution.
4. Finally, this increases the precision and testability of claims about the human mind.

And, that is what the study of language is all about.

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7 Some Hypotheses About Syntactic Processing in Sentence Comprehension

V. M. Holmes
University of Melbourne

INTRODUCTION

Remarkably little can be said with any certainty about the role of syntax in normal verbal communication. Given the initial interest in syntax triggered by Chomsky's (1957, 1965) theories of language, it might seem somewhat surprising that psychologists have come up with so few lasting generalizations about this issue. One reason for this curious state of affairs is, however, well known. The idea espoused in the early 1960s, that operations for understanding and producing speech might be analogous to syntactic rules, proved to be far too simple a view of the relation between the grammar and psychological processes (Fodor & Garrett, 1966). Many researchers reacted to the failure of this theory by abandoning the study of syntactic processing altogether. One of the few attempts to tackle this problem was provided by Fodor and Garrett (1967) and Fodor, Garrett, and Bever (1968), who postulated instead that the listener utilizes strategies based on certain cues in the surface structure of a sentence to recover the underlying structure relations. However, reliable evidence for the existence of these strategies has been slow to accumulate.

This fact highlights another reason for the dearth of established principles in psycholinguistics. Much of the early research investigated sentences divorced from their basic communicative function and, consequently, did not increase knowledge of processes involved in actual comprehension and production situations. Thinking they could build a "performance model" based on any kind of linguistic performance at all, researchers employed tasks that called upon a multiplicity of unspecified cognitive processes. Rote