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REFERENCE RELATIONS AND SYNTACTIC PROCESSING: EVIDENCE OF A PRONOUN'S INFLUENCE ON A SYNTACTIC DECISION THAT AFFECTS WORD NAMING

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REFERENCE RELATIONS AND SYNTACTIC PROCESSING: EVIDENCE OF A PRONOUN'S INFLUENCE ON A SYNTACTIC DECISION THAT AFFECTS WORD NAMING

by

WAYNE COWART

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

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Abstract

REFERENCE RELATIONS AND SYNTACTIC PROCESSING:
EVIDENCE OF A PRONOUN'S INFLUENCE ON A SYNTACTIC DECISION
THAT AFFECTS WORD NAMING

by

Wayne Cowart

Advisor: Professor Helen S. Cairns

Several experiments demonstrate and assess an interaction between reference relations and syntactic processing in sentence fragments such as As they soar gracefully over the field, flying kites... . The evidence indicates that listeners rapidly assume the possible (but not necessary) coreference relation between they and flying kites in this fragment and that this assumption influences the syntactic interpretation of flying kites (i.e., the choice between the structures related to Flying kites is fun and Flying kites are fascinating). However, the mechanisms that implement this relation appear to use only some of the listener's relevant knowledge. When coreference is blocked by syntactic principles (e.g., If they want to believe that visiting uncles...), they produces no effect. But when positing a relation with they yields a pragmatic anomaly (e.g., Whenever they lecture during the procedure, charming babies...) the effect of they appears to be

undiminished. These facts are interpreted as evidence that the language processing system is partitioned in such a way that the device that first attributes a referent to they does not have access to pragmatic information. The results also bear on certain questions about syntactic influences on lexical processing.

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CHAPTER ONE

An Approach to the Modularity Question in Psycholinguistics

One of the central risks of empirical research is that a problem cannot be studied productively until it can be described in some framework, language or universe of discourse. Yet this framework can never be shown to be appropriate in advance. On this view, all research, however empirical, rests on speculative foundations.

Since the framework within which any particular problem is viewed is essential to any progress that might appear, it is important to specify that framework as plainly as possible. Since the framework is the product of speculation and personal judgement, there is little to be gained in trying to defend it. The buttresses it needs and can have are the successes of the investigations it informs. Given this perspective, one objective of Chapter 1 is to outline the framework which has informed the research reported here. This is taken up in Section 1 below. Section 2 reviews some of the published literature relevant to the question whether the language processing system exhibits modular structure.

1.1 The framework of the investigation

This study assumes that a complete theory of human psychology will explain how human intelligence and rationality arise from the interaction of many limited and simple mechanisms, none of which individually exhibits any intelligence at all (see Dennett, 1978,

for discussion of this viewpoint). A theory that meets this test can be said to explain (though not explain away) intelligence and rationality in man.

Unfortunately there don't appear to be any theories in psychology that deal with an interesting range of phenomena, survive empirical tests, and satisfy these criteria. Rather, those theories that seem to have something interesting to say and have received some empirical support turn out to be thickly populated with homunculi ("little men in the head"). Though there are theories that specify simple, limited functions that might be implemented by a machine without resort to intelligence, these well-specified simple functions seem to be inevitably involved in conspiracies with other functions that are so weakly specified that only beings with human-like intelligence could implement them, homunculi. In research on vision, for example, work on the first few stages of processing in the neural pathway that links the retina and the visual cortex has identified populations of cells with remarkably narrow sensitivities to visual stimuli (Hubel and Weisel, 1962). Nevertheless, the link between the phenomena of visual perception and these preliminary levels of analysis remains poorly understood at best. Any theorist bold enough to propose some account of that linkage seems forced to choose between incorporating intelligent subfunctions or falling on the wrong side of the facts.

Though this reliance on the intelligence of homunculi is a disappointing reminder of the primitive state of current understanding, theories haunted by homunculi are not necessarily to be feared. Homunculi are dangerous only to the extent that they must exercise

something like the full range of intelligent abilities available to the creature whose capacities the theory is to account for. To the extent that the task assigned to a homunculus can be narrowed and constrained in ways that reduce the role of intelligence, genuine scientific progress can be made, so long as these restrictions are not matched by enrichment of the demands placed on other components of the theory. On this view, genuine progress is possible whenever intelligent abilites can be partitioned into subfunctions that have more limited scope for action, rely on less rich and varied information, or implement less complex relations among the elements of the problem, though they may still require some quota of unspecified intelligence in the device that implements them.

Modern linguistic theory presents a particularly interesting texture when viewed in this light. One fundamental assumption upon which there is wide agreement is that the grammatical principles that, in part, account for the structure and interpretation of sentences can each be assigned to one of the several distinct components of the total grammatical system. Principles associated with any one component are distinguished in terms of the vocabulary in which they are expressed, their form, and mode of application. For example, while rules of phonology are expressed in terms of phonetic properties such as voicing or tongue height, the rules of the syntactic component characteristically refer to constituent categories, such as noun phrase, prepositional phrase, verb, and so on. While the form of phonological rules allows them to specify the environments in which an operation occurs, there appear to be syntactic rules whose form prevents them from mentioning the context of their application.

The modular structure of linguistic theory suggests that the various components of the theory might be viewed as the responsibilities of distinct subcomponents of the language processing system, the ensemble of mental mechanisms that confer on humans their unique linguistic abilities. Since the syntactic and phonological components of grammars seem to be relatively well advanced toward fully formal, though not necessarily fully adequate, accounts of their respective domains, they might each be implemented by homunculi that were quite stupid, even if not wholly mechanical. The syntax homunculus could be limited to the vocabulary of syntactic theory. This would make him unable in principle to retain knowledge of phonology, knowledge of the real world, or any other domain. His intelligence would have to be sufficient only to deal with those areas where syntactic theory, however empirically adequate or inadequate it may be, is not yet fully formalized. This is possibly substantial, but still very much less than that of normal humans.

Assuming a close parallel between the components of a linguistic theory and the components of the language processing system is, of course, a long leap, and one that many psychologists would be loathe to take. Almost every aspect of the relation between linguistic theory and psychological theory is controversial. For this reason it is necessary to give much closer consideration to this relation.

Many different views of the relation between linguistic theory and the psychological theory of language processing can be found in the literature, often in the guise of some position on the relation between "competence" and "performance" (see Valian, 1979, for a review of some variants). The view assumed here is that linguistic theory and the

psychological theory of language processing are theories of fundamentally different kinds. On the face of it they are about different things. The linguistic theory of some natural language specifies the constituency of a hypothetical class of abstract objects, sentences. Its task is to project all and only the real members of this class and to assign to each just those grammatical properties that real speaker/hearers assign to them. By contrast, the theory of language processing is about the machinery that humans employ in producing and understanding sentences. Its task is to specify the real-time procedures humans use to organize speech and interpret utterances, and to describe the devices that implement those procedures.

The differences parallel those between the theory of arithmetic and the programs that actually implement addition, subtraction, etc. on a pocket calculator. The theory of arithmetic specifies 'what' the calculator is doing; it provides an interpretation constructed from a set of axiomatic entities and relations. The programs or algorithms define concrete real-time procedures that represent the relations specified by the theory of arithmetic (cf., Marr, 1977). Since all calculators have specific physical limitations that prevent them from dealing with numbers larger than some maximum, all real calculators project only a finite domain of mathematical expressions, even though the theory of arithmetic specifies an infinite (in fact, nondenumerable) domain. Machines that exploit different physical phenomena (machines can be based not only on electrical and mechanical principles, but even on fluid dynamics and other more exotic phenomena) employ radically different procedures, yet they all conform within their respective domains to the theory of arithmetic. Thus despite

vast differences in the physical events observable inside diverse machines, they enjoy a very abstract fundamental kinship so long as each faithfully implements the theory of arithmetic.

For the purposes of this study, the theory of grammar, especially universal grammar, is assumed to relate to the real-time procedures humans employ in interpreting sentences in roughly the same way that the theory of arithmetic relates to the procedures that implement it in specific machines. Thus while the language processing system is presumed to respect the constraints defined by a linguistic theory, this is not taken to mean that there is any intimate similarity between linguistic principles as represented by a universal or language particular grammar, and the real-time procedures employed in comprehension. Similarly, to say that a calculator respects the Associative Law is not to say that there is some specific, discrete representation of the Associative Law in the calculator.

The view assumed here is that human linguistic behavior is to be accounted for by an ensemble of theories consisting of 1) a linguistic theory, 2) a theory of language processing, and 3) a theory of neurophysiology. To the extent that a phenomenon is explained, it is explained by the complete ensemble, not solely by any one of its components. Thus, if listeners regard a certain sentence as well-formed, it is not just the linguistic theory that is involved, but also the processing theory that enables listeners to perceive the sentence's structure and to discern its relation to the principles of some natural language. On the same assumptions, if there is some phenomenon that the theory cannot accomodate, there is no way in principle to determine in advance what part of the theory will have to

change to accomodate the phenomenon. In principle, findings in neurophysiology can lead to adjustments in the theory of universal grammar and conclusions about universal grammar can lead to insights in neurophysiology, though in practice these sorts of links are likely to be rare.

It may be helpful to illustrate this last point with another (regretably long-winded) calculator analogy. Suppose there is a calculator whose sole capability is to generate a series of pseudorandom numbers when given some "seed" number to initiate the process. Suppose further that some fourth millenium archeologist, specializing in computing artifacts of the second millenium, undertakes an analysis of this bizarre machine, starting with no evidence but the intact, working machine itself. As she proceeds, the archeologist posits a theory of the computation the calculator performs (comparable to the theory of arithmetic in the earlier examples), a theory of the algorithms it employs, and a theory of the hardware structure and properties of the machine. Suppose then that her theory of the computation posits a logical process that involves 10^{12} intermediate representations in expressing the relation between any two numbers in a series the machine generates, and further suppose that her initial theory of the algorithm is a fairly close reflection of the theory of the computation. In particular she assumes that if the theory of the computation specifies 10^{12} intermediate representations, then the algorithm will construct 10^{12} intermediate numbers. Suppose now that the archeologist has observed that the machine appears to be absolutely consistent in the sense that, it always generates exactly the same pseudo-random series whenever it is initialized with a particular number, though

the series is unique for each seed. Finally, suppose that the archeologist observes that her account of the machine's hardware capabilities specifies that it will drop a bit or otherwise scramble a number often enough that it could compute a series of 10^{12} numbers without error only half the time. Obviously the complete ensemble of theories provides an inadequate account of the machine's real behavior. The key point here is that this failure may be repaired by modifications to any one or all of the theories. Further study may reveal that the archeologist's account of the hardware's error rate was wrong. Alternatively, the hardware-level error rate analysis may be correct but the algorithms may incorporate previously unnoticed error-correcting routines that greatly reduce the effective error rate. Another possibility is that the algorithm implements the relation between any two numbers by way of a shortcut routine that involves only 10^3 intermediate steps. Finally, it may also be that the theory of the computation is wrong, that there is a way to express the logical relation between each pair of numbers in the pseudorandom series with only 10^3 intermediate logical steps. Thus a seemingly hardware-level observation might lead to modifications in any part of the ensemble of theories.

The intended suggestion here is that a similar situation holds in the study of human linguistic abilities. Given any particular observation that stands in defiance of the claims that the total ensemble of theories makes for some theorist at some moment, the overall theory might in principle be brought into conformity with the facts by adjustments to any of the constituent theories. On this view, linguistic theories are potentially vulnerable to findings derived from laboratory experiments on language processing, and processing theories

are potentially vulnerable to findings derived from linguistic research.

Having said this, however, it must be emphasized that the vulnerability of linguistic and psycholinguistic theories to a variety of kinds of findings results not from any direct, logical relation between the two kinds of theory, but from their joint accountability for the facts of human linguistic ability. There appear to be no interesting entailments for a processing theory that derive from the linguistic theory it implements. Likewise, many of the details of a processing theory have no bearing whatever on the linguistic theory the processor implements. Thus selecting a linguistic theory that contains a fairly rich transformational component entails almost nothing about the procedures the processor will employ, except that they must somehow implement the relations captured by the transformational rules. The calculator analogy may be helpful once again; what's being claimed here is that the choice of a linguistic theory entails almost nothing for the processing theory for exactly the same reason that selecting a theory of the computation that a calculator is to do, in and of itself, entails nothing interesting about the form of the algorithm that implements the theory. If this conception of the relation between linguistic theory and processing theory is viable, most of the worry about "psychological reality" in the psycholinguistic literature is misguided. Almost all of these discussions either mistake a linguistic theory for a theory of the algorithms that underlie linguistic ability or assume a much more intimate logical relation than in fact obtains on the view outlined here.

There is of course something vaguely unsatisfying in all this.

Some investigators seem to share the intuition that one's choice of linguistic theory must have some consequences for the associated processing theory. The views presented here endorse this intuition in two ways. First, by holding the linguistic theory and the processing theory jointly responsible for the facts of human linguistic ability, there is some kind of vague reciprocal relation between them. Modifying one of them might force the other to adjust in some way to accommodate a fact whose previous explanation had depended on the detail changed. Second, the assertion that the processing theory must somehow faithfully represent or implement the linguistic theory, at least within some reasonably comprehensive domain, 'feels' as though it imposes some constraints, given any particular choice of linguistic theory. What is unsatisfying here is that these constraints, if they are real, are both loose and unknown. Perhaps the looseness demonstrated in the calculator examples above would be less unsettling if it were possible to be explicit about what constraints remain. Unfortunately, to be explicit about any such constaints is to provide some theory of representation that for any pairing of a linguistic theory and a processing theory will determine whether or not the processing theory is a possible representation of the linguistic theory. Until someone provides such a theory very little can be said about the logical relation between a linguistic theory and an associated processing theory.[1]

Up to this point, this discussion has assumed that some linguistic theory has a role in any explanatory account of human linguistic abilities. This is neither a logical necessity nor uncontroversial. As Marr (1977) has argued, it is quite possible for there to be domains in the large complex of human abilities within which no "Type 1" theory

(comparable to a linguistic theory) is available. In Marr's terms an ability admits of no overarching theory of the computation (i.e., is of "Type 2") when it is realized "...by the simultaneous action of a considerable number of processes, whose interaction is its own simplest description..." (emphasis in original, p. 38). Linguistic ability might be such a domain if it were to turn out, for example, that an utterance's interpretation were the product of a large number of versatile processes, say one for each word, with no overarching control or independent structural analysis. General-purpose problem solving, as in chess playing, may be an example of a domain without a Type 1 theory in the sense that behavior may be governed by the interaction of a large and unsystematic collection of narrow abilities such as remembering moves and positions seen in previous games, systematically projecting and remembering possible further developments of the current game, estimating the relative values of various pieces and positions, speculating about what possibilities the opponent will and will not notice, etc.

Linguists and psycholinguists who hold that there is a general theory of the computation applicable to human linguistic ability are making a bet. The rawest observation sentences relevant to linguistic comprehension are of the form given in (1).

(1) $B(p,l)$

Where: B is some behavioral predicate such as "p judges l to be unacceptable," "p asserts that x and y in l are not coreferential," or "p took s milliseconds to read l,"
p is some person in a context, and
l is a linguistic stimulus.

In English, expressions such as "person *p* judges utterance *u* to be unacceptable," "person *p* asserts that constituents *l* and *m* must corefer," or "person *p* took *s* milliseconds to read sentence *l*" might satisfy this formula. The linguist's bet is that a coherent and explanatory theory can be built upon a class of observations abstracted from ones of the form (1). These derived observations are of the form shown in (2).

(2) $s(l)$

Where: *s* is a putatively linguistic predicate such as "is/is not acceptable" (or possibly "grammatical"), "is the subject of sentence *s*," "*l* is coreferential with constituent *m*," etc., and *l* names a linguistic entity or a set of them.

In effect, the linguist abstracts observations about linguistic objects from observations about people in specific contexts responding to linguistic objects. This research strategy will be justified just to the extent that research based on the abstracted class of observations yields a relatively compact and coherent account of what is and is not an acceptable word string in a given language and what linguistic properties people attribute to the strings they consider to be sentences, among other things. The view assumed here is that this bet has, in part, paid off already and that any satisfactory account of human linguistic ability will have to incorporate some linguistic theory on pain of failing to capture key systematic properties of the linguistic system.

These suggestions should not be taken to deny that human linguistic ability has some earmarks of Marr's Type 2 theory. All sorts of expertise can be invoked in the process of determining the speaker's

intentions, discovering the pragmatic implications of information the speaker may have provided, planning a response, etc. It seems quite implausible that there is any small set of coherent theories that can account for the total human response to an utterance up through even a very short interval after the utterance is heard. In this sense "language behavior" has a Type 2 theory. If there is a Type 1 theory, its domain is more narrow than this. It applies only to the human ability to make extremely fast, putatively structural judgements about utterances, what strings are not acceptable on structural grounds, what constituent functions as the structural subject of a given sentence, what constituents must be coreferential, what constituents may not be coreferential, etc.

It is far from clear that those who would do without any distinct linguistic theory (cf., Bates, et. al., 1982, Lakoff and Thompson, 1977, Tyler and Marslen-Wilson, 1977, Marslen-Wilson and Tyler, 1980, Marslen-Wilson, Tyler and Seidenberg, 1978) are in fact prepared to accept the consequences of this position. Even if the strategy based on observations abstracted from person and context is abandoned, it is still the case that any theory that purports to account for linguistic ability is going to be held responsible for observations of the form (1). That entails that any such theory must provide some account of the language of linguistic description, i.e., terms such as sentence, noun, verb phrase, etc., since no one seems to be willing to do without these. Unless the theory that explicates these terms can positively show that their interpretation involves some of the details of utterances that abstracted linguistic observations leave out of account, it is not clear that a distinct linguistic theory within the

larger theory of linguistic ability has in fact been avoided (see Cowart, 1982, for further discussion of the possibility of constructing a theory of linguistic ability without a linguistic theory).

Returning now to the suggestion that the language processing theory might be organized into a set of components with one component for each component of the linguistic theory, it is clear that this proposal is simplistic. For exactly the same reasons that the theory of language processing cannot be derived from a theory of linguistics, the modular structure of a linguistic theory cannot be assumed to be reflected in the modular structure of the language processing system. The modularity questions for linguistics and psycholinguistics are independent; a unitary processing system might implement a modular linguistic theory, the processing system might be modular even if the linguistic theory is not, and if both are modular, they may be modular in different ways, that is, one module of the processing theory might implement principles that fall into two different modules of the linguistic theory.

In principle, any sort of evidence that can reveal the structure or character of the language processing system can be relevant to the question whether it is organized into two or more modules. In practice only a couple of general types of evidence relevant to modularity seem to be within reach for now. One kind of evidence comes from the study of brain-injured subjects who seem to have some part of normal linguistic ability still intact while other parts are lost. The contrast between Broca's aphasia and Wernicke's aphasia is a classic of this type, but one where the evidence is extremely difficult to interpret because of its variability and because of the uncertain relation

between the performance of normal and abnormal individuals. See Caramazza and Zurif (1976) and Samual and Benson (1979) for two recent contributions to the body of evidence suggesting that Broca's aphasia results at least in part from the disruption of mechanisms that implement syntactic knowledge. Wolfe (1983) describes a particularly elegant example of this kind relating to the visual illusion called vection (the illusion of motion a train passenger frequently experiences when a train on an adjacent track begins to move while his own remains stationary). Wolfe and his colleagues first demonstrated that the mechanisms that induce vection have a binocular component (i.e., the illusion is sensitive to stimulus features that are evident only upon comparison of the left and right visual inputs). Second, experiments on stereoblind subjects (those lacking the normal capacity for construing binocular disparities as perceived depth in a scene) demonstrated that the illusion of vection, including its binocular component, was not impaired in these subjects. This suggests, of course, two independent mechanisms that interpret binocular disparities, one that construes depth and another that induces vection. Something similar might be possible in language if subjects with minimal language abnormalities can be shown to possess abilities that are in some way related to others they lack.

The other major accessible kind of evidence on possible partitioning of the language processing system appears when the mechanisms that control some phenomenon are shown to be sensitive to some properties of a stimulus, but not to others. Forster (1979) discusses some studies that indicate that on certain tasks grammatical properties of linguistic stimuli can affect subject performance but matters relating

to the real-world plausibility of the events the stimuli describe cannot. Chapter 3 below will describe a process involved in pronoun interpretation that also seems to be sensitive to some features of the input but not others. Again there is a particularly compelling example of this style of argument from research on vision. The evidence indicates that the process by which the eye is focused is color blind; the brain can only focus the eye on objects delineated by brightness contrasts. Since many other visual phenomena are sensitive to color contrasts, this suggests that focusing is the responsibility of a modular component that is distinctive both in terms of its role and in terms of the scope of the information it can exploit in doing its task (see Wolfe, 1983, and references cited there for further discussion of this and other modular subsystems in vision).

It is in relation to these kinds of evidence that any implications deriving from modularity in linguistic theory can be properly construed. Modular linguistic theories suggest modular language processing systems because such a linguistic theory claims that the properties that human listeners ascribe to the utterances they hear fall into categories or constellations where there is, more or less, much interaction and mutual dependency within these groupings but only highly constrained interaction between groupings. The question of which constituent in an English sentence will control the number agreement property of the verb (e.g., He walks vs. They walk) does not depend upon facts of pronunciation (except as they bear on determining what words the speaker has used) nor on personal knowledge. That people walk dogs and not vice versa does nothing to reduce the perceived unacceptability of a sentence where the verb is made to agree with its

object instead of its subject (e.g., The dogs walks John). Thus while a modular linguistic theory need not be reflected in a modular processing theory, the linguistic theory does offer psychologists some tools for asking sharp questions about modular processes. The trick appears to be to identify discrete decisions listeners must make in the normal course of interpreting particular sentences (e.g., x is/is not a noun phrase, x is/is not coreferential with y), then to find relatively uncontaminated means of determining which way such a decision has gone at a certain moment, and finally to systematically manipulate the availability of various kinds of information that are potentially relevant to the subject's decision. To the extent measures are available that are narrowly sensitive to particular details of language processing, it should be possible to learn something about the modular structure of the system, if indeed it is modular.

To summarize these introductory remarks, this study assumes that one way to advance understanding of complex human abilities such as the capacity to interpret sentences is to attempt to resolve the mechanisms that support these abilities into some ensemble of simpler, more nearly mechanical functions that give rise to the complex ability through their interaction. Where the ability in question can, in part, be described by a "theory of the computation" in Marr's sense (Marr, 1977), this theory, or a preliminary version of it, can serve as a useful tool for exploring the structure of the real-time processes that implement the ability. A version of this strategy is applied in the investigation described in this thesis.

1.2 Some research literature bearing on modularity

The first section below examines the question whether interpretations assigned to preceding portions of an utterance can influence the syntactic analysis of ambiguous structures. The last study considered in this section, Tyler and Marslen-Wilson (1977) was the original goad that prompted much of the work described in Chapter 3. The critical analysis of the Tyler and Marslen-Wilson study outlined at the end of Section 1.2.1 raises three issues that bear on the present research. These are discussed in the subsequent three sections. The issues are 1) What is the character of the procedures that select referents for "arbitrary"pronouns such as they (also see Chapter 2) and how do they relate to the rest of the language processing system?, 2) What evidence is there that the syntactic analysis assigned to the material preceding a given item can affect the lexical processing of that item?, 3) In what ways might the outcomes of experiments on the modularity question be sensitive to the experimental tasks used.

1.2.1 The syntactic autonomy question. The notion that the language processing system might include a distinct and independent device concerned with syntactic analysis entered the psycholingistic literature as an uncautiously considered import from linguistic theory. In much early work in psycholinguistics there was a now notorious tendency to assume a rather straight-forward relation between grammars and the processing systems that implement them (see Fodor, et. al., 1974, Chapters 5 and 6 for a comprehensive review of the work of this period). From the viewpoint of earlier theory and research in psychology, one of the most striking features of early transformational linguistic

theories (e.g., Chomsky, 1957, 1965; Katz and Postal, 1964) was the prominent role assigned to purely formal or configurational sentence properties and relations. As Fodor, et. al. (1974) remark, when psychologists had previously concerned themselves with language, considerations of meaning were generally uppermost. Thus it is perhaps unsurprising that the prominent role assigned to syntax in early processing models inspired by transformational linguistic theory was challenged rather early on.

One possible view of many of the distributional regularities captured by a syntactic theory for some language is that they are secondary reflections of the principles that determine a sentence's interpretation. That is, there are principles that determine how word meanings must be organized together to convey propositions. Coincidentally, the application of these principles will result in certain regularities of word order and constituent structure. Before Chomsky's work began appearing in the mid-1950's there were few dissents from this view or other views that similarly denied the independent status of syntax. Among Chomsky's important achievements were his demonstration of the independence of syntax; of the possibility of grammatical sentences being uninterpretable and interpretable word strings being ungrammatical.

The independence or autonomy of syntax severely challenges one of the central ideological tenets of contemporary psychology, that is, the unity of psychological processes (cf., Kessen, 1981). Behaviorism assumed not only that similar principles of learning applied to all organisms but also that similar learning principles account for all learning within a single organism. Despite the wholesale abandonment

of many aspects of behaviorism, it still seems to be widely assumed that relatively uniform accounts of memory, knowledge representation, inferencing, etc., will explain human capabilities in language processing, chess playing, mathematical reasoning, or, more generally, all areas of problem solving and reasoning. Any account of syntactic knowledge that achieves substantial coverage is an implicit challenge to the principle of the unity of processes because all such accounts reveal knowledge of great complexity and richness of structure. This suggests either that other systems of knowledge as rich and complex as that involved in syntax can also be retained and imployed with comparable facility, or that special mechanisms subserve language, which gives up the unity principle. The only way to avoid this dilemma seems to be to find some exceptional property of language that allows generalized mechanisms to handle it with exceptional facility. No such property seems to be forthcoming.

This thesis can offer no insights into the source and motivation of the unity principle. Given the principle's wide acceptance, however, it is hardly surprising that among the enormous number of psychological studies of language published since 1960, there is only a very minor fraction that explicitly manipulates any syntactic variable, addresses questions about the use or recovery of syntactic analyses of sentences, considers the role of syntax in the expression or recovery of a sentence interpretation, or otherwise shows any interest in syntactic phenomena.

Forster and his colleagues provided an early formulation of what was first called the "constancy hypothesis" and later became the autonomy of syntax thesis. According to Forster and Olbrei (1973), the

constancy hypothesis assets that "...the component of total processing time directly attributable to syntactic processing remains constant despite variations in meaning" (p. 322). This proposal was in part a counter to investigations by Slobin (1966) and Herriot (1969) that had suggested substantial interaction between syntactic and semantic processing.

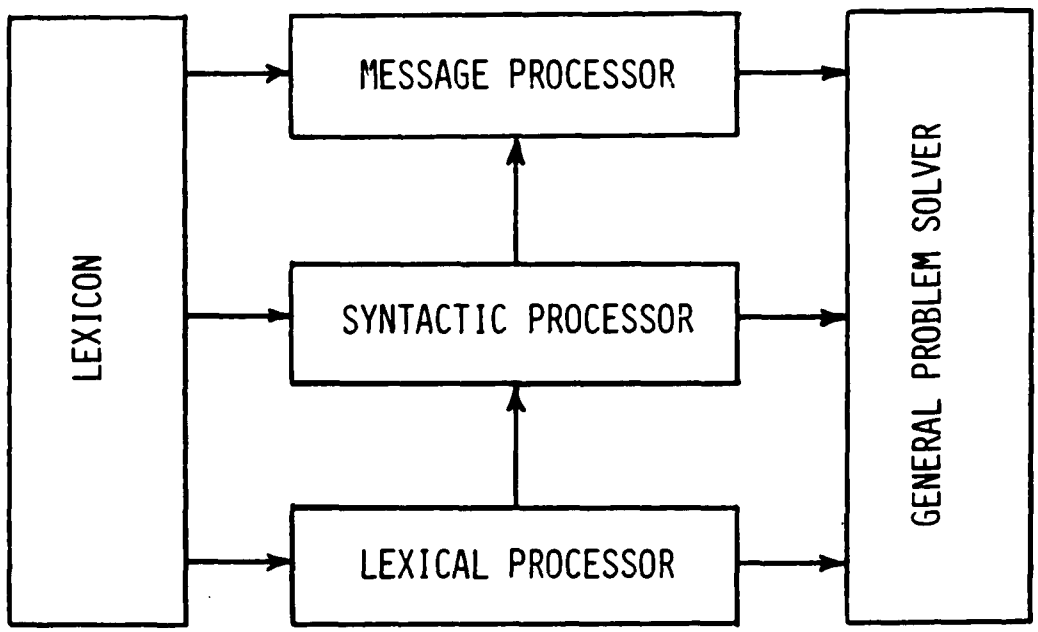
A very influential result obtained by Slobin (1966) suggested that syntactic analysis was either unnecessary in some cases or could be radically facilitated by semantic properties of the sentence. He found that the predictable increase in processing difficulty (i.e., processing time) associated with passive sentences did not appear when the sentence was "nonreversible." That is, when the subject and object noun phrases could not, by virtue of their selection restrictions, exhange grammatical roles, passive sentences were not more difficult to process than were actives (e.g., The flowers were watered by the girl was as easy as its active counterpart). Herriot (1969) obtained a similar result relying only on pragmatic knowledge to control reversibility (e.g., The doctor was examined by the patient).

Forster's reevaluation of the views suggested by Slobin and Herriot began with Forster and Ryder (1971). This study demonstrated a persistent correlation between syntactic structure and processing difficulty in the face of semantic variation. Extending this result, Forster and Olbrei (1973) demonstrated that when appropriate methods were applied, the reversibility effect that Slobin and Herriot had observed disappeared. Specifically, Forster and Olbrei replaced Slobin's picture verification task (which had produced long reaction times, RTs, and was subsequently criticized on other grounds) with a

judgement task subjects performed immediately upon reading the test sentence. They also controlled for plausibility to insure that spurious differences between the four categories resulting from the intersection of the reversibility and passive/active parameters did not distort their results. Across several experiments varying in mode of presentation and response, as well as in other ways, Forster and Olbrei found that passives were consistently more time-consuming to process whether or not they were reversible.

Forster (1979) reviews additional evidence that supports the autonomy of syntax thesis, therein formulated as the claim that "...there is no higher level processor that is capable of directly intervening in and altering the operation of the syntactic processor" (p. 44). Crediting Garrett (1976) for the phrasing, Forster describes his aim as an effort "...to decompose sentence processing activity into quasi-independent subsystems...in which there is a corespondence between levels of processing and levels of oinguistic description" (p. 81). He provides an unusually comprehensive view of the architecture of the mental functions involved in language. The system Forster suggests includes the ensemble of subcomponents shown in Figure 1. The Lexical Processor is responsible for providing a lexical analysis of speech input. It has access only to the Lexicon and a phonemic analysis of the input. Forster explicitly denies that the lexical analysis this processor provides is subject to any influence originating in the Syntactic or Message Processors, or in the General Problem Solver. Similarly, the Syntactic Processor is taken to be sensitive to input from the Lexical Processor but not from the Message Processor or General Problem Solver and the Message Processor is taken

FIGURE 1: FORSTER'S MODEL



to be immune to influence arising in the General Problem Solver. The Message Processor is roughly what other theorists might call a semantic processor except that Forster assigns to it some functions that go beyond narrower conceptions of the semantic domain.

Forster attributes central importance to the assumption that the flow of information is one-way. According to him, it is the one-way flow of information that "...implies total autonomy of processing" (p. 35).

It is instructive to compare Forster's formulation with that of Cairns (in press), another advocate of the autonomy thesis. According to Cairns...

> "The hypothesis that the Structural Processor is autonomous says simply that there is a collection of processing operations which it performs based only on the form of the message to be decoded, and not on its content. If the Structural Processor is indeed autonomous, then it will use information about the grammar of the language on which it is operating, formal information derived from the lexicon (stipulating the form class of individual words and the sentence frames in which they may appear, ordered by preference), and structural cues from the input sentence, such as function words, clause boundary markers, etc. What it cannot use is non-linguistic information derived from general conceptual knowledge, real world knowledge, or the conceptual representation of the previously analyzed linguistic material." (p. 31)

Where Forster stresses the direction of information flow, Cairns places relatively heavier emphasis on the kinds of information the syntactic processor (her Structural Processor) does and does not use.

There are several reasons for preferring a theory that makes these sorts of qualitative contrasts between modules the central issue. First, it is possible to derive constraints on the direction of information flow, or more importantly, constraints on the kinds of information passed between modules, from constraints on the properties of the

two modules, especially contrasts in their respective vocabularies. If, to take an extreme example, a phonlogical processor is assumed to have a vocabulary of binary phonetic features (e.g., [± VOICED], [± CORONAL], etc.) while an associated syntactic processor has a vocabulary of constituent types (e.g., noun phrase, preposition, etc.) if follows directly that they can't communicate at all. Without further machinery that somehow maps expressions in one vocabulary into expressions in the other, their outputs would be mutually unintelligible. By contrast, specifying the direction of information flow between two modules contributes nothing to discriminating their capabilities and structure, which by assumption is the main task. Second, barring the syntactic component from accepting any input from interpretive processes may actually undermine modularity so far as those components are concerned. Syntactically ambiguous expressions are just those whose syntactic construal cannot be selected on purely syntactic grounds. The choice of a syntactic interpretation in these cases can only involve nonsyntactic information. If the choice of syntactic interpretation for one part of an expression has consequences for the syntactic analysis of another part, two possibilities seem open. Either the syntactic system will be unable to take account of a preference determined by another component, or other components will have to be equipped to work out the syntactic consequences of choices they make between alternatives originally provided by the syntactic component. Multiplying components capable of doing syntactic analysis is of course completely contradictory to the leading ideas that motivated the proposed autonomous syntactic component in the first place. Third, restricting the direction of information flow between components in

and of itself does nothing to limit the functional capacites of the total system. Two modules might communicate only by a strictly one-way channel and have identical capabilities. In such a case a modular theory would be equivalent to a nonmodular one. Finally, stipulating a bar against communication between the syntactic component and interpretive processes during comprehension may have the effect of imposing an entrirely separate syntactic processor on the theory of language production. But obviously multiplying processors is not a very attractive theoretical gambit when the multiplication is achieved by including mirror images of processors already proposed.

As Forster observes, it appears to be much easier to obtain laboratory results that seem to go against his autonomy theory than it is to obtain results that support it. Nevertheless, he argues, the "meager list" of findings that do support the theory tend to outweigh a much larger list of contradictory findings. Given the obvious difficulty of discriminating the operational characteristics of one hypothetical component in the larger cognitive system, this does not seem unreasonable. More generally, Forster's view of the critical empirical role of particular tasks merits more attention than it has received. In describing the empirical obligations of his autonomy theory Forster proposes that "...if syntactic processing is not autonomous but is 'guided' by an assessment of the plausible semantic relations that hold between the key lexical items, then there should be no task that is simultaneously sensitive to syntactic effects and insensitive to plausibility" (1979, p. 44). In other words, if syntactic processing is in fact merged with semantic or pragmatic processing, then there should be no task that discriminates them. Though here

Forster treats the autonomy question as an all-or-none issue, which it needn't be, the role assigned to the task is entirely appropriate. Where questions of modularity are concerned, tasks used in psycholinguistic experiments are interesting only in so far as they are selective. Their role is roughly analogous to the stains biologists use to reveal structure in tissue samples. (Stains are used to change the color of just some kinds of cells in a sample so that these cells can be discriminated from their context and their structure studied.) From this point of view some of the arguments against autonomy theory have been based on a kind of nonresult, i.e., a failure to discriminate in processing experiments the contributions of kinds of information that can be discriminated on other grounds. Such evidence may in fact properly lead to the conclusion that the processing system does not make some particular distinction. However, adequate evidence for such a claim cannot be that some one task fails to detect the distinction (much less that a particular experiment failed to detect it). Rather, the theorist who wishes to deny a distinction must argue that, given the limits of existing technique and pending further developments, there appears to be no way to detect such a distinction in sentence processing. By the same logic, all participants in the study of sentence processing need to be especially concerned with questions about the variety of possibly discriminable influences that any given task is sensitive to.

Marslen-Wilson, Tyler and their associates have been prominent critics of the autonomy thesis, interpreted as a claim about the direction of information flow. Marslen-Wilson (1973, 1975) showed that subjects appeared to be taking advantage of an ongoing semantic analysis

of speech they were shadowing even when shadowing latencies were less than 300 msec., i.e., well before any relevant clause boundary. This finding was later interpreted as a challenge to claims about when semantic analyses are able to affect a listener's performance that arose from the work of Bever, Garrett and Hurtig (1973) and Hurtig (1978). Taken together, the latter two studies indicate that listeners do not choose between alternate interpretations of syntactically ambiguous clauses until the clause boundary, even when prior context indicates the more likely interpretation. This suggests that syntactic analyses are both temporally prior to semantic analyses and insensitive to the semantic analysis of prior context, as Forster's autonomy thesis predicts.

Marslen-Wilson, Tyler and Seidenberg (1978) also reject this sort of processing model. In the first of two experiments this study compared the rhyme and category monitoring tasks with materials where the target was either immediately before or immediately after a clause boundary and where the "informational completeness" of the clause was varied. In practice, clauses were not informationally complete if they contained a pronoun but not its antecedent and informationally complete if they contained no pronoun. There were two results. First, there were no significant differences between the rhyme and category results. Though this is an argument from a *non*result, Marslen-Wilson, et. al., concluded that this showed that there was no qualitative difference in processing to either side of the clause boundary. This indicated to them that semantic processing (as presumably reflected by the category monitoring task) was as much advanced as phonological processing both before and after the clause boundary. Second, they found that

informationally less complete clauses do not produce the same disparities in processing at the clause boundary as do informationally complete ones. The evidence, however, was hardly unambiguous. RTs to targets after the clause boundary in Experiment 1 were 36 msec. faster when the clause was informationally incomplete, though the completeness variable was confounded with a materials variable. In Experiment 2 RTs after the clause boundary were faster than those before the clause boundary, regardless of completeness in one third of the cases. (Carroll, Tanenhaus and Bever, 1978, have proposed a notion of "functional completeness" which is similar in import to Marslen-Wilson, et. al.'s notion of informational completeness; see Note 2.)

Marslen-Wilson and Tyler (1975, 1980) report on a study in which subjects performed various word monitoring tasks at various word positions in materials that were intended to represent normal prose, syntactically well-formed but semantically deviant prose, and unstructured word strings. They found a variety of differences across the many conditions included in their experimental design. The findings are, according to Marslen-Wilson and Tyler, incompatible with a model in which there is a delay between the time when a subject begins processing a sentence and the moment at which ongoing syntactic and semantic analyses of current input, as well as prior context, have some effect on observable performance. However, Cowart (1982) argues in detail that this conclusion is not in fact supported. In particular, there are defects in the statistical analysis and in the interpretation of this work, as well as confounding of syntactic and semantic anomalies in the materials. Upon closer examination the results do not

seem to support any conclusion of interest in relation to syntactic processing.

Frauenfelder, Sequi and Mehler (1980) described one of the best designed and most persuasive studies to produce results indicating some semantic influences on syntactic processing. French has a pair of pronouns, qui and que, that can appear in identical surface contexts but whose grammatical consequences are radically different. Both can serve as a relative pronoun. However, qui indicates that the head of the relative clause is the clause subject while que is used to indicate that the head is in the object role. The sample materials in (3) illustrate these properties.

(3) (a) Le savant [qui connait le docteur] travaille dans une universite modern.

(b) Le savant [que connait le docteur] travaille dans une universite modern.

(3a) translates as The scientist who knows the doctor works in a modern university. In (3b), however, the subject noun phrase and its included relative clause translate as The scientist who the doctor knows. When subjects monitored for a word-initial phoneme immediately after the clause boundary in materials similar to (3) RTs were much longer with cases like (3b) where the clause subject followed the verb. Quite different results were obtained with materials patterned as in (4).

(4) (a) L'Editeur [qui publie la revue] demande beaucoup de rigeur.

(b) Les articles [que publie la revue] demandent une lecture attentive.

Here the subject noun phrase translates roughly as The editor who

publishes the journal in (4a) and as The article that the journal publishes in (4b). The grammatical contrast between (4a) and (4b) parallels the contrast in (3). The difference is that the sentences in (4) are "nonreversible," i.e., the relevant noun phrases can normally relate to publish only as they do here; journals don't publish editors and articles don't publish journals. RTs to target phonemes following the clause boundary here were not significantly different in the qui and que cases. These results seem to indicate that some kinds of putatively semantic information can affect the processes that assign underlying grammatical roles to noun phrases.[3] This study stands in marked contrast to the findings reported in Chapter 3. This contrast will be considered further in Chapter 4.

A key element in the series of studies in which Marslen-Wilson, Tyler and their associates have advanced their "on-line, interactive" theory of language processing appeared in Tyler and Marslen-Wilson (1977). As with other studies in this series, the task was well designed to tap features of relatively early phases of sentence processing. Here subjects heard sentence fragments consisting of an initial subordinate clause followed by an incomplete structurally ambiguous main clause, as in (5).

(5) (a) If you walk too near the runway, landing planes...
(b) If you've been trained as a pilot, landing planes...

The aural presentation was interrupted immediately after the ambiguous clause fragment. At the same moment, a slide appeared bearing one of two possible verbal continuations of the fragment, is or are. The subjects read the verb as rapidly as possible and the interval between

the offset of the ambiguous fragment and the onset of the subject's vocalization was timed. The logic of the experiment turns on the grammatical relation between the syntactic analysis of landing planes and the number property of the following verb. When treated as the name of a class of objects, landing planes is syntactically plural and therefore compatible only with a verb form such as are. When landing planes is viewed as an action, the expression is syntactically singular and compatible with is but not are. Thus relative naming times for the two verb forms may be taken to indicate which of the two syntactic analyses of landing planes the subject has chosen.

Tyler and Marslen-Wilson found that by varying the "semantic" content of the initial subordinate clause (as illustrated in the contrast between (5a) and (5b)), they could control which of the two verb forms subjects read faster. When the verb form was "compatible" with the interpretation of landing planes induced by the first clause, RTs were shorter than when the verb form was "incompatible." They interpreted this finding as evidence that their subjects used knowledge of the semantic analysis of the preceding subordinate clause to determine either which syntactic analysis would be given priority, or to suppress the less preferred analysis altogether. Though they acknowledge that the result does not determine such conclusions, they argue that their result seriously undermines any claim for the autonomy of syntax.

There are several nonsemantic facts about the experimental sentences that may contribute to the obtained effect. First, there is an asymmetry in the use of third person plural pronouns between the contexts that are supposed to bias toward singular and plural verbs. Those contexts that bias toward plural verbs contain third person plural

pronouns in 24 of 28 cases, while the contexts biasing toward singular verbs include only one containing such a pronoun. By contrast, the second person pronoun you, or one of its derivatives, is twice as common in the contexts biasing toward the singular verb, appearing in twelve cases versus six. Apparently the third person pronouns bias toward the plural noun phrase reading of the ambiguous phrases because each of these 'needs' some antecedent and each ambiguous phrase can be such an antecedent if interpreted as a plural noun phrase. In addition to some asymmetries involving it, there are 17 cases in which a context clause contains either the verb form toward which it is supposed to bias or some very closely related form. Seven of the contexts biasing toward are contain are, -'re, or were, while only one context biasing toward is contains one of these. Ten of the contexts biasing toward is contain is, -'s, or was, while none of the contexts biasing toward are contains one of these. Townsend and Bever (1982), using a methodology derived from Tyler and Marslen-Wilson's, found evidence that the forms of be used in Tyler and Marslen-Wilson's materials may have affected the outcome.

In Chapter 3 new research is discussed which strongly suggests that a major component of the effect Tyler and Marslen-Wilson observed was due to the asymmetric use of third person plural pronouns in the clauses that biased toward are. A further experiment shows that this effect does not seem to be sensitive to two plausibly "semantic" phenomena that are nonetheless relevant to the ultimate interpretation of full sentences containing these ambiguous fragments. The role of the pronoun, the effect of syntactic structure on lexical processing (as in the apparent relation between the interpretation of landing planes and

the following verb form) and the character of the task Tyler and Marslen-Wilson used will be taken up in turn.

1.2.2 Pronoun antecedent selection. As noted above, the experiments reviewed in Chapter 3 will examine the suggestion that the liberal use of third person plural pronouns in Tyler and Marslen-Wilson's materials heavily influenced their results. As background to those experiments it will be useful to consider existing evidence on the relation between a pronoun and its antecedent. This relation falls within the broader domain of anaphoric relations and has two principal aspects; 1) identification of anaphoric expressions, and 2) selection of appropriate antecedents. In the cases relevant to the Tyler and Marslen-Wilson experiment, the critical problem is the second of these. This problem, antecedent selection, is complex and appears to involve many types of information. The range of relevant information types is surveyed in Chapter 2 with a primary focus on grammatical factors. As will be seen below, the existing experimental literature on pronouns and anaphora is generally concerned with extragrammatical factors.

Assuming that pronouns do play a crucial role in Tyler and Marslen-Wilson's result, questions about what falls on either side of this distinction between grammatical and extragrammatical factors in antecedent selection becomes central to an evaluation of their theoretical position. Indeed, their strong interaction claim can be formulated as the claim that grammatical and extragrammatical factors interact in the process of antecedent selection and in particular that extragrammatical factors can influence the operation of processes that interpret grammatical factors. In order to approach this issue

it will first be helpful to say a little more explicitly what grammatical and extragrammatical factors are taken to be. Grammatical factors in antecedent selection are just those sentence properties that play a role in a sentence grammar and interact with other grammatically determined sentence properties. For example, reflexive pronouns are highly sensitive to clausal structure; neglecting some complications, each of them must have an antecedent in its own clause. The grammatical elements that delimit clauses also play a role in many other grammatical phenomena; they define, for example, the domain within which pronouns such as them may NOT have an antecedent. Thus, in (6) the same boundary type is involved in principles that determine that themselves in (6a) must be coreferential with the men and that them may not be coreferential with the men in (6b).

(6) (a) The women said the men wanted themselves to win.
(b) The women said the men wanted them to win.

This same boundary is also implicated in the analysis of question formation, and other phenomena.

The question now is, what kinds of extragrammatical influences on anaphor/antecedent relations have been considered in the psychological literature and what evidence might there be that these influences interact with grammatical factors in some way. For these purposes, extragrammatical factors are simply those that do not play a role in a sentence grammar.

In the course of outlining a general approach to the problem of discourse anaphora, Stenning (1978) provides a survey of some of the factors relevant to the problem. Among these he includes article

definiteness, syntactic agreement, clause subordination and stress, all of which are obvious candidates for a list of grammatical factors in anaphora. In addition to these, Stenning also lists class inclusion relations and other relations of shared meaning or sense that are generally not reflected in sentence grammars. Stenning suggests that the problem of discourse anaphora should be treated as both universally extragrammatical and agrammatical; he rejects attempts to deal with indeterminate anaphoric relations within sentences (those involving, say, he, but not each other, or themselves) within sentence grammar, and further proposes that an understanding of discourse anaphora will not result in a discourse or text grammar that generates all and only the well-formed discourses of some language. The first of these positions is supported by the observation that the principles that govern anaphoric relations between coordinate clauses within one sentence (e.g., those joined by and) are indistinguishable from those that govern anaphora between the same clauses when they are separated into two independent, consecutive sentences. It seems more likely that a theory of anaphoric relations between sentences can be extended "downward" to cover some intrasentence phenomena than that any grammatical account can be extended "upward" to deal with between-sentence relations. Therefore the reasonable strategy seems to be to assume that the theory of discourse anaphora will also be responsible for some intrasentence phenomena and will be distinct from sentence grammar. The second general position Stenning advances, the view that the theory of discourse anaphora should not be another kind of grammar, is based on the observation that the bounds on the set of well-formed discourse do not seem to be nearly so well-defined as with the set of well-formed

sentences. Rather, it appears that backgrounds can be invented that render almost any pair of sentences somehow intelligible. It might also be added that it is not at all clear that the full set of (conceptual) objects that a discourse theory will have to provide in order to have an antecedent for each anaphor can be constructed by a grammar. At any rate, the formal character of a theory of discourse anaphora is not critical to the question at hand. The critical point is that it is thought to be distinct from sentence grammar.

A number of experimental studies have sought evidence for strategies that could influence anaphoric relations. Grober, Beadsley and Caramazza (1978) required subjects to provide completions for sentence fragments of the form shown in (7) such that each completion provided a reason for the event described in the fragment.

(7) (a) NP_1 AUX NP_2 $\begin{matrix}\text{because}\\ \text{but}\end{matrix}$ PRONOUN...

(b) John may scold Bill because he...

Judges inferred what coreference subjects had assumed for each completion. Grober, et. al., hypothesized that subjects would apply what is termed a parallel function strategy; that is, the antecedent of the pronoun would be the noun phrase in the main clause that had the same grammatical role as did the pronoun in the subordinate clause (i.e., John in (7b)). Though Grober, et. al. found that a parallel function strategy could account for most of their results, there was also evidence of influences related to the semantics of verbs, modals and clausal conjunctions. Kail (1976) reported that children aged 3 1/2 to 6 years used something like a parallel function strategy to decide coreference when they acted out or answered questions about pronoun-

bearing sentences. While Wykes (1981) was mainly concerned with other issues, this study also found some evidence for a parallel function strategy in 5 year olds.

Garvey and Caramazza (1974) suggested that "implicit causality" may play a role in coreference relations. The verbs in cases such as (8) sometimes suggest that one of the indivdiuals mentioned in the main clause somehow intitiated the event described. The suggestion is that a subject pronoun in the embedded clause is likely to be taken as referring to the causal agent mentioned in the main clause.

(8) John telephoned Bill because he wanted some information.

In (8) John is taken to be the initiator and therefore the referent of he. Using a sentence completion paradigm, Garvey, Caramazza and Yates (1974) found some experimental evidence that direction of causality plays a role in coreference assignments, though the salience of this factor varied with certain other semantic and syntactic features of the sentence. Caramazza, Grober, Garvey and Yates (1977) found additional evidence for the role of implicit causality when they timed subject efforts to say aloud the name of the individual that a pronoun referred to in test sentences. Furthermore, these authors found that the effect of implicit causality was evident even when gender marking on the pronoun ruled out all but one candidate antecedent. A more recent finding of Ehrlich (1980), however, partly contradicts this last claim. Ehrlich varied the conjunction used in cases similar to (8) and found, first, that implicit causality seemed to play a role only when the conjunction was because (as opposed to and or but), and, second, that the effect of the conjunction disappeared when there was only one candidate

antecedent that matched the gender of the pronoun. Readers use a two-stage strategy, Ehrlich proposes, in which candidate antecedents are first examined for properties such as gender. Only if this process fails to select an antecedent does the reader consider more general knowledge, in particular, the "event relations" that Ehrlich suggests as an alternative to implicit causality. Oleron (1981) reports some evidence from a study of 5 to 8 year old French children which also indicates that causal relations determined by verbs have an effect on coreference assignment.

Hirst and Brill (1980) examined the process of coreference assignment and came up with an analysis contradictory to Ehrlich (1980). The schema and example in (9) represent the materials Hirst and Brill used.

(9) (a) John Xed while Henry Yed. He Zed.
(b) John spoke at a meeting while Henry drove to the beach. He brought along a surfboard.

All the examples fit the schema in (9a) except that the positions of John and Henry were reversed in half. No other names were used. The results of a preliminary experiment were used to select five alternative second sentences for each first sentence. One of these alternatives strongly biased the reader toward the first name as the antecedent of he and another produced a weak bias in the same direction. Another two second sentences produced weak and strong biases in the opposite direction and a fifth sentence produced no bias at all. Subjects saw the sentences of each pair sequentially. When the second sentence appeared they pressed a "John" or "Henry" button to indicate which name was the antecedent of he. Hirst and Brill found that the

relative plausibility of the alternative antecedents, as assessed in their preliminary experiment, affected the time required to respond. Where the bias induced by the second sentence was weak or absent, decision times were longer than where the bias was strong, independently of which clause the antecedent was in. In a second experiment similar materials were used except that the clauses were rearranged according to the schema in (10).

(10) John Xed. He Zed after Henry Yed.

In these materials he cannot be related to the second name. Nevertheless, Hirst and Brill report that the relative plausibility of the two candidate antecedents (as empirically determined) affects the time required to choose the antecedent of he in these cases as well. These authors concluded that sentence integration occurs during rather than following the assignment of coreference relations, even when that coreference assignment is syntactically constrained. They thus reject the kind of two-stage analysis suggested by Ehrlich (1980).

Garrod and Sanford (1977) examined anaphoric relations involving lexical noun phrases (e.g., the vehicle) in sentence sequences like (11).

(11) A bus came roaring round the corner. The vehicle narrowly missed a pedestrian.

Such sequences were presented one sentence at a time and followed by a question the subject had to answer. The critical measure was the time required to read the second sentence. Garrod and Sanford found that the length of this interval was in part a function of the "semantic

distance" between the anaphor and antecedent (e.g., between the category term vehicle and the instance term bus). The semantic distance values reflected the number of times that a given instance term appeared when subjects were asked to list instances of the category term. Thus if subjects were given the term flower and listed rose as an example far more frequently than nasturcium, then the semantic distance between flower and rose would be relatively small and that between flower and nasturcium relatively large.

Since reading time for second sentences in pairs like (11) was greater when semantic distance was relatively great, Garrod and Sanford concluded that subjects were integrating the second sentence as they read it. That is to say, these authors propose that the reading times reflect both subjects' attempts to determine whether any noun phrase in the second sentence is an anaphor, and if so, what its antecedent is.

In overview it is clear that most experimental studies of pronouns and anaphora have been primarily concerned with the influence of semantic or interpretive aspects of sentences or antecedent selection. Among the proposed influences several are so global in character and so inexplicitly stated that they can only be assessed empirically. Implicit causality (Garvey and Caramazza, 1974, Garvey, Caramazza and Yates, 1974, Caramazza, Grover, Garvey and Yates, 1977, Ehrlich, 1980), relative plausibility of alternate coreference assignments (Hirst and Brill, 1980) and semantic distance (Garrod and Sanford, 1977) are in this category. The only reasonably explicit criterion is the parallel function strategy studied by Grober, Beadsley and Caramazza, 1978).

The general thrust of these studies is of course that listeners rely upon their general knowledge of the world, as well as their capacity to exploit this knowledge in inferring speaker intentions, to select pronoun antecedents. However, it is obvious that a number of more concrete and specifiable issues also become involved. The gender, number and definiteness of noun phrases is obviously relevant, as well as various structural principles (see Chapter 2 and Stenning, 1978).

How then are these two kinds of influence implemented? There might be a single mechanism that considers structural and integrative factors simultaneously, but the proposals of Forster, Cairns and other advocates of autonomy theory (see above) suggest an alternative in which these influences are implemented by distinct subsystems. This issue is reflected in the pronoun and anaphora literature as the question whether antecedent selection is a one- or two-stage process. Generally only studies that yield some reaction time measure are likely to be relevant to this question. Of the studies reviewed above, only four reported reaction time data, and of these, two suggest a one-stage theory while the other two support a two-stage theory. Caramazza, et. al. (1977) found that implicit causality affected reaction time even when the range of antecedents was limited to one by manipulating the gender of the pronoun and the available antecedents, as in (12).

(12) Sue telephoned Bill because he withheld some information.

This led Caramazza et. al. to favor a one-stage analysis. Ehrlich, however, using a very similar approach, found that reaction times to coreference decisions were speeded where gender information was

helpful. On this evidence Ehrlich advocated a two-stage theory in which factors such as gender are considered first and interpretive factors considered only when gender and similar factors fail to determine the outcome. Hirst and Brill (1980) manipulated structures to control pronoun choices. As in (13), the he in the subject position of the second sentence cannot have Henry as its antecedent.

(13) John spoke at a meeting. He drove to the beach after Henry got the surfboard.

They found that plausibility still affected the time required to make coreference decisions even when one candidate antecedent is eliminated in this way. This led Hirst and Brill to support a one-stage view of antecedent selection in which the process of integrating the pronoun with previous material is indistinguishable from the process by which syntactic influences on antecedent selection are considered.

All three of these studies, however, suffer from design characteristics that may obscure the operation of the antecedent selection processes that apply in normal discourse. In each of these studies subjects are required to explicitly, consciously consider the problem of coreference and to announce (orally or by a button push) which name was the antecedent to the pronoun. This is problematical because antecedent selection is not normally a conscious process and because consciousness, being essentially integrative in character, may involve cognitive resources that are not normally exploited in antecedent selection. This view is reinforced somewhat by the observation that the RTs reported in these studies are quite long, generally in the three to eight second range. Obviously, antecedent selection cannot normally

take anywhere near this long unless sentences with pronouns in them are to be so difficult to interpret that one or two subsequent sentences may go by in a discourse before a pronoun-bearing sentence is fully integrated. There seems to be little basis on which to credit such a view.

Assuming that these objections are well-founded, only one of the studies that produced RT data is methodologically sound, that of Garrod and Sanford (1977). Their mean reading times for the second sentences in their materials were around 1.5 seconds and their task seems likely to have called attention to the antecedent/anaphor relation somewhat less than did the other RT studies.

Since subjects were not required to make any overt response to the critical sentence (apart from the keypress that brought up the question) the reading times ought to be a relatively clean measure of normal reading time. On these grounds the Garrod and Sanford study is the most reliable of the RT studies reviewed above. Unfortunately, these authors used anaphors other than pronouns. Nevertheless, it is of some interest that they found that when phrases that served as anaphors in one experiment were moved and changed into indefinite noun phrases (the vehicle became some vehicles) in another experiment, the semantic distance effect disappeared. Apparently this was because structural factors ruled out any possible anaphoric role. This may be taken to suggest that anaphoric relations are handled by a two-stage process which considers structural factors before dealing with semantic distance. (Note, however, that Garrod and Sanford did obtain a nonsignificant trend that seemed to reflect some residual influence of semantic distance even when structural factors blocked coreference.)

There are also some questions to be asked about the role of parameters such as gender and definiteness in studies of pronouns and anaphora. In the studies reviewed here, such factors are universally assumed to be syntactic in character, yet the grounds for this categorization, apart from tradition, are not altogether clear. In English, at least, there do not appear to be any syntactic rules that are sensitive to gender. Where a pronoun and its antecedent occur in the same sentence, there have been proposals that provide syntactic transformations to control the relation between the form of the pronoun and the relevant properties of the antecedent (i.e., gender and number). These approaches however have been abandoned in current work on pronouns and anaphora within the generative framework (see discussion in Chapter 2). Moreover, it appears that, apart from rules that block coreference between certain positions within one sentence, essentially the same principles determine what pronoun can take what antecedent whether the candidate noun phrases are in the same sentence, in consecutive sentences, or in sentences separated by one or more other sentences. If there is in fact only one set of principles, then obviously they cannot be principles of sentence grammar (see Stenning, 1978, for a more detailed exposition of this point of view).

The status of the number parameter is more difficult to determine. Obviously the subject/verb agreement phenomenon in English indicates that number is a syntactic property of noun phrases. However, since syntactic operations that involve number have no direct bearing on coreference, it may not be appropriate to regard even this parameter as syntactic for the purposes of anaphora. Again the principles that

involve number in questions of anaphora appear to be uniform whether the pronoun and antecedent are in the same or different sentences.

If gender is not a syntactic parameter for purposes of anaphora, then only two of the studies reviewed above provided an effective syntactic manipulation of coreference possibilities, Hirst and Brill (1980) and Garrod and Sanford (1977). Unfortunately the Hirst and Brill study is compromised by the methodological considerations discussed above. Thus the Garrod and Sanford Study, which generally supported a two-stage analysis of anaphora mechanisms, seems to be the only RT study that used an appropriate methodology and that manipulated syntactic influences on anaphora without relying solely on parameters (such as gender) of uncertain status.

To summarize, there appear to be several interpretive parameters (such as implicit causality, parallel function, plausibility and semantic distance) that affect pronoun/antecedent relations, several more structural parameters (gender, number, definiteness) of uncertain status, and some unambiguously syntactic influences. Much current research is of doubtful reliability because of methodological considerations, especially the use of tasks that invite or require the subject to become consciously involved in a coreference decision. The one study that seems most secure on methodological grounds (Garrod and Sanford) produced evidence that suggests a two-stage process in which subjects consider syntactic influences on coreference possibilities before they consider interpretive factors.

1.2.3 Syntactic context effects on lexical processing. Of the hundreds of psycholinguistic studies published in the last ten years,

only a handful reflect any explicit attempt to assess the role of syntactic structure in lexical processing (if any). This is a curious fact because during the same period there has been an enormous amount of work done on "priming" effects and other word-to-word context effects, as well as a substantial body of work on sentence context effects. Interestingly, however, relatively little of the work on sentence contexts reflects any attempt to control syntactic variables or even an interest in doing so.

Despite this relative neglect, there are some experimental results that suggest that lexical processing is sensitive to syntactic influences. The first task of this section is to review some of this evidence. This review is followed by a consideration of some plausibility arguments suggesting that syntactic effects are worth seeking.

Perhaps the earliest attempt to discriminate syntactic effects on lexical processing appears in Miller and Isard (1963). This was a shadowing experiment in which subjects attempted to repeat accurately auditorily presented sentences which were heard against a noisy background. Miller and Isard found evidence that individual words within "semantically anomalous" strings which were consistent with syntactic constituent order constraints (eg., Gadgets kill passengers from the eyes) could be heard more reliably than words in haphazardly scrambled strings. This suggests, of course, that conformity to syntactic constraints yields some perceptual advantage even when no plausible semantic interpretation is available. More recent shadowing studies by Marslen-Wilson (1973, 1975) have measured the interval between the time when the subject hears a word and the time when he reproduces it. Marslen-Wilson (1973) reported that about 11% of the

subjects sampled were able to shadow prose with a lag of less than 300 msec., which is much faster than the 500 to 1500 msec. mean latencies that some similar studies report. Given a mean syllable duration of about 200 msec., the four fastest shadowers (with mean latencies of 254 to 287 msec.) were little more than one syllable behind the input material (cf., Marslen-Wilson and Welsh, 1978). The total pool of 14 subjects produced 111 errors where a word in the input was replaced by another word or a word was added. With rare exceptions the words the subjects inserted were structurally appropriate. This was true for the fast shadowers as well as the slower ones. From this, Marslen-Wilson concluded that syntactic and semantic constraints were affecting subject performance from very early on. This tends to support the view that the effects Miller and Isard observed were perceptual.

Marslen-Wilson (1975) reported a shadowing study in which the input contained some three-syllable target words that were not semantically or syntactically consistent with their prior contexts, as well as some words that were. There were also conditions in which these target words, both the twoanomalous varieties and the normal ones, were distorted by the replacement of one of their syllables to form a non-word. The major result here was that subjects were much more likely to replace a distorted word in the input with the correct original word when the syllable replacement affected the second or third syllable and where the word was syntactically and semantically consistent with prior context. Since restorations were generally faster than correct reports, they did not appear to be the products of special additional processing. The results of the four fastest shadowers did not appear to be qualitatively different from those from slower shadowers. The

evidence that consistency with context affected performance even when subjects were only a syllable or so behind the input, strongly suggests that lexical processing is sensitive to higher-order constraints from very early in the comprehension process, even before all of some incoming words can be heard. Any conclusion based on these studies must, however, be very cautiously stated because of the very small scale and design characteristics of these studies. They yielded less than 200 errors between them, produced results too small to interpret in several categories and did not counterbalance materials (in the second study). Without more information, the content of the syntactic and semantic manipulations is unclear.

Aaronson and Scarborough (1976) used a word-by-word reading paradigm in which subjects saw the words of a sentence one at a time. The subject pressed a key to advance the display from word to word through the sentence. The intervals between key presses were measured. The duration of the interval between the key press that caused a word to be displayed and the key press that replaced that word with the next was taken as the reading time for that word. Aaronson and Scarborough's results showed marked effects for clausal structure, with reading times being longer around clause boundaries. However, this result appeared only when the subject was required to provide a verbatim recall of the sentence, not when the task required only a correct answer to a comprehension question. Furthermore, Chang (1980) used the same task in a study addressed to other issues and found no clause effects in his reading time results, though he did replicate Caplan's (1972) clause boundary effect with a probe task appended to the end of the word-by-word sentence presentation.

Mitchell and Green (1978) modified the word-by-word task. They presented several words at a time and their subjects read relatively lengthy passages on each trial. Along with a number of other effects, Mitchell and Green observed that reading times were relatively long for word groups appearing at the ends of clauses and sentences. Though they also looked for other phenomena, they found no other effects that might be ascribed to syntactic processing. Contrary to the Cue Deletion Hypothesis, relative pronouns did not speed processing. Contrary to the Verb Complexity Hypothesis, Mitchell and Green did not find that processing was slowed by verbs permitting a relatively large variety of following structures. Verbs that impose relatively narrow selectional constraints on their contexts also did not speed processing relative to verbs bearing more liberal constraints. Graesser, Hoffman and Clark (1980) presented paragraphs one sentence at a time and obtained a reading time measure for each sentence. Though the effect was marginal and difficult to interpret, this produced some evidence that a word takes longer to process when its grammatical category "is not predicted on the basis of previous words in the sentence" (p. 147).

Several recent studies suggest that syntactic structure may affect word processing in reading at a relatively early stage. Healy (1976) found that subjects had much greater difficulty detecting t in the than they even when the words of the text were scrambled. Among the several plausible accounts of this effect, there is the possibility that the unique syntactic status of the causes it to be processed differently, even in syntactically ill-formed strings. Drewnowski (1978) reported a similar effect. Fluent young readers and adults were more likely to overlook t's in the than in other words, even with scrambled

word order. The effect could be removed by scrambling the text at the level of letter sequences or by presenting the text with the words vertically arranged in non-sentential order. In the same vein, proofreaders are more likely to overlook spelling errors in "function words" than in "content words" of equal length, according to Haber and Schindler (1981). They found that misspellings that changed the overall shape of a word were more likely to be detected, but that this effect was larger for function words than content words. Though any syntactic contribution is at least confounded with other possible influences in each of these studies, collectively they lend some support to the proposal that somewhat different reading strategies are applied to words according to their actual or potential syntactic function.

A lexical decision task used by Goodman, McClelland and Gibbs (1981) produced a different kind of evidence for syntactic influences on lexical processing. In this study subjects made a word/nonword decision about the second item (a noun) in a pair of words presented together. When the final word in the pair was chosen so as to yield a well-formed noun phrase (as in my turkey), the word pair was considered syntactically appropriate. When it was not a possible consituent as in your led, or men power, it was syntactically inappropriate.[4] The results showed that lexical decisions were faster in the syntactically appropriate condition. However, when this effect was tested in a condition where the syntactically related trials were mixed with those showing a "semantic" relation (eg., door window) the contrast between the syntactically appropriate and inappropriate conditions disappeared. Though these results are compatible with other analyses as well, they

suggest that syntactic factors play some role either in lexical access or in automatic processes immediately following lexical retrieval.

Seidenberg, Tanenhaus, Leiman and Bienkowski (1982) and Tanenhaus, Leiman and Seidenberg (1979) studied cases where lexical items have both noun and verb readings. In their task subjects hear a sentence context and are presented with a visual word shortly afterward. The task is simply to read the word, i.e., it is a naming task. The ambiguous word was the last word in the sentence context and the word to be named was semantically related to one of its readings. Thus the ambiguous item rose appeared in the contexts She held the rose and They all rose. The question was whether rose would facilitate naming of flower in both cases relative to a control. In the earlier study, Tanenhaus, et. al. found that the sentence context facilitated flower regardless of whether the syntactic context selected the noun or verb reading of the ambiguous word, provided the word to be named appeared with no delay. But when the target word was delayed by 200 or 600 msec., the context facilitated only target words that were related to the syntactically appropriate reading of the ambiguous word. In the example given, with 200-600 msec. delay, only She held the rose facilitated flower. The more recent study by Seidenberg, et. al., replicates this finding.

There is, however, a problem with the implementation of this paradigm. Tanenhaus, et. al. intended their contexts to determine the syntactic category of the ambiguous word prior to its presentation. The question was whether subjects would access both readings of the ambiguous word even when prior context effectively ruled out one reading on syntactic grounds. Most of the sentence contexts used are

infinitive forms (e.g., to trip) when they were to determine a verbal interpretation of the ambiguous word. The problem here is that these contexts were presented auditorily. The phonemic sequence [tU] is ambiguous between the orthographic forms to, two and too. Since, on syntactic grounds, any of these forms could have appeared in the position occupied by [tU] (ignoring subsequent context), it was in fact the use of the following potentially verbal item that disambiguated [tU] instead of vice versa. In other words, [trIp] disambiguated [tU] instead of the reverse. This problem affects 80% of the contexts biased toward the verb reading of their respective ambiguous words in the Tanenhaus, et. al. study. Another sort of difficulty undermines the contexts intended to determine noun readings. English has many derived adjectives based on verbs. Thus planting can be derived from the verb plant and used in John worked in the planting shed. The verb readings of the noun-verb ambiguities used by Tanenhaus, et. al. can generally enter into this process. This is important because in 75% of the contexts Tanenhaus, et. al. used to bias toward noun readings of noun-verb ambiguities, the word preceding the ambiguous item was the or of. Noun phrases beginning with the and prepositional phrases beginning with of can both have adjectives in the next position, e.g., the red table, of cold steel. The remaining 25% of Tanenhaus, et. al.'s noun-biased sentence contexts have an adjective immediately ahead of the ambiguous item. Since multiple adjectives can appear ahead of a noun (e.g., the cold, hard steel), none of the sentence contexts Tanenhaus, et. al. intended to determine the noun reading of an ambiguous word does in fact achieve that level of constraint. It is true that syntactic principles admit only the noun reading in

their cases, but this limitation arises from the absence of any derivational ending on the ambiguous item, from properties of the item itself, or from the fact that the sentence ends immediately afterward. In other words, in order to determine that the last item must be a noun it is necessary to consider the full sentence, including the ambiguous word at its end.

On this analysis it becomes apparent that in almost all of the materials Tanenhaus, et. al. used to disambiguate noun-verb ambiguities, the subject could determine the appropriate reading of the last word only after hearing that word and accessing it in the mental lexicon. Given this, it is not surprising that both readings of the ambiguous word influenced the naming task in the no-delay condition. Though Seidenberg, et. al. did not publish the materials used in their replication of the effect observed by Tanenhaus, et. al., their discussion gives no indication that they were aware of the difficulties outlined above. Pending further research, it remains to be seen whether a context that syntactically constrains the grammatical category of a word completely independently from the word itself can block access to a reading of an ambiguous word.[5]

Taken together, the studies reviewed above lend little support to the suggestion that lexical processing may be sensitive to syntactic processing in some ways. The Miller and Isard (1963) study could be sensitive to a variety of effects arising after lexical retrieval. The only reliable, possibly syntactic effect evident among the word-by-word reading studies is a tendency for reading time to be longer toward the end of a clause. But this might also reflect integrational processing of some kind. The detectability studies on t and the in text suggest

that reading strategies can reflect syntactic factors, but they don't necessarily show that this effect reflects an influence on lexical processing. Notwithstanding the critique of the materials used in the Tanenhaus, et. al. (1979) and Seidenberg, et. al. (1982) studies, these investigations provide the strongest evidence of syntactic involvement in lexical processing because they show that syntactic context is sufficient to determine which reading of a noun-verb ambiguity will be used within about 200 msec.

Apart from these few, equivocal findings there is also some explicit skepticism about the possibility of syntactic effects on lexical processing. Fischler and Bloom (1979) argue that knowing the syntactic category of a lexical item does little to help identify the word, particularly in view of the many items in a language like English that can play multiple grammatical roles. Graesser, Hoffman and Clark (1980) suggest that linguistic theories of syntax are "only marginally applicable to psycholinguistic theories of syntactic processing" (p. 137) because the analyses such theories provide are imposed on sentences as wholes without considering the fact that the words in sentences are read from left to right. These authors do acknowledge, however, that syntactic rules do "specify constraints on what categories of words occur at different locations in phrases and sentences" (p. 137).

Despite this skepticism, there are substantive reasons for investigating possible syntactic effects on lexical processing. In general, if the lexical processing system is going to be open to context effects, especially in its retrieval stage, there are several reasons why it might be more advantageous for the system to exploit

syntactic context relations than semantic or pragmatic relations. First, the semantic and pragmatic factors generally considered in the sentence context literature exert at most a probabilistic influence; the constraints they suggest can almost always be violated without sacrificing syntactic or interpretive coherence. By contrast, syntactically derived constraints tend to be categorical. The word following the may not be a preposition or a verb (though, as noted above, it may be an adjective derived from a verb). Second, in many instances where a lexical item has multiple readings, various readings are associated with different subcategorization or selectional constraints. Therefore, syntactic context is potentially able to contribute to the recognition of such items. In English it is unlikely that any such possibility is fully realized because verbs and prepositions generally precede their complements. Thus while various readings of the verb return are specified as transitive, ditransitive or intransitive, the context that determines which reading or class of readings is intended will not appear until after the verb. In this case, it may of course be useful in selecting an interpretation of the word, but it cannot support any anticipatory or expectancy effect relative to the verb itself. This, however, is a fact about English. There are other languages that place complements before verbs and prepositions. In these languages it is at least possible to derive expectancies about some classes of items from the complement structures preceding them. Third, the syntactic relations listeners or readers posit between contexts and lexical items should be more uniform across individuals than the associative relations involved in typical priming studies. Thus heavy reliance on associative relations and other ideosyncratic systems

in lexical processing will tend to increase the difficulty speakers have in correctly anticipating how various utterances will be integrated (or processed).

It is obvious, however, that the opportunities for facilitating lexical processing on the basis of prior syntactic context are limited in English. There seem to be only two general sources from which such constraints might arise, contextual constraints associated with particular items in the lexicon, and syntactic rules. Lexical constraints such as subcategorization and selection restrictions could work either of two ways. If there is a mechanism for assessing the useability of each lexical item on the basis of some arbitrary initial substring of a sentence, then words whose lexical constraints are violated by prior context could be made unavailable for the analysis of subsequent material. For example, a verb like eat that takes animate subjects could be ignored in some lexical searches in sentences with inanimate subjects. Lexical constraints could also be used to project properties of material following an item that imposes some contextual constraints. Thus, verbs like put that obligatorily include a place adverbial in their complements could be used to predict some of the properties of any substring following them. In English, there is a contrast between those constraints that reach forward of a verb and those that restrict following material. Only selection restrictions (those defined over notions such as [± ANIMATE], [± HUMAN], [± COUNT], etc.) can reach forward. While constraints on subsequent context could arise from either this kind of mechanism or subcategorization constraints (those defined over constituent types such as noun phrase, prepositional phrase, etc.). This of course is a fact about English,

not language in general. There are other languages in which a verb's complements must precede it and in these languages it would be possible to restrict some lexical searches to items whose selectional and subcategorization constraints were satisfied by prior context.

Syntactic rules affect some grammatical properties of some items following certain other items or structures. An example is the agreement rule in English that makes verb form dependent upon the number property of the subject. Principles of case that control the choice between he and him, among others, are another example.

In overview, while it is clear that there are various syntactic principles and relations that could in principle contribute to lexical processing (in either its preretrieval or postretrieval stages), evidence of such effects has rarely been sought. Where it has, the results have been equivocal at best. However, the designs of the studies that have produced this evidence generally could not have produced clear cut evidence on syntactic effects in any case.

In the context of this discussion it should also be noted that there is as yet no empirical demonstration that priming effects based on associative relations could in fact be generally helpful in language processing. In particular, it has not been shown that words in sentence context are commonly preceded (within a short span) by a word or words with which they are associatively related. Or, to put it the other way around, it has not been shown that words in normal speech or text are commonly followed by words with which they are associatively linked. If all or most words have associates and if these are activated upon each presentation of a word, this activity will be largely wasted unless some associate of the word will show up frequently after

the word. Though the general claim here is clear enough, it is difficult to formulate precisely. How frequently a word's associates must turn up in near subsequent context in order for a priming or spreading activation mechanism to be advantageous depends upon the relative advantage assumed for processing a word with prior priming context and the relative cost assumed for processing a word without such context. Nevertheless, it is clear that unless the ratio between the cost of word processing without priming context and the advantage obtained from priming context is extreme, a word's associates must follow it closely on, say, 20% or more of its uses in order for the priming mechanism to be generally helpful.

1.2.4 Modularity and the choice of experimental task. Relatively inconspicuous variations of the task subjects perform in a psycholinguistic experiment can substantially affect the outcome, sometimes quite paradoxically. It is therefore surprising that the analysis of tasks is generally allowed to rest on a large element of untested speculation. Though some speculation is inescapable, given the depth of mystery that still shrouds most mental activity, there are opportunities for much more careful and direct experimental evaluation of tasks themselves than has so far been undertaken.

This thesis will not challenge this unfortunate tradition other than to call attention to it. The following discussion will, however, suggest some grounds for preferring the naming task of Tyler and Marslen-Wilson (1977) over other tasks that might have been used in the experiments described below.

The central concern of this study is with the possible modular

structure of the mental functions underlying human linguistic ability. The question arises at two levels of analysis. First, does linguistic performance engage any functions that are dedicated to subserving linguistic performance and at least partly isolated from other mental functions that also have some role in linguistic performance. Second, if there are uniquely linguistic mental functions, are these in turn partitioned into two or more subfunctions? Given these concerns, the appropriate tasks for experiments addressed to questions related to these issues are those that have the greatest prospect of revealing genuine differentiation in mental functions.

One dimension of psycholinguistic tasks that seems to be sensitive to this criterion is the involvement of consciousness. That is, psycholinguistic tasks may vary in the extent to which they require subjects to retain and employ explicit conscious criteria in the execution of the experimental task. The involvement of consciousness may in turn affect the likelihood of detecting any partitioning of the mental functions involved in language.

There are two reasons for giving particular consideration to the role of consciousness in psycholinguistic experiments addressed to questions about modularity. First, consciousness is integrative; it seems able to receive information from every possible mode of sensation and cognition. It also seems to be capable of very rapidly integrating information derived from different modalities in pursuit of some consciously determined objective. Behind the wheel of an automobile a driver routinely integrates information derived from visual, acoustic and symbolic modes of analyzing the environment. Decisions are made, usually rapidly and without apparent effort, that nonetheless reflect

consciously determined plans to go to a certain place by a certain route, etc. Obviously, if an integrative function of this kind is involved in performing the task specified for some experiment, it is possible that many different kinds of mental resources will influence the behavior that ultimately appears. If mental functions related to language are in fact partitioned into distinct kinds, any attempt to discern this structure that involves conscious processes suffers some danger of actually obscuring that structure through this mixing of multiple influences.

A second reason for being cautious about involving conscious criteria in psycholinguistic tasks is that normal language processing is in many respects inaccessible to consciousness. Listeners have essentially no access to the procedures by which they determine what is the underlying subject of a sentence, what coreference possiblities are open for a given noun phrase, what lexical item is represented by a given phonemic structure, or what phonemic structure is signaled by a given acoustic pattern. More particularly, they are apparently unaware of the lexical status of items in sentences they hear unless the items are unknown to them, or, whether an utterance is ungrammatical, or whether it contains certain phonemes. That is to say, while utterances can be evaluated in these terms, listeners seem to have little or no awareness of these matters in the normal course of sentence analysis. Thus tasks that require subjects to evaluate utterances according to consciously maintained criteria bearing on these issues may either distort normal linguistic processing or be performed by functions other than those dedicated to language.

With these considerations in mind, several commonly used

psycholinguistic tasks become somewhat suspect. The lexical decision task, where the subject decides whether a presented letter string is or is not a word, is suspect because listeners don't ordinarily question the wordhood of the items in a sentence as they hear it. The character of the lexical decision task is also called into question by findings such as those of Forster and Chambers (1973) that show slower reaction times for the lexical decision task than for an otherwise similar naming task. This of course is not the expected result if the two tasks are performed by more or less the same process. In principle, it should be possible to perform lexical access, then make an immediate word/nonword decision. Naming could be done by the same procedure with the addition of an oral read-out of the phonemic information found in the lexical entry. The disparity between the naming task and the seemingly simpler lexical decision task suggests that the latter involves either different mechanisms than those involved in more common tasks, or that the usual mechanisms are exploited in an unusual way.

Seidenberg and Tanenhaus (1979) and Donnenwerth-Nolan, Tanenhaus and Seidenberg (1981) have provided some evidence that indirectly suggests that the lexical decision task involves some addition to the work involved in the naming task. Their evidence indicates that rhyme relations between words affect performance on a lexical decision task, even though nothing about the task or materials seems to require that subjects consider rhyme relations. Obviously, any analysis of rhyme relations that is going to affect performance must be performed before a response is executed. Thus the lexical decision task seems to reflect linguistic analyses of the input well beyond those necessary

for lexical access. Apparently, the function that controls the lexical decision task cannot respond narrowly to the outcome of lexical access, but rather depends upon some analysis that follows an at present unanalyzed complex of automatic linguistic analyses.

It may be that the phoneme monitor task is vulnerable to similar arguments. Cairns, Cowart and Jablon (1981) observed seemingly paradoxical results using similar materials with a phoneme monitor task and a probe task. They observed that when a lexical item appeared in the presence of prior "biasing context" this tended to reduce RT to monitor the initial phoneme of the word following the target but to increase RT to the target word when it was presented for recognition after the sentence. Cairns, et. al. suggested that even though the phoneme monitor task seems to require no more than a phonemic analysis of the input, it is in fact sensitive to relatively high levels of integrative analysis. If this conclusion is well founded, the unexpected sensitivity of the phoneme monitor task may be attributable to the involvement of a conscious evaluation of the input that is unlike any involved in normal speech processing.

Given the foregoing considerations, the attraction of the task Tyler and Marslen-Wilson (1977) used is that it requires little conscious decision-making of any kind. Though the subject must attend to events in two modalities, when the visual word appears at the end of the sentence fragment, there is no decision to make about whether to read it. It is only necessary to read it. A conscious criterion is involved to the extent that the subject could attempt to shadow the auditory input as well as reading the visual input. Nevertheless, the naturalness and familiarity of the reading task, the lack of decision-

making or evaluation within the visual modality, and the unnaturalness and difficulty of a shadowing task seem to combine to make Tyler and Marslen-Wilson's task relatively very free of conscious involvement. Note also that it contrasts with naming tasks such as Forster and Chambers (1973) used where the subject sees a series of visual words and names only those that are distinguished by some graphic characteristic, such as being printed in an italic typeface. The attraction of the Tyler and Marslen-Wilson task is not simply that it is a naming task, but that it is a naming task with so little reliance on conscious decision-making.

It should be stressed that what is at issue here is not the familiar notion of 'ecological validity.' Stanovich (1981), in a discussion of context effects, formulates the question about ecological validity this way: "...how well are we approximating in our laboratory experiments the real magnitudes of context effects that occur in the actual reading situation?" (p. 258). Apart from the scale of the observed effects, one can also ask whether the task an experiment requires is representative of tasks people actually perform outside of laboratory conditions. The preceding discussion has, however, been motivated by a primary concern for what might be termed systemic validity. A task exhibits systemic validity when it effectively reveals the architecture of the system of mental functions that enable normal language use. Of course, neither the architecture of mental functions involved in language use nor the specific procedures involved in a particular task are known a priori. Therefore the systematic validity of a given task can only be estimated relative to some preliminary assumptions about the character of the mental

processes invoked by some task. Nevertheless, the utility of the notion is that it reasserts the importance of a task's capacity to discriminate functional architecture, an issue of singular scientific importance, while retaining the emphasis on normalcy associated with the notion of ecological validity.

1.3 Prospect

As indicated earlier, most of the experiments to be reviewed in Chapter 3 used the next-word naming task of Tyler and Marslen-Wilson (1977). However, the comments on the Tyler and Marslen-Wilson study, as well as the analyses of several other studies discussed in Section 1.2, suggest that the interpretability of psycholinguistic research often rests upon the linguistic details of the materials used. Therefore the task of Chapter 2 is to examine the materials for the experiments described in Chapter 3 from a linguistic point of view.

Notes for Chapter One

[1]Berwick and Weinberg (1983) present a much more detailed and explicit account of the relation between a linguistic theory and a processing theory (i.e., between a grammar and a parser) than the one provided here. Their account is also somewhat more optimistic about the possibility of deriving constraints on the processing theory from the linguistic theory.

[2]Carroll, Tanenhaus and Bever (1978) argue that "functional completeness" affects the degree to which listeners treat word sequences as segmentation units. Functional completeness resides in those "...linguistic sequences which can be directly mapped onto complete propositional structures..." (p. 192). On the face of it, this proposal requires that the processing systems that deal with structural properties of a sentence (e.g., its clausal structure) be partly dependent upon at least some of the processes that deal with sentence interpretation. The evidence which Carroll, et. al. provide for their claim is not, however, particularly compelling. None of the first five experiments they report is remotely an "on-line" task and any effects observed can as easily be attributed to processes arising after the original perceptual analysis of the input as they can to those arising within that analysis. A sixth experiment used a timed sentence comprehension task. Though this is nearer to an on-line task, the fact that subjects were responding a word or more after the critical relative clauses leaves open the possibility that something more than a first pass perceptual analysis of the input is involved. The results themselves seem to endorse this conclusion. The key finding in support of Carroll, et. al.'s claims was evidence that sentences including an object relative (i.e., relative clauses such as whom the boy kissed where the relative pronoun whom functions as the object of the verb in the clause) took longer to comprehend than those including subject relatives when there was a neutral prior context, but that this difference disappeared when there was a "congruent" context sentence. The context was congruent when it used the noun phrases involved in the relative clause in roughly the same functional roles relative to the same verb as in the clause itself. Apparently the congruent context helped subjects overcome the difficulty of construing whom as the object of kissed when whom appears two words ahead of the verb. There was, however, a main effect for context, suggesting that all sentences were easier to comprehend with congruent context. It is not clear whether the 30 msec. trend in this direction for the subject relatives is independently significant, but this trend and the main effect suggest that whatever the comprehension task measures includes intersentence processes that involve more than the assignment of functional roles to noun phrases. These results do little to buttress the claim that any structural stage in sentence processing is open to functional influences.

[3]Holmes (1978) reports two experiments that used English materials similar in some respects to those used by Frauenfelder, et. al. A timed sentence comprehension task was employed. Unlike Frauenfelder, et. al., Holmes found that object relatives were reliably

more difficult to process when selection restrictions rendered them nonreversible and when the appropriate grammatical relations for a relative were instantiated in a preceding sentence (cf., Carroll, Tanenhaus and Bever, 1978; see Note 1 above). However, the object relative effect disappeared in one circumstance where there were apparently no cues on which to avoid it. This unexpected finding, together with questions about the character of the task, make these results difficult to interpret and less convincing than the Frauenfelder, et. al. experiment. It should also be noted that the materials used in the case where the critical sentence was preceded by a context sentence were sometimes ill-formed with respect to discourse structure. Consider, for example, the sequence in (i). (These sentences formed a sequence in one part of Holme's experiment. Items (i a,b) correspond to her examples (7b) and (3b), respectively.)

(i) (a) The bus narrowly missed hitting the lorry.
(b) The lorry avoided the bus that the van crashed into.

The universal use of the determiner the suggests, incorrectly in (i a), that the object named by each noun phrase was mentioned previously in the discourse. Thus, on one reading, (i a) and the main clause of (i b) describe the same encounter. This is at least a little odd because the two sentences make out different vehicles to be the primary active agent in the encounter. Furthermore, it is odd to take the second use of bus as coreferential with the first on the ground that the second use provides more information about the bus (in the relative clause) than does the first. Usually, more informative mentions precede more 'anaphoric' ones. However, taking the second use of bus to refer to a different bus does little to improve the situation so far as discourse structure is concerned because of the use of the with both bus and van.

[4]Noun phrases represented half of the syntactic contexts used. The other half of the well-formed cases were either sentences or sentence fragments consisting of a noun and a verb, as in we agreed, or they broke.

[5]Michael Tanenhaus has described for the author a recent experiment which appears to satisfy the objections raised here to the study by Tanenhaus, et. al. (1979). Instead of [tU], as in the earlier study, here to was pronounced as [tʌ], with the same vowel as but. This form can be used as an infinitive marker with a verb, or as an preposition. In these materials, however, the prepositional interpretation is ruled out by prior context. Thus [tʌ] in such cases determines that the next item must be either a verb or adverb. Since the word appearing in the final position of each sentence was ambiguous between verb and noun readings, the use of [tʌ] should have the intended effect of determining the verb reading. Tanenhaus reports that the pattern of results reported earlier holds with this change.

CHAPTER TWO

Linguistic Background to the Experiments

The first task of this chapter is to identify a class of "arbitrary" pronouns that exhibit a distinctive set of linguistic and extralinguistic properties. Since the referential characteristics of these pronouns are critical to the experiments described in Chapter 3, Section 2.2 reviews various kinds of knowledge listeners use to determine the reference of such pronouns. The experiments discussed in Chapter 3 also make critical use of ambiguous expressions such as flying planes or moving displays. Section 2.3 reviews the properties of the two interpretations that may be assigned to these constructions and considers why some expressions of the form VERBing NOUNs are unambiguous.

2.1 The "arbitrary" pronoun they

Among the pronouns of English there is a subset that enters into a relation called "arbitrary reference." The they in The men told the women that they had beaten the challengers is of this type. The they may be taken as coreferential with the men or the women; or, it may refer to a set including both the men and the women, or some group the sentence doesn't mention. However, they cannot be coreferential with the challengers. This is a fairly characteristic instance; a pronoun of this type may be coreferential with some NP in the linguistic context, or it may refer to some individual or set in the extralinguistic context.

When the pronoun derives its reference directly from another NP, this "antecedent" may precede or follow the pronoun, subject to certain structural conditions. Where multiple antecedents are fully eligible, there is an interpretation for each pairing of pronoun and antecedent, though some pairings may prove unacceptable or implausible on further analysis. Various dimensions of sentence and discourse structure affect the choice of antecedent or referent (see below). All of the English third person personal and possessive pronouns take arbitrary reference; these will be termed "arbitrary" pronouns. The following discussion is concerned only with those cases where the pronoun takes some NP as its antecedent.[1]

The arbitrary reference relation contrasts with the links between other pronouns and elements in their contexts. Reflexive and reciprocal pronouns (eg., themselves, each other) differ in that they cannot take antecedents outside of the sentences in which they appear; furthermore, their antecedents are often fully determined by syntactic structure and certain principles of interpretation (assuming the analysis of Chomsky, 1981). First- and second-person personal and possessive pronouns contrast with arbitrary pronouns in that the former take no linguistic antecedents at all. Recent analyses of interrogative pronouns such as who, what, etc., and the "universal" pronouns such as everyone, each, all, etc. suggest that these expressions do not fall together with any of the pronouns already mentioned, but rather serve to bind variables in the logical form representation of a sentence (LF representation) in the manner of quantifiers in formal logic (Chomsky, 1981). In any case, they plainly do not take antecedents in anything like the sense in which arbitrary pronouns do.

2.2 Information types to which the interpretation of *they* is sensitive

An interesting feature of the arbitrary reference relation is that it is sensitive to influences arising at several different levels of grammatical analysis, as well as to influences that are apparently altogether beyond the scope of grammar. Lexical distinctions between masculine and feminine or singular and plural forms eliminate some possible antecedents. Obviously, what the pronoun in (1) refers to depends upon whether *she*, *he* or *they* is used.

(1) The man told the woman that PRONOUN had won.

The coreference possibilities of *they* are limited by syntactic structure in (2).

(2) a. The men said they thought the boys would leave the girls.
b. The men said the boys thought they would leave.

The system of interpretive rules that constructs LF representations expresses these coreference restrictions (Chomsky, 1981). Note that the principles relevant to *they* that are expressed at the LF level are entirely prohibitive; that is, they can specify that *the boys* or *the girls* in (2a) may not be coreferential with *they*, but they cannot determine whether *they* is coreferential with *the men*. Similarly, in (2b) the appropriate representation in LF will allow *they* to be coreferential with either *the men* or *the boys*, but it contributes nothing to a choice between the two.

The examples in (3) represent a contrast exploited in the design of Experiment 4 (see Chapter 3).

(3) a. Whenever they want to save money, visiting relatives...

b. Whenever they want to believe that visiting relatives...

In (3a) they and visiting relatives may refer to the same individuals, but in (3b) they may not. Within the framework of Chomsky (1981) this contrast, as well as the coreference phenomena illustrated in (2), is explained by the theories of government and binding. The theory of government is concerned with "...the relation between the head of a construction and the categories dependent upon it" (p. 5). More specifically, "...a (lexical, WC) category governs its complements in a construction of which it is the head" (p. 50). Though this idea can be formalized in a number of empirically distinct ways (see the discussion in Chomsky's Chapter 3), the choice between various formalizations has no consequences for the relatively straightforward cases relevant to the present study. The theory of government also includes a notion of governing category. Again neglecting complications related to alternative formalizations, the governing category for an NP is that NP or S that minimally contains the NP and its governor (roughly, the verb or preposition that determines the case of the NP). Together with the theory of government, the theory of binding specifies the properties of those sentence elements that have some referential function. Pronominal elements like they are said to be "free" in their governing categories, while R-expressions[2] like visiting relatives are simply free (Chomsky, 1981, Chapter 3, especially p. 188). To say that an element is free in a certain domain is to say that it is not bound by (i.e., it is not coindexed[3] with) any c-commanding[4] NP in that domain. The effect of these stipulations is to require that a pronoun such as they cannot be

coreferential with any c-commanding NP in its own clause, while an R-expression such as visiting relatives cannot be coreferential with any c-commanding NP, whatever clause it may be in (cf., Lasnik, 1976).

The properties of example (3a) are determined by these principles in the following way (see Figure 2). The pronoun they is governed by the TENSE element in INFL (the node that dominates tense and agreement morphemes). As a consequence, the governing category of they is the S node of the sentence in which it appears. Since no other NP under this S c-commands they, the rules do not restrict the reference of they. Since visiting relatives is an R-expression and therefore free, its governing category (the rightmost S node in Figure 2) can be ignored. However, as noted above, coindexing between an R-expression and another NP is blocked only when the other NP c-commands the R-expression. Since they does not c-command visiting relatives in this structure, the binding principles for R-expressions present no bar to these NPs being coindexed and thus coreferential. Indeed, since neither visiting relatives nor they c-commands the other, none of the binding principles can apply to the relation between them. Thus, even if the two NPs were exchanged or if they were replaced by an R-expression, the binding rules would still not apply. Other factors aside, the two NPs could be coreferential.

In example (3b) (see Figure 3) the introduction of believe and the complementizer that has the effect of making visiting relatives the subject of a sentence embedded in the VP of the sentence of which they is subject. Since an R-expression is free according to the binding theory, it must be disjoint with any c-commanding NP, even one outside

FIGURE 2: PERMITTED COREFERENCE EXAMPLE

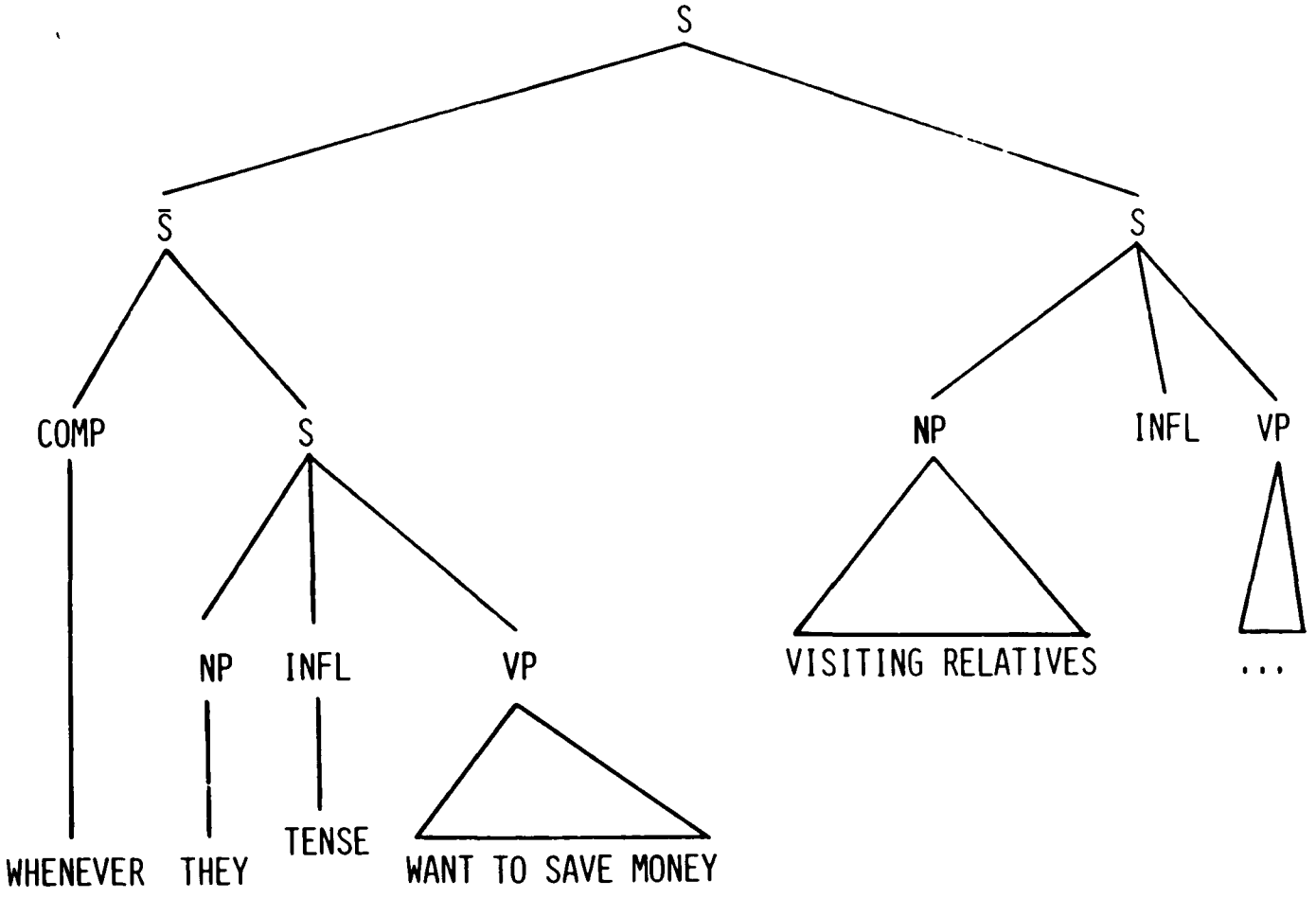
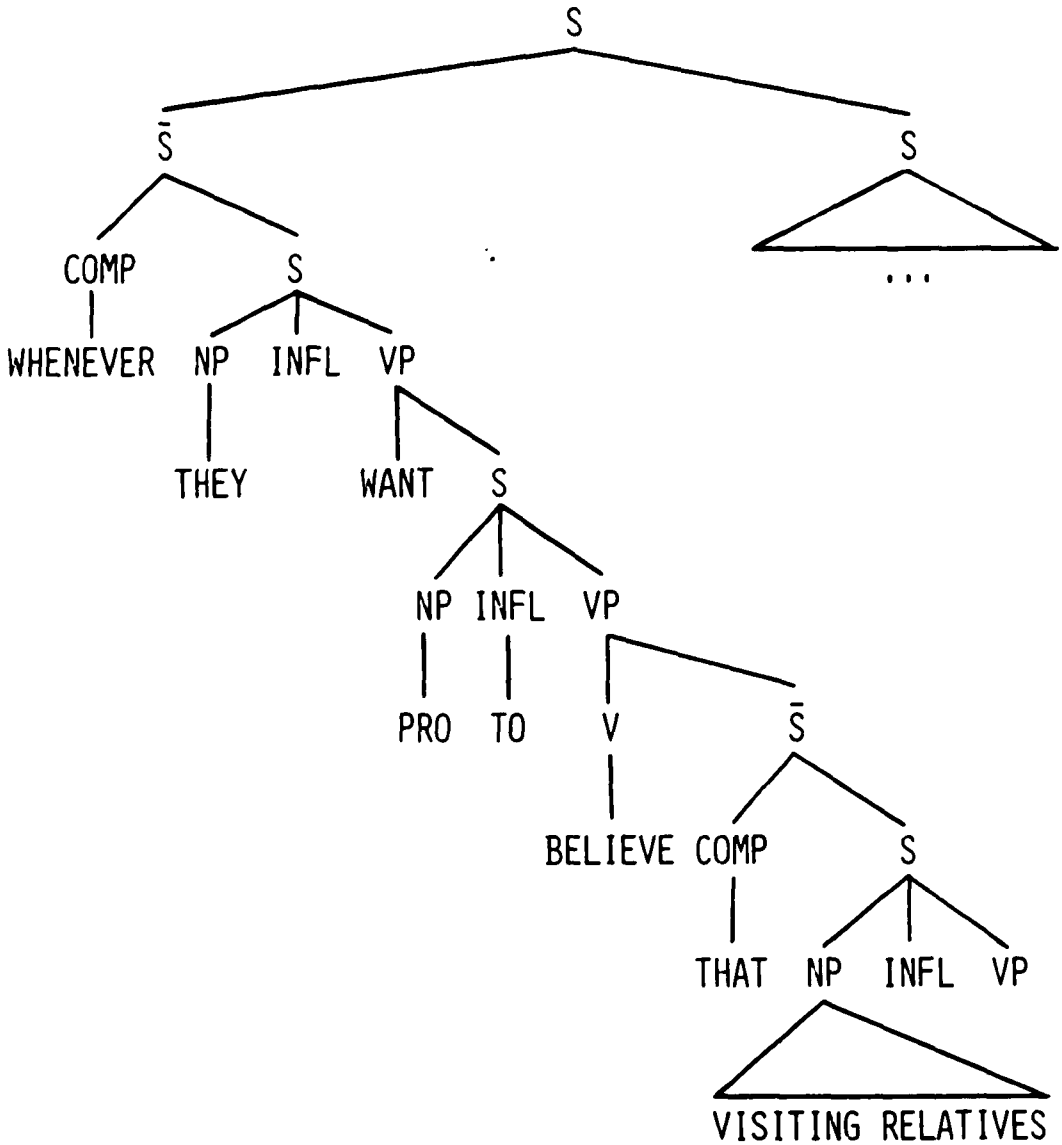


FIGURE 3: BLOCKED COREFERENCE EXAMPLE



the domain defined by its governing category (i.e., the S node of the that-complement in the case of visiting relatives). Thus visiting relatives must be disjoint with they.

Example (4) illustrates a complex phenomenon of a different order. Here the operative mechanism is apparently the system of syntactic selectional restrictions described by Chomsky (1965).

(4) a. Just because they saw no hope of improvement, the guards continued to terrorize the prisoners.

b. Just because they saw no hope of improvement, the chains continued to terrorize the prisoners.

Though judgements may differ as to the plausibility of the alternatives, it is plainly possible for the they in (4a) to derive its reference from either the guards or the prisoners, while in (4b) only the prisoners is possible. In Chomsky's system there is a very small set of features such as [±ANIMATE], [±ABSTRACT], [±COUNT], etc., that can specify the contexts into which lexical items may be inserted. In this framework, they cannot be related to the chains in (4b) on the grounds that the verb see takes only subjects marked [+ANIMATE] (assuming that selection features required by the verb are assigned to the pronoun). If they is derivatively [+ANIMATE] in this context, it cannot take the [-ANIMATE] chains as an antecedent. Setting aside questions about whether selection restrictions are somehow derived from semantic descriptions, Chomsky (1965) proposed that, whatever their source or motivation, these constraints should be expressed within the syntactic system.

Another kind of influence on the arbitrary reference relation is illustrated in (5).

(5) Even though they had been known as grumpy old bachelors for many years, the children took an instant liking to the men.

If bachelor is defined within the linguistic system as [+ADULT], and children as [-ADULT], then the system of semantic analysis that interprets the predicate had been known as grumpy old bachelors will apparently attribute the feature [+ADULT], among others, to the referent of they. This would account for the apparent impossibility of taking children as coreferential with they. Aside from the fact that it is less well understood, the phenomenon involved here is distinct from that illustrated in (4) in two respects. First, the operative feature [+ADULT] is not among those over which syntactic selection restrictions are defined (Chomsky, 1965). This is to claim that this feature is not in the vocabulary recognized by the syntactic system. Second, the form of the selectional rules is such that a noun in the position of bachelors cannot select any item in the position of they.

There are also cases such as (6) which seem to reflect principles unlike any of those discussed so far.

(6) Once they had been securely handcuffed, the priests no longer feared the convicts.

Though there seems to be no principle of language that rules out handcuffing priests, most speakers seem to find it much easier to relate they to convicts than priests. The relevant influence seems to be purely a matter of pragmatic (i.e., real-world) knowledge; listeners regard handcuffing priests as less likely than handcuffing prisoners.[5]

There may in fact be no systematic difference between the kinds of linguistic constraint captured by selection restrictions (as illustrated in (4) above) and the kinds of constraints attributed above to pragmatic knowledge. Chomsky (1965) demonstrated that a certain range of constraints on English sentence structure could be captured by setting up a small number of binary features such as [±COUNT], [±COMMON], [±ANIMATE] and [±HUMAN]. However, it is difficult to formulate an explicit criterion that distinguishes between these features and others such as, say, [±ADULT] or [±MATURE] that might be used to express the putatively pragmatic constraints operative in sentences such as (7).

(7) Whenever they lecture during the procedure, charming babies attract a lot of attention.

Though there does seem to be some intuitive sense in which the selectional features Chomsky used are more central than those involved in the pragmatic cases like (7), there are numbers of possible theoretical accounts of this contrast. For the present, we need consider only three.

First, it might be that something close to the set of selectional features Chomsky proposed is an integral part of the syntactic system and that those constraints that are not representable within this system are expressed by some other, presumably interpretive, component of the linguistic system. On the further assumption that distinct components of the processing system realize distinct components of the grammar, selectional anomalies will affect the performance system differently than will pragmatic anomalies. Second, it might be that a single grammatical component expresses the constraints relevant to both selectional and pragmatic anomalies; these putatively distinct types may in fact constitute a

homogenous class of phenomena. Nonetheless, there might still be dimensions along which these constraints vary, eg., simplicity of representation or frequency of use. Given this, pragmatic constraints might be somehow harder to process, slower to access or something of this sort. Some difference in performance might also arise if pragmatic constraints engage nonlinguistic conceptual knowledge in different ways than do selectional constraints. Finally, the apparent difference between selectional and pragmatic constraints may be entirely illusory. Both types may be represented in the same grammatical component and be realized by the same processing mechanisms. Though the fourth experiment described below could conceivably distinguish this latter situation from either of the first two, it can go no further than that.

This account of the factors that affect arbitrary reference relations is far from complete. Among other things this framework does not distinguish arbitrary pronouns from either lexical nouns or those pronouns that do not require antecedents in the sense that arbitrary pronouns do. Consider the examples in (8).

(8) a. Though they seem to have said nothing new, the rocks looked interesting.

b. Though they were expected to eat heartily, the beans still didn't look very appetizing.

The sentences in (8) seem odd when uttered outside of any related context. Without contrastive stress on <u>they</u>, they seem to yield a marked sense of anomaly. This is apparently due to a tendency to relate the <u>they</u> in each sentence to the NP at the beginning of the second clause, at least momentarily. However, no such difficulty appears if the

they in each case is replaced by I, you, or the men. It is not at all clear what explains the apparent difference between, for example, they and you. Minimally, there seems to be some sense in which they and other arbitrary pronouns 'insist' upon being related to other NPs in a way that is not characteristic of full NPs or pronouns such as I, and you. Note, however, that this difference may not be reflected at any level of grammatical description; in particular, representations in LF as developed by Chomsky (1981) make no referential distinctions between, for example, second person and third person personal pronouns. Furthermore, this does not seem to be a failing of that theory. Any attempt to specify positive referential links between arbitrary pronouns and their antecedents at the level of LF would apparently require that the vocabulary of LF be expanded to represent the semantic and pragmatic influences suggested by (5) and (6). Since this expansion is otherwise unmotivated, given the class of problems handled at LF, and since consistent application of any expanded descriptive power in LF would complicate but not enrich the descriptions of the phenomena that are handled by the theory as presently constructed, it does not seem wise to extend the theory of LF in this way.

For the sake of completeness, assume that language-related competence (N.B.: not linguistic competence) includes a referential component that is generally concerned with relations between referring expressions and the set of 'objects' considered salient in a given discourse at a given moment, and with discovering grammatically indeterminate relations between referring expressions within and across sentences, ie., with certain aspects of anaphora.[6] This component, for present purposes, will contain a principle specifying that arbitrary pronouns refer to some

entity mentioned in the linguistic context unless there are no entities of the appropriate kind or there is contrastive stress on the pronoun. In the latter two cases the function of the pronoun is assumed to be deictic. This seems to be the minimal grammatical analysis of arbitrary pronouns. Apart from the exceptions noted, the analysis states simply that each such pronoun has an antecedent. By hypothesis, there is a general principle of making sense that entails that the antecedent will be consonant with lexically determined properties of the pronoun ([±MALE], [±SINGULAR], etc.), as well as with any syntactically derived properties. Other components of competence (possibly incorporating much pragmatic, domain-specific knowledge) are assumed to carry out the analyses which determine whether or not a given element in the universe of discourse is a possible antecedent. The search for the antecedent is taken to be a function of performance mechanisms, ie., though linguistic and extra linguistic context affects the outcome, it does not determine that there will be a search, the order in which candidate antecedents are evaluated, nor the procedure by which different kinds of information are evaluated.

Despite the considerable gaps in the currently available account of arbitrary pronouns, the above survey should be sufficient to establish the claim that there is a great variety of distinguishable influences that may affect the relation between an arbitrary pronoun and particular candidate antecedents. This observation confronts psycholinguistic theory with an interesting problem; how are these disparate kinds of information brought to bear on the problem of finding the appropriate antecedent for an arbitrary pronoun in some actual utterance?

2.3 Linguistic properties of VERBing NOUNs expressions

Expressions of the form VERBing NOUNs (eg., flying planes, amusing children) may accept either or both of two distinct analyses. Some of these expressions exhibit the characteristics of simple plural noun phrases, with the participial verb form functioning as an adjective. Others, though they also function as NPs, show characteristically clausal properties. The following discussion reviews these facts in more detail and then considers the question why only some of these expressions are ambiguous.

2.3.1 The plural NP reading. Expressions such as dripping faucets and frightening novels have the characteristics of simple plural NPs; a) they invoke subject-verb agreement and alternate with explicitly singular forms, as in (9a,b), b) they enter into conjunctions with other NPs, as in (9c) (cf., (9d)), and c) the participial forms in them often accept modification by adverbs, as in (9e-g).

(9) a. Dripping faucets irritate John.
b. The dripping faucet irritates John.
c. Dripping faucets and noisy pipes irritate John.
d. *Dripping faucets and cleaning drains irritate John.
e. Constantly dripping faucets irritate everybody.
f. Very frightening novels sometimes attract large audiences.
g. Terribly frightening novels repel some readers.

Notice also that the participial forms in (9) relate to the nouns they modify differently than do the verbs from which these participial forms are derived. The nouns modified by the participial forms go into

subject position with the corresponding verbs. Thus creaking stairs is paired with Stairs creak loudly but generally not with John creaked the stairs.

2.3.2 The nominal reading. Though expressions such as whistling tunes and sanding floors occur freely in typical NP positions as in (10), they do not invoke subject/verb agreement, as in (10a, b).

(10) a. Sanding floors makes a lot of dust.
b. Sanding a floor makes a lot of dust.
c. John hates sanding floors.
d. John is tired of whistling tunes.

Several factors suggest that members of this class of expressions derive from underlying clauses. One indication is that they can accept sentence-like aspect markings, as in (11).

(11) a. Having sanded the floor allowed John to judge the quality of the wood in it.
b. Having been sanding floors for years left John skeptical about the claims for the new product.

There are also forms that suggest passivization.

(12) a. The floor's being sanded too often ruined it.
b. The tune's being whistled too loudly made it unpleasant.

Though this class of VERBing NOUNs is typically used without them, these forms freely include subjects as in (13).

(13) a. John's sanding floors provides most of his income.

b. Mary's whistling tunes pleases the baby.

There seem to be regular relations between the sentential uses of verbs and their uses in these expressions; this is further evidence of the sentence-like character of these forms. An intransitive verb like die cannot enter into expressions of this kind, as in (14a). Verbs that obligatorily take place adverbs in sentences require them in their nominal uses as well. Thus no form such as (14b) is acceptable, but a form such as (14c) is. The use of make invoked in (14d) cannot be invoked by a nominal that begins as does (14e), but can be invoked in (14f).

(14) a. *Dying swans is...

b. *Putting plates is...

c. Putting plates on the table is...

d. The committee made John chairman.

e. *Making John causes...

f. Making John chairman causes...

Note also that the meaning of nominals such as (14c,f) is quite simply related to the meaning of the verb in sentential uses.

There are also indications that these expressions acquire subjects from context in interpretation. Thus a and b of (15) are odd because in each case the nominal seems to acquire an inappropriate subject in interpretation. This problem is relieved when an alternate subject is available within the same or a prior sentence.

(15) a. Amusing his grandchildren kept the baby occupied all day.

b. Getting pregnant caused John's schedule to change.

c. Grandpa couldn't have been more pleased. Amusing his grandchildren kept the baby occupied all day.

d. Mary said getting pregnant caused John's schedule to change.

To the extent that the oddity of (15a) is relieved in (15c), this indicates that the choice of subject in the nominal interpretation is not determined by principles of sentence grammar.

The government binding theory predicts these facts. Within the government binding theory VERBing NOUNs constructions have subjects when interpreted as nominals, even though such elements don't necessarily have any phonetic realization (Chomsky, 1981:64); thus, flying planes may be analyzed as ($_{NP}$($_{S}$ PRO flying planes)). The element PRO in such a construction is defined as having the properties of an ordinary pronoun like they, except that it lacks a phonetic matrix. Even though the position of PRO itself is, by definition, ungoverned, nominal VERBing NOUNs expressions typically appear in contexts which permit them to be coreferential with preceding NPs or to take some extrasentential or even extralinguistic antecedent. This analysis may help to account for some of the psychological properties of VERBing NOUNs expressions that will be discussed in Chapter 4.

2.3.3 Ambiguity in VERBing NOUNs. Flying planes is typical of a fairly large number of VERBing NOUNs expressions which can be given either of the two syntactic interpretations discussed above. Thus, both Flying planes is... and Flying planes are... is possible. For present

purposes, however, the interesting issue is why some expressions of this form can take only one of these interpretations. Not surprisingly, the answer lies in the syntactic properties of the stem from which the participial form is derived. Expressions like frightening novels can take only the plural NP reading because frighten takes only animate objects in ordinary sentential uses and therefore provides no possible sources such as John frightened the novels. As noted above the nominal interpretation is also impossible when the underlying verb is intransitive, as in die, sleep, cry, etc. Thus both the selectional and strict subcategorization properties of verbs may prevent their being used to form nominal VERBing NOUNs expressions.

Only the nominal interpretation is available when the noun associated with a given participial form cannot appear as the subject of the verb underlying the participial form. Thus, whistling tunes cannot be interpreted as a plural NP for the same reason that The tunes whistled loudly is out; each violates the constraint that whistle takes animate subjects.

Often, less clear cut pragmatic factors can also affect the relative accessibility of the nominal and plural NP interpretations even though neither is strictly blocked by selectional or strict subcategorization facts. Managing directors is most easily taken as a plural NP but can be used as a nominal in Managing directors is an essential part of every chief executive's job. Obviously the critical fact here is that listeners tend to think of directors managing, as in the plural NP reading, rather than as being managed, as in the nominal reading. Since the inverse assumptions are generally made about children, managing children is most easily taken as a nominal.

Notes for Chapter Two

[1]Note that there are occasional cases where third person pronouns seem to become involved in obligatory coreference. E.g.:

(A) She looks like she's pregnant.
(B) Your arguments have no point to them.

The second she in (A) apparently must refer to the same individual as does the first she. In the second sentence, them seems to be obligatorily coreferential with your arguments.

Though it is a matter of some interest to determine what mechanism(s) account for such cases, their existence has no apparent bearing on the critical cases considered in this monograph.

[2]The category of R-expressions includes "...noun phrases with heads that are in some intuitive sense 'potentially referential' (e.g., John, wood, sincerity, book, etc.) and variables...", where variables are certain empty NPs (i.e., traces) that are "bound" by another element in the same sentence (Chomsky, 1981:102). For example, in wh-questions such as (A), who binds the variable t.

(A) Who did Mary give the money to t.

[3]The government binding theory assumes some extragrammatical mechanism that assigns an index to each NP. Coreference is denoted by assigning the same index to each of two NPs. When, for whatever reason, two NPs do not have the same index, they are interpreted as disjoint in reference, i.e., they cannot refer to the same individual or set.

[4]Chomsky (1981:36) defines c-command as the relation that obtains between α and β in either (A) or (B):

(A) $[_{\gamma} \ldots\alpha\ldots\beta\ldots\ ]$

(B) $[_{\gamma} \ldots\beta\ldots\alpha\ldots\ ]$

Where α is an immediate constituent of γ.

For example, in an NP including a prepositional phrase, the structure (C) shows that NP_1 has two immediate constituents, NP_2 and PP.

(C) $[_{NP_1} \ldots NP_2 \ldots PP \ldots\ ]$

Each immediate constituent of NP_1 c-commands the other. However, the PP also contains an NP, as shown in (D).

(D) $[_{NP_1} \ldots NP_2 \ldots [_{PP} \ldots P\ \ NP_3 \ldots\ ]\ ]$

Since NP_2 is an immediate constituent of NP_1 and NP_3 is not, NP_2 c-commands NP_3 but NP_3 does not c-command NP_2. Thus in (A), α c-commands not only β, where β is another immediate constituent of

γ, but also all the constituents of β.

[5]Notice that apparently semantic properties of the verb may also play a role in these cases.

(A) Once they had been securely handcuffed, the priests no longer interested the convicts.

While judgements on isolated examples like these do not seem to be very stable, in (A) it seems easier to take the priests as the ones who get handcuffed. If this effect is real, it may be related to the fact that the verb fear posits a certain mental state of its subject while interest posits a mental state of its object.

[6]The stress on the notion of language-related competence is intended to call attention to two assumptions. First, this discussion assumes that (in dealing with the problems discussed here) some of the knowledge listeners invoke is relevant to nonlinguistic as well as linguistic communication. Any principle that is relevant to the interpretation of, say, gestures, pictorial signs, and linguistic utterances is language-related in the sense intended. The notion of linguistic competence is taken to cover only knowledge that is exclusively related to the interpretation of linguistic structures. Second, this discussion assumes that a kind of competence/performance distinction is needed in some non-linguistic domains. Suppose that there is some interesting consistency across listeners about the range of objects in a room that are regarded as possible referents. The assumption is that here too a distinction must be drawn between the principles that describe such consistencies and the mechanisms and procedures that actually implement them.

CHAPTER THREE

Language Processing with Cataphoric *They*

The four experiments discussed below are all addressed to certain questions about how listeners process sentence fragments similar to (1).

(1) As they soar gracefully above the field, flying kites...

The example contains both the arbitrary pronoun *they* and a VERBing NOUNs expression. These elements may interact. If the VERBing NOUNs expression is interpreted as a plural noun phrase, it may provide a referent for *they*, otherwise *they* must derive its reference from some noun phrase in prior or subsequent linguistic context, or be taken to refer to some extralinguistic entity. When the fragment in (1) appears in isolation there is evidently a strong tendency for readers or listeners to take *they* and *flying kites* as coreferential. In broad terms, the experiments discussed below were intended to determine whether this tendency is as real as it is apparent and, if it is, to assess the kinds of information listeners may bring to bear when selecting antecedents for *they* in such circumstances. The first three experiments were addressed to the first part of this problem and the fourth to the second.

As will be seen below, the method by which these questions are addressed involves context effects in which entire sentence fragments similar to (1) serve as prior context for a verb, usually *is* or *are*. The effects of the prior context will be measured by relative changes

in reaction time (RT) to two verb forms, that is, as changes in relative "bias." As suggested in Chapter 1, it is important to determine whether such context effects arise because the subject's response to the preferred form has been speeded, or the response to the non-preferred form has been slowed. Only if the response to the preferred form is speeded can these results be attributed to any variety of priming mechanism. Thus, the results of each of the RT experiments discussed below are also tested for their relevance to this further question: Do any observed context effects arise from facilitation of responses to preferred forms or from inhibition of responses to non-preferred forms?

3.1 A preliminary theory and a task

3.1.1 Theory. The experiments discussed below may be described in relation to a simple preliminary theory of the procedures by which materials similar to (1) are processed. Because the factors that affect a listener's choice of a referent for they are ultimately quite complex, for expository purposes it will be convenient to assume that the language processing system includes a device, a "scanner," whose function it is to find a referent for they whenever none is mentioned in prior linguistic context. With access to a description of subsequent context, such a scanner is potentially able to interact with another device, a "selector," that resolves uncertainties arising from syntactic ambiguity. Note that such a selector must base its decisions on non-syntactic properties of the input since the uncertainties arising from syntactic ambiguities, by definition, cannot be resolved by reference to syntactic criteria alone.

In terms of a scanner and a selector, Experiments 1 - 3 are

intended to determine whether the scanner can influence the selector in favor of the interpretation of flying kites in (1) that corresponds to the plural noun phrase analysis of its syntactic structure.

Since the evidence of Experiments 1 - 3 indicates that an influence of this kind can occur, Experiment 4 will address some questions about the kinds of information about relations between pronouns and antecedents that may become involved when the scanner examines expressions like flying kites as potential sources of referents for they.

3.1.2 The experimental task. Tyler and Marslen-Wilson (1977) used an experimental paradigm that seems relevant to the questions outlined above (see Section 1.2.1). The employed a next-word naming task designed to assess the compatibility of a visually presented probe word (which the subject reads aloud) and a preceding auditorily presented context sentence fragment. They used sentence fragments similar to (2) and presented a verb form via a tachistoscope at the offset of the auditory input.

(2) If you walk too near the runway, landing planes...

The verb was always either is or are on the experimental trials. Each verb presentation was either "appropriate" or "inappropriate" in relation to the material that preceded it. Appropriateness was determined by a pretest. If a given first clause was shown on the pretest to bias readers toward the plural noun phrase reading of the ambiguous phrase, then are was appropriate and is inappropriate. With a first clause biased the other way, the appropriateness values reversed. Tyler and

Marslen-Wilson found that reading times for the inappropriate verbs were on the order of 30 msec. slower than those for the appropriate verbs. Of course, both is and are were used equally often in the appropriate and inappropriate conditions.

A similar method was used in the experiments discussed in this chapter. Here the presence or absence of a pronoun in the auditorily presented context is used to vary the bias of an ambiguous expression appearing at the end of the auditory material. However, the bias of the ambiguous expression cannot be measured directly, but only as it affects subjects' preferences for singular and plural verb forms. For example, suppose subjects are required to read is immediately after hearing a fragment ending in flying planes. If changes in prior context affect RT to is, it is assumed that the change in prior context affects the interpretation of flying planes, since this expression is compatible with a following is only on one of its interpretations.

3.2 Experiment 1: Judgement task

The first experiment was a judgement task designed to determine whether the pronoun they can affect subjects' preference for alternate readings of an ambiguous fragment when there is relatively ample time for consideration. Since a subject's choice of structural analysis cannot be assessed directly, changes in preferences for singular and plural verb forms will be taken as the index of these changes. The experiment also contrasted be with have in the role of the "probe" verb and non-pronominal noun phrases (e.g., the birds) with the pronoun you as control contexts.

3.2.1 Subjects. The subjects for the experiment were 40 Queens College undergraduates to whom the experiment was administered in a classroom setting.

3.2.2 Materials and design. The experimental sentence fragments were all structurally similar to the examples shown in (3) and (4).

(3) As the birds soar gracefully above the field, flying kites...

(4) Unless you show signs of great genius, challenging ideas...

The underscored constituents in (3) and (4) are the control contexts which are replaced by they in the experimental condition. In order to provide for counterbalancing, 24 items modeled on each of the two example types were constructed. Some of the ambiguous phrases were taken from Tyler and Marslen-Wilson (1977) and others were newly constructed. The experimental sentence fragments all conformed to the following criteria: 1) Each began with a single subordinate clause, followed immediately by a two-word ambiguous VERBing NOUNs expression; 2) None of the subordinate clauses contained any instance of the verbs be or have in any form (apart from one case, an error); 3) None of the subordinate clauses contained any pronoun apart from those specifically manipulated in the experiment; 4) The noun phrase which alternated between they and its respective controls was always the subject of the subordinate clause; and 5) The material intervening between the subject position in the subordinate clause and the ambiguous phrase was of moderate length, from three to 15 syllables. The 48 experimental items and 24 fillers were assigned a pseudorandom order. Two presentation

versions of the materials were then constructed in such a way that the items appeared in the same order in both versions. The only difference between the two versions was that where a control context appeared in one, an experimental context, i.e., they, appeared in the other. An equal number of control and experimental contexts appeared in both versions. Below each sentence fragment there were two verb forms, either is and are or has and have. Be and have were used equally often in each of the cells defined by the other factors in the experiment. This contrast was designed to oppose a verb which shows a singular/ plural contrast in its initial segment with one that does not. This was of greater importance in Experiment 2 than in Experiment 1. Half of the 48 experimental sentences compared they to a non-pronominal noun phrase control as in (3) and half contrasted they with you as in (4). The interest in this contrast arises from the possibility that the pronoun you may relate to the gerundive interpretation of the VERBing NOUNs expression differently than does a non-pronominal noun phrase, quite apart from questions about the reference of the subject noun phrase. As noted in Chapter 2, the implicit structure of phrases like flying planes on their gerundive interpretation is something like (PRO's) flying planes... or (Your) flying planes... . That is to say, the subject of the verb is deleted in the two-word expression. Since the possessive pronouns your and their can fill the subject position on the gerundive interpretation of the ambiguous phrase, it is possible that an instance of you or they in the prior context facilitates the selection of this anlaysis in a way that non-pronominal noun phrases do not. The noun phrase controls were taken as contexts which, by hypothesis, contribute no bias toward either interpretation of the

ambiguous phrase, while you was taken as a control which might bias toward the opposite interpretation from the one which the experimental treatment was expected to facilitate. Thus, the experiment was designed to assess the effects of three factors and their interactions: Context (the pronoun they vs. a control context), Control Type (a non-pronominal noun phrase vs. you), and Verb (be vs. have). These were crossed by a Groups factor (Materials Set 1 vs. 2). The experimental materials for Experiment 1, and all subsequent experiments, appear in the Appendix.

3.2.3 Procedure. The test booklets were distributed to participants together with a machine-readable response form. The first page of the booklet included detailed instructions which were then read aloud as the participants followed along. The critical portion of the instructions went as follows:

> "For each item your task is this: Suppose that you are required to construct a complete sentence that begins with the sentence fragment. Further suppose that whatever words you may add to make the sentence complete, the first of those added words must be one of the two verb forms shown below the fragment. The question is: Which verb form seems most natural to you? Note that there is a way to complete each fragment using either of the verb forms, but usually one will sound better to you than the other; that is the one you are to choose."

One sample item was provided at the bottom of the page of instructions. All subjects completed the task within about 25 minutes.

3.2.4 Results. The results provided by each subject were divided into eight categories (or cells) as determined by the intersection of the three factors. Each subject judged six items in each of these categories. The number of cases on which the subject chose the

singular verb form was taken as the index of the subject's performance in each cell.

An analysis using subjects as the random factor showed that subjects chose singular verb forms in 42% of the cases where one of the two control contexts was present and that this fraction fell to 29% where they replaced the control (see Table 3-1). This difference is significant by an analysis of variance ($F(1,38)=31.23$, $MS_e=1.74$, $p < .001$).

There were also two unexpected significant interactions involving the Context factor. The interaction between Groups and Context was significant ($F(1,38)=10.35$, $MS_e=1.74$, $p<.005$), as was the interaction among the Groups, Verb and Context factors ($F(1,38)=24.09$, $MS_e=1.05$, $p<.001$). Inspection of the table of means for the latter interaction (Table 3-1) revealed that the overall context effect was absent for one subject group when the verb used was be ($t(38)=1.25$, $p>.1$). (Where they are available and there is no indication in the text to the contrary, one-tailed tests are used throughout.) For this same group the context effect was present and significant when the verb was have ($t(38)=3.86$, $p<.001$). Thus both the significant interactions are explained by the absence of the context effect in one verb category for one subject group.

Another unexpected result appeared in the contrast between the two control context types. Summing across all other conditions, subjects selected singular verb forms in 37% of cases where the control context included you. This decreased to 33% with non-pronominal noun phrases as controls. This difference was significant ($F(1,38)=4.12$,

TABLE 3-1

EXPERIMENT 1, By-subjects data: Mean numbers of items per cell on which subjects selected singular verb forms. The cell values have a potential range of zero to six.

		Context	
	Verb	Control	Pronoun
Group 1	Be	3.13	1.38
	Have	2.50	1.65
Group 2	Be	1.80	2.13
	Have	2.70	1.68
Overall		2.53(42%)	1.71(29%)

MS_e=1.10, $p<.05$).

To determine whether the observed effects were consistent across various sentence fragments, a by-items analysis was performed using items as the random factor. In this analysis Control Type and Verb were between-items factors since each item appeared on only one level of each factor. The score for each level of the Context factor for each item was the difference between the number of subjects choosing the singular verb form and the number choosing the plural form. This single value, termed a bias index hereafter, is taken as an index of the strength of subject preferences vis a vis the plural verb form. The bias index was used here and in subsequent experiments in part because it simplified computations by eliminating one factor and all its associated interactions from some experimental designs. More importantly, bias indices are more directly related to questions about pronoun effects than are the pairs of separate measures for singular and plural verb forms from which they are derived.

The analysis showed a marked reduction in preference for singular verb forms when <u>they</u> appeared in the first clause of the sentence fragment (see Table 3-2). With control contexts the mean bias index was -3.17, indicating a small overall preference for plural verb form continuations of the fragments. This value changed to -8.58, indicating a significantly stronger preference for plural forms, when <u>they</u> appeared in the first clause ($F(1,44)=28.26$, $MS_e=24.92$, $p<.001$). No other main effect or interaction approached significance. In particular, the Control Type factor was not significant ($F(1,44)<1$), indicating that the difference between <u>you</u> and noun phrase controls that appeared in the by-subjects analysis is not present when the results are expressed in

TABLE 3-2

EXPERIMENT 1, By-items data: Bias scores entered in the table were computed by subtracting the numbers of subjects who preferred a plural verb form from the numbers who preferred a singular form for each sentence fragment. The cell values have a potential range of from -20 to 20 with negative values indicating a preference for plural forms.

	Context	
Control Type	Control	Pronoun
You	-1.75	-8.33
Non-pronominal Noun Phrase	-4.58	-8.83
Overall	-3.17	-8.58

terms of bias indices instead of numbers of subjects preferring singular verb forms.

To obtain a nonparametric test of the main effect, the items were categorized according to whether they showed a bias to singular or plural verb forms in the two Context conditions (counting 0 as a bias to singular). On this analysis 14 items changed bias between the control and pronoun context conditions and 34 did not. All of the changes were in the direction of a bias to plural forms. This difference is significant by a χ^2 test (χ^2=12.07, df=1, $p<.001$)(Siegel, 1956, pp. 63-67). Subjects preferred plural forms for 29 items (60%) with a control context. This increased to 43 items (90%) with they in prior context.

3.2.5 Discussion. The general result of Experiment 1 is that there is a significant increase in preference for plural verb forms when they is present in prior context. Since the choice between singular and plural verb forms is directly linked to the choice between alternative interpretations of the ambiguous phrase, the shift toward plurals also indicates a shift toward the plural noun phrase reading in the presence of they. Overall these results indicate that the procedures that select antecedents for cataphoric instances of they are able to influence the procedures that select a syntactic analysis for an ambiguous expression such as flying planes.

3.3 Experiment 2: Next-word naming task

While Experiment 1 demonstrates an effect of they on preferences, it cannot distinguish between an effect which emerges during initial presentation and processing and an effect which arises as the result

of some post-presentation decision-making process. Thus the next-word naming task employed by Tyler and Marslen-Wilson (1977) is a natural complement to the judgement task used in Experiment 1 since it yields measures of events that intervene between the presentation of the ambiguous expression and production of the verb which follows it. If the changes in preference demonstrated in Experiment 1 appear as soon as the alternative analyses of the ambiguous phrase are constructed, then the pronoun-induced bias should be evident in reaction time (RT) data from the naming task. If, however, the bias arises only after input has been evaluated, no effect should appear.

3.3.1 Subjects. Twenty-two Queens College undergraduates volunteered to participate in the experiment and each was paid $2.00 for his or her services.

3.3.2 Materials and design. In so far as the transition from the judgement task to the next-word naming task allows, the materials for Experiment 2 were identical to those for Experiment 1 (see Appendix). Each of the two presentation versions of the materials served as the script for a materials tape for Experiment 2. Of course, the verb choices which were printed below the fragments for Experiment 1 were delected from the tape recorded versions. Again the systematic contrast between the two materials sets lay exclusively in the presence of they on one tape where its control appeared on the other. Since the intonation pattern applied to ambiguous expressions of the kind used here can have marked effects upon syntactic interpretation (cf., breeding pigeons with stress on the first vs. the second word) an attempt was made to read the fragments with neutral intonation. More

rigorous control of intonation was left for Experiment 3.

Two sequences of slides were prepared with each slide bearing a single word. This was always is, are, has, or have. Since corresponding items on the two presentation lists used in Experiment 1 always appeared with the same pair of verb forms, that same sequence of verbs was used for Experiment 2. The difference between the two slide sequences was simply that where one used a singular verb form, the other used a plural form. The slide sequences were pseudorandomly ordered so that each verb form appeared equally often in each sequence.

The design of Experiment 2 paralleled that of Experiment 1 except that subjects were placed in four groups according to which of four materials conditions they were exposed to.

3.3.3 Procedure. Subjects were seated before a darkened enclosure which incorporated the translucent viewing screen of a projection tachistoscope and a microphone. The screen was about .56m away from the subject. The image was projected from behind the screen. The subject rested his or her head against the enclosure in such a way that the field of view was limited to events relevant to the experiment. The subject also wore a headset.

Sentence fragments were presented to subjects over the headset. At the offset of each fragment an inaudible tone on the materials tape started a digital millisecond timer and simultaneously opened the shutter of the tachistoscope, which displayed one of the word slides. As soon as each word slide appeared, the subject read aloud the word shown. The subject's phonation operated a voice-activated relay which stopped the timer. The experimenter recorded the time displayed, and

advanced the slide. To insure that subjects attended to the sentence fragments, they were also asked to decide whether the verb presented made a good continuation of the preceding fragment and to press a "yes" or "no" button on a small console to indicate their decision. These responses were not recorded. Less than 10 seconds elapsed between the offset of one trial and the onset of the next. The 72 trials were run without interruption.

The instructions consisted of a simple description of the sequence of events on a typical trial of the experiment. Subjects were told to listen carefully to each sentence fragment and to speak each visually presented word clearly and loudly as soon as it appeared.

3.3.4 Results. The results from each subject were divided into 16 categories. Eight categories were those determined by the three factors, Context, Control Type, and Verb. Within each of these eight categories, subjects in Experiment 1 were presented with six fragments. For Experiment 2 three members of each set of six were presented with a singular verb and three with a plural verb. Thus each of the 16 RTs per subject was the mean of three RTs. Within each of the eight cells of the analysis the mean RT obtained for the fragments presented with a plural verb was subtracted from the mean RT obtained with singular verbs. The resulting eight bias (or difference) scores per subject were the values used in subsequent analyses. The data from six subjects were excluded from the analysis.[1] The three within-subjects factors were crossed by a Groups factor with subjects nested under Groups. The four levels of Groups were related to the various materials sets to which subjects were exposed.

For all subjects, when an individual score lay more than two standard deviations above the subject's mean, the score was reduced to that criterion value. Less than four percent of all scores were affected by this adjustment. Approximately three percent of the raw scores were missing due to equipment failure, experimenter error and other difficulties.

Overall there was a marked tendency for reaction times to plural verb forms to be shorter than those for singular forms. The implications of this tendency will be considered below.

The central finding of Experiment 2 is that the general advantage of plural over singular verb forms was significantly greater when they was present in prior context (see Tables 3-3 and 3-4). That is, while reaction times to plural forms were nine msec. faster than those for singular forms when a control context was used, this difference grew to 52 msec. when they was present, an increase of 44 msec. ($F(1,15)=6.32$, $MS_e=.01$, $p<.05$). This effect is hereafter termed the pronoun bias effect (PBE). This difference was evident in the results of 12 of the 16 subjects ($p=.01$ by the sign test) and in all four of the cell means determined by the interaction of the Control Type and Verb Type factors. Apart from a non-significant tendency for the difference scores obtained with have to be smaller than those obtained with be, no other main effects or interactions achieved or approached significance. In particular, the difference between the two control types did not yield a significant interaction with Context ($F(1,15)<1$, $MS_e=.01$)(see Table 3-3).

A preliminary by-items analysis revealed large differences in the mean reaction times obtained from the four subject groups (i.e., from

TABLE 3-3

EXPERIMENT 2, By-subjects data in milliseconds: Bias values were obtained by subtracting mean RTs obtained with plural verbs from those obtained with corresponding singular verbs. The values in the Pronoun Effect column were obtained by subtracting mean RTs obtained with Control contexts from those obtained with they in prior context.

Control Type	Verb	Verb Type	Context		Pronoun Effect
			Control	Pronoun	
You	Be	is	638	666	28
		are	611	596	-14
		Bias	27	70	
	Have	has	646	684	38
		have	673	647	-26
		Bias	-27	37	
Non-Pronominal Noun Phrase	Be	is	644	665	22
		are	619	588	-31
		Bias	25	78	
	Have	has	665	663	-2
		have	657	638	-19
		Bias	9	25	

TABLE 3-4

EXPERIMENT 2, By-subjects data in milliseconds: The bias values were obtained by subtracting the mean RT for plural verbs from the mean RT for singulars in the same column. Pronoun effect values were obtained by subtracting each mean RT value in the Control column from the corresponding value in the Pronoun column. (Due to rounding, all of the bias and effect values shown depart from the values expected, given the mean RT values shown, by ± 1 msec.)

	Context		
Verb Type	Control	Pronoun	Pronoun Effect
Singular	648	670	21
Plural	640	617	-22
Bias	9	52	

the subjects assigned to the four materials conditions), with group means ranging from 582 msec. to 710 msec. Since each of the four means obtained for each fragment was provided by a different subject group, overall differences between the groups could seriously obscure effects of the experimental manipulations. For this reason, the values that formed the basis of the by-materials analysis were standard scores based upon the mean and standard deviation of the 48 item means for each group of four subjects. Since the standard scores for all groups had identical means and standard deviations, all irrelevant between-group differences were eliminated. However, the effects of all experimental manipulations could still be observed in terms of relative departures from the group mean. As with the by-subjects analysis, the item mean obtained with each plural form was subtracted from the corresponding item mean obtained with the singular form and the resulting bias values entered into subsequent analyses. Again there was an overall tendency for RTs with plural forms to be faster than those with singular forms.

The critical results of the by-items analysis parallel those of the by-subjects analysis. With control contexts singular verbs were read two msec. faster than plurals, while plurals were read 49 msec. faster than singulars when <u>they</u> appeared in prior context. This shift was significant ($F(1,44)=5.43$, $MS_e=.01$, $p<.05$) but appeared in the results for only 28 of 48 fragments ($p=.10$ by the sign test). The failure of <u>they</u> to shift the bias of 20 items apparently reflects the size and direction of the bias these items showed in the neutral condition. Post-hoc analyses suggested that those items for which RT to a plural verb was much shorter than RT to a singular verb in the control

context condition were relatively unlikely to show any shift in bias under the influence of they. This question is considered in more detail in Section 3.4.5 below. As with the by-subjects analysis, there was a non-significant tendency for bias indices obtained with have to be smaller than those obtained with be. No other main effects or interactions approached significance. The interaction between Control Type and Context was again insignificant ($F(1,44)<1$, $MS_e=.01$).

A further by-subjects analysis of variance was performed in order to assess the pronoun effects shown in Table 3-4. This analysis was based on raw millisecond RTs instead of the bias indices used in the analyses reported above. The design for this analysis included a Verb Type factor which replaced each of the bias indices used in the previous analysis with a pair of RT values, one for trials using singular verbs and another for plural verb trials.

On this analysis the Verb Type by Context interaction was significant ($F(1,12)=5.92$, $MS_e=5182$, $p<.05$). Two-tailed t-tests using error terms derived from the ANOVA indicated that the Context effect did not achieve significance with either singular or plural verbs ($t(12)=1.69$ and $t(12)=1.78$, respectively, $p>.1$ in both cases). Thus while the interaction indicates a significant PBE, this effect arises approximately equally from inhibition of responses to singular verbs with pronoun prior contexts and from facilitation of plural verbs in the same contexts.

This analysis provided a further confirmation of the PBE by way of the main effect of the Verb Type factor. On average, RTs to singular verbs were slower than those to plural verbs (659 and 628 msec., respectively). Though this effect was significant

($F(1,12)=11.81$, $MS_e=5048$, $p<.01$), the singular/plural contrast was far larger on the Pronoun level of the Context factor than on the Control level (see Table 3-4). Using error terms derived from the ANOVA, the singular/plural contrast was assessed by way of t-tests on each level of the context factor. These reveal that while the singular/plural contrast was significant with Pronoun contexts ($t(12)=3.60$, $p<.01$, two-tailed) this contrast did not approach significance in the control context condition ($t(12)<1$).

There were other significant factors and interactions, but none of these appear to be relevant to the theoretical questions at issue. See Note 2 for details.

3.3.5 Discussion. The results of Experiment 2 show that the context effect observed in Experiment 1 is also evident in RT measures with the same materials. Apparently those factors that affected preferences for verb forms are engaged within the interval between the offset of a sentence fragment and the onset of the subject's response. This experiment provides no reliable evidence that this effect is sensitive to either the type of control or the verb type used.

There is also no reliable evidence on the facilitation/inhibition question. Table 3-4 indicates, however, that the obtained PBE results about equally from facilitation of plural verbs and inhibition of singular verbs with *they* in prior context.

3.4 Experiment 3: Next-word naming task with control for intonation

Experiment 2 was potentially deficient in one important respect. Since a different recording of each sentence fragment was used in the control context and *they* conditions, it may be that the obtained

effects arise from differences in intonation that biased listeners toward particular interpretations of the ambiguous phrase.

Experiment 3 used a cross-recording technique to control for intonation effects and obtained measures on many more materials items within each experimental condition.

3.4.1 Subjects. Twenty-four Queens College undergraduates participated in the experiment and each was paid $2.00 for his or her services.

3.4.2 Materials and design. The materials for Experiment 3 were very much like those for Experiment 2 except that the Control Type and Verb factors were eliminated from the design (see Appendix). The control contexts used were non-pronominal noun phrases throughout and the verb used in the naming task was always is or are. Given the evidence of the by-items analysis of Experiment 1 (that the context effect is weaker with nonpronominal noun phrase controls) this was the stronger test of the hypothesis. The control you also may suggest a subject for the nominal reading of the VERBing NOUNs expression (see Section 2.3.2). This might produce an unwanted bias against the plural noun phrase reading in the control case.

The design included one experimental factor, Context (pronoun present in prior context, or absent). This was crossed by a Subject Groups factor required for counter-balancing the materials.

Control of intonation was achieved by making a single tape recording bearing both versions of each sentence fragment. Thus, this master tape included a sequence of the form shown in (5a) for each item on the materials list (neglecting fillers).

(5) (a) Context clause with non-pronominal noun phrase subject/VERBing NOUNs expression//Context clause with subject they/VERBing NOUNs expression

(b) As the birds soar gracefully above the field/flying kites//As they soar gracefully above the field/flying kites

Two copies of the master tape were made. Each of these was edited to yield one of the two sets of experimental materials. On each copy a different version of the context clause was retained in the final tape. However, on both copies the same version of the ambiguous phrase was retained. This was always the version that had been recorded with they present in prior context. Thus all subjects heard exactly the same phonetic rendition of each ambiguous phrase. The materials tapes also included 40 filler sentence fragments of diverse types. Again two slide sequences were prepared such that one used a singular form where the other used a plural, and vice versa.

3.4.3 Procedure. The same procedure and instructions were used in Experiment 3 as in Experiment 2 except that the 80 trials were run in two blocks of 40 each. The practice session was extended to 20 trials.

3.4.4 Results. The 40 measurements obtained from each subject were divided into four categories determined by the intersection of the Context condition with two verb forms. Means were computed within each of these categories and the resulting four means were the basis of further by-subjects analysis. Within each level of the Context condition the mean RT obtained with the plural verb was subtracted from that obtained with the singular verb. Thus each subject was represented by

two bias scores in the anlysis of variance, each based on 20 RTs.

As with Experiment 2, there was an overall tendency for RTs to plural forms to be faster than to singulars. The principal finding of Experiment 3 is, however, that the advantage of plural over singular forms increased from 11 msec. with Control contexts to 60 msec. in the presence of Pronoun contexts, i.e., they (see Table 3-5). This increase of 49 msec. was significant ($F(1,20)=13.39$, $MS_e=.002$, $p<.005$). The prédicted pattern appeared in the results from 19 of the 24 subjects ($p=.001$ by the sign test).

There were unexpected significant differences among subject groups ($F(3,24)=3.69$, $MS_e=.007$, $p<.05$). This reflected the fact that for one group the mean bias indices indicated an overall 98 msec. advantage for plural verbs while another group showed a 12 msec. advantage for singulars. Both of these groups showed the predicted main effect for Context.

A second unexpected result appeared in the interaction between the Context and Groups factors. The interaction was significant ($F(3,20)=5.99$, $MS_e=.002$, $p<.005$), reflecting, in part, the fact that in one subject group the overall effect of context was reversed (Table 3-6). All of the five subjects that did not show the context effect were in this one group. In this instance there was no difference between the results with singular and plural forms in the presence of they and a 38 msec. advantage for plurals with control contexts. The significant interaction term, however, was due to other comparisons which were consistent with the predicted pattern.

The by-items analysis showed the same pattern as the by-subjects analysis, though the context effect was weaker ($F(1,36)=5.30$, $MS_e=.01$,

TABLE 3-5

EXPERIMENT 3, By-subjects analysis: Mean RTs in milliseconds. The values in the Pronoun Effect column were obtained by subtracting each value in the Control column from the corresponding value in the Pronoun column. The Bias values were obtained by subtracting each are value from the corresponding is value.

	Context		
Verb Type	Control	Pronoun	Pronoun Effect
Is	682	720	38
Are	671	660	-11
Bias	11	60	

TABLE 3-6

EXPERIMENT 3, By-subjects bias data in milliseconds showing the interaction between Context and Groups factors: The bias values shown for each group in each context condition result from subtracting the mean RT obtained with the probe *are* from the mean RT obtained with *is*. Positive bias values indicate that subjects responded faster to *are* than to *is*. The PBE values were obtained by subtracting each Control bias value from its corresponding Pronoun bias value. The PBE values show how much the advantage of *are* over *is* is increased (or decreased, where the value is negative) going from the Control to the Pronoun context condition.

	Context		
Subject Group	Control	Pronoun	Pronoun Bias Effect
Group 1	-43	18	61
Group 2	11	63	52
Group 3	37	159	122
Group 4	38	0	-38

$p<.03$). The general pattern appeared in the results for 26 of the 40 sentence fragments ($p=.02$ by the sign test). There was an unexpected significant interaction between the Groups factor and Context ($F(3,36)=2.99$, $MS_e=.01$, $p<.05$). In one block of fragments only four of ten showed the predicted pattern, and thus the context effect was reversed in this cell (Table 3-7).

The unexpected interactions that appeared in both the by-subjects and by-items analyses of Experiment 3 are considered further in Section 3.4.5 below.

A further by-subjects analysis of variance was done using the millisecond RTs rather than the bias indices in order to partition the PBE observed above into its facilitation and inhibition components. Thus each bias index from the analysis discussed above was replaced by the two RT values from which it was computed. The ANOVA included a Verb Type factor (_is_ vs. _are_) to accomodate this change.

In this analysis the interaction between Context and Verb Type was related to the PBE. This interaction (paralleling the main effect of Context in the foregoing analysis) was significant ($F(1,20)=13.30$, $MS_e=.001$, $p<.005$). There was no main effect of Context ($F(1,20)=4.07$, $MS_e=.001$, $p<.1$), which indicates only that the 13 msec. difference in column means in Table 3-5 is not reliable. However, testing Context separately for _is_ and _are_ reveals a significant 38 msec. increase in RT to _is_ with Pronoun contexts ($t(20)=4.00$, $p<.001$). The 11 msec. decrease in RT to _are_ in Pronoun contexts is not significant ($t(20)=1.16$).

The main effect of Verb Type was also significant ($F(1,20)=8.61$, $MS_e=.004$, $p<.01$) indicating that (as in Experiment 2) RTs to _are_ were

TABLE 3-7

EXPERIMENT 3, By-items bias data in arbitrary standard score units showing the interaction between Context and Materials Groups factors: The bias values shown for each materials group in each context condition result from subtracting the mean standard score value obtained with the probe *are* from the mean standard score value obtained with *is*. Positive bias values indicate that subjects responded faster to *are* than to *is*. The Pronoun Bias Effect values show how much, in standard score units, the advantage of *are* over *is* increased (or decreased, where the value is negative) going from the Noun Phrase Control context to the Pronoun context condition. The millisecond values from which the values in this table are ultimately derived are shown in Table 3-8.

Materials Group	Context		Pronoun Bias Effect
	Control	Pronoun	
Group A	-.024	.081	.105
Group B	-.022	.129	.150
Group C	.094	.058	-.036
Group D	.046	.055	.009

TABLE 3-8

EXPERIMENT 3, By-items summary of millisecond data: Mean RTs organized by materials groups. The values in the Pronoun Effect column were obtained by subtracting each value in the Control column from the corresponding value in the Pronoun column.

Materials Group	Verb Type	Context		Pronoun Effect
		Control	Pronoun	
Group A	Is	584	808	224
	Are	715	678	-37
Group B	Is	729	689	-40
	Are	629	646	17
Group C	Is	742	625	-116
	Are	634	697	63
Group D	Is	673	761	88
	Are	690	604	-86
Overall	Is	682	721	39
	Are	667	656	-11

generally faster than RTs to is (see Table 3-5). However, when the is/are contrast is tested separately on each level of the Context factor, only the 60 msec. difference with Pronoun contexts is significant (for Control contexts $t(20)=.79$, while for Pronoun contexts $t(20)=4.34$, $p<.001$). These results simply mirror the results of the analysis on bias indices.

The unexpected interaction between Groups and Context in the analysis of bias indices appeared in this analysis as a significant three-way interaction among the Groups, Context and Verb Type factors ($F(3,20)=5.99$, $MS_e=.001$, $p<.01$). Table 3-9 suggests that this interaction arises from the results obtained for one subject group. The source of the group differences indicated by these results will be considered in relation to the bias index analysis in the next section.

3.4.5 Post-hoc analysis. Post-hoc analyses revealed a probable cause for the unexpected interaction that appeared in both the by-subjects and by-items ANOVAs. Of the 40 experimental sentences, there were 16 that showed a bias to is with Control contexts (i.e., with no pronoun present, RTs were shorter for is than are). Among the 24 cases biased to are in control contexts there seems to be a kind of ceiling effect at work. If there is a large difference between RTs to is and are without a pronoun in prior context, there is little chance that this difference will increase when a pronoun is present. Apparently, a large contrast between is and are in control contexts eliminates, reduces or at least masks any further effect attributable to the pronoun.

Note that the issue here is the total size of the difference

TABLE 3-9

EXPERIMENT 3, By-subjects analysis: Mean RTs in milliseconds organized by subject groups. The values in the Pronoun Effect column were obtained by subtracting each value in the Control column from the corresponding value in the Pronoun column.

Subject Group	Verb Type	Context		Pronoun Effect
		Control	Pronoun	
Group 1	Is	586	622	36
	Are	629	604	-25
Group 2	Is	726	762	36
	Are	715	699	-16
Group 3	Is	742	808	66
	Are	704	649	-55
Group 4	Is	675	689	14
	Are	637	689	52

between mean RT to _is_ and _are_. This issue is not to be confused with the question whether changes in the size of this difference, going from Control to Pronoun contexts, arise by way of RT to _is_ becoming slower or RT to _are_ becoming faster. The suggestion here is simply that if _are_ is a great deal faster than _is_ with a Control context, the chances will be small that this difference will be greater with Pronoun context, regardless of whether the effect of the pronoun is to slow responses to _is_ or speed responses to _are_.

Several statistical tests support this analysis. Of the 16 sentences biased to _is_ with Control contexts, 14 show the PBE. However, of the 24 initially biased to _are_, only one half show the effect. This difference is significant by Fisher's exact test ($p=.02$). Table 3-10 shows the number of items in each materials group that showed an initial bias to _is_ and, in the second column, the number of items showing the PBE in that group. Though there appears to be a strong linear relation between the two columns in this table ($r^2=.94$), this relation is not statistically significant. The observed differences between the numbers of items initially baised to _is_ and _are_ for various materials groups are, nonetheless, relevant to the unexpected effects reported above. Furthermore, since each subject group saw each materials group in only one experimental condition, this difference between materials groups also has implications for the results from various subject groups.

It is also possible to assess the relation between the bias of items in the Control condition and the strength of the obtained PBE by way of an analysis of covariance (ANCOVA). For these purposes the results for each sentence fragment were reduced to two values.

TABLE 3-10

EXPERIMENT 3, Post-hoc analysis of materials bias effects: There were ten sentence fragments in each of the Materials Groups A - D. The first column of the table shows the number of items that were biased toward the gerundive nominal reading of the VERBing NOUNs expression in each group of ten when the control context appeared in the first clause. The number in the second column is the number of items showing the pronoun bias effect in the same group.

Materials Groups	Items Biased Toward Is	Items Showing the Pronoun Bias Effect
Group A	6	8
Group B	6	9
Group C	1	4
Group D	3	5

The first of these values was a "bias index," a single value that measures the average relative preference for is or are. This value is obtained for a given item by subtracting mean RT to are from mean RT to is, both expressed in standard score units. Thus, positive bias values indicate that subjects read are faster than is. The original four mean RTs for each item were reduced to two bias values, one for the control condition and one for the experimental condition. For the purposes of the ANCOVA, the bias value for the control condition for each item was taken as an index of the inherent bias of the item, the degree to which intrinsic properties of the item predisposed listeners to prefer is or are as a continuation. Thus the covariate for each sentence fragment was its bias index for the control condition.

The second value representing each materials item was an "effect index" obtained by taking the difference between the two bias values for the item. This difference essentially measures the extent to which introducing they into the first clause of the item changed subject preferences for is and are. Positive effect values indicate an increased preference for are. The effect index for each item served as the variate for the ANCOVA.

The ANCOVA provides an adjustment to the average effect index for each materials group (see Table 3-11). It also reveals that there was a significant difference in the effect indices obtained in various materials groups ($F(3,36)=2.99$, $MS_e=.02$, $p<.05$). This essentially replicates the interaction between Materials Groups and Context reported for the by-items analysis in Section 3.4.4. However, when the analysis of effect means is adjusted for bias, the significant

TABLE 3-11

EXPERIMENT 3, Post-hoc analysis of covariance results: The number in the Bias Mean column for each Materials Group is the difference between RT to the probe *is* vs. the probe *are* expressed in arbitrary standard score units, as measured in the Control context condition. Negative values mark those groups where the items were, on average, biased toward *is*. The numbers in the Effect Mean column represent the experimental effect for the same materials. This value is the difference between the bias value shown in the first column and a similar value computed for the experimental condition with the pronoun in prior context. Positive values in this column mark those groups where, on average, the pronoun in prior context produced a shift in favor of the plural noun phrase reading of the VERBing NOUNs expression (cf., Table 3-7). The values in the Adjusted Effect Mean column represent the same quantities after they are adjusted according to the outcome of an analysis of covariance using the Effect Mean as the variate and the Bias Mean as the covariate for each item. Thus, the values in the last column approximate what the values in the second column would have been had the values in the first column been uniform. The means of the millisecond values from which the values in this table are ultimately derived are shown in Table 3-8.

Materials Group	Bias Mean	Effect Mean	Adjusted Effect Mean
Group A	-.024	.105	.0595
Group B	-.022	.150	.1068
Group C	.094	-.036	.0312
Group D	.046	.009	.0306

effect of the Materials Groups factor disappears ($F(3,35)<1$, $MS_e=.01$). This analysis indicates that most of the variation in the effect produced by they in various materials groups can be explained by variations in the inherent bias of the materials, as measured by the results obtained in the control condition. In other terms, variations in the size of the effects obtained with individual items were highly correlated with the inherent bias of the items ($r^2_{between}=.93$).

Similar post-hoc analyses of the data from Experiment 2 produced similar results.

3.4.6 Discussion. Experiment 3 replicates the pronoun bias effect and demonstrates that the effect observed in Experiment 2 cannot be attributed to varying intonation patterns on the ambiguous phrases. In Experiment 3 intonation patterns were identical across the two tapes. Indeed, the effects observed in the presence of the control for intonation are larger than those observed previously.

Taken together, Experiments 2 and 3 support the claim that cataphoric instances of they can markedly affect the interpretation assigned to expressions such as flying planes when the pronoun is appropriately positioned in prior context. Furthermore, these experiments demonstrate that these effects emerge immediately after presentation of the ambiguous expression.

Post-hoc analyses indicate, however, that the presence of the pronoun in prior context cannot increase differences in RT to is and are if the difference is already large and in favor of are.

The results of Experiment 3 contradict those of Experiment 2 in only one respect. In Experiment 2 the PBE resulted about equally

from facilitation of RTs to plural verbs and inhibition of RTs to singular verbs, neither effect being independently significant. However, in Experiment 3 the PBE appears to result largely from inhibition of RTs to is. Here less than one quarter of the increased difference between RT to is and are with Pronoun contexts is contributed by facilitation of are. Furthermore, the inhibition component is independently significant and the facilitation component is not.

3.5 Experiment 4: Naming task with disrupted coreference

Section 3.1.1 introduced the preliminary notions of a scanner that seeks a referent for an arbitrary pronoun like they and a selector that resolves ambiguities arising from syntactic structure, as with VERBing NOUNs expressions. In terms of these hypothetical entities, the results of Experiments 1 - 3 show that the scanner can interact with the selector. When one but not both of the interpretive options available to the selector will help resolve a reference problem for the scanner, this fact seems to influence the selector's decision in favor of the interpretation that will be most useful to the scanner, at least in the limited range of cases considered here.

As noted in Chapter 2, there are many factors that can ultimately influence the choice of a referent for they in cases like (1). Given this, the question arises whether the scanner is able to take account of all of these factors at the moment when it exerts its influence on the selector. Thus, the purpose of Experiment 4 is to assess the roles of three particular kinds of information in the scanner's decision. The materials discussed in the next section are designed to distinguish the contributions of the listener's knowledge of logical form,

selection restrictions and the practical properties of familiar real-world entities. The results of Experiment 4 will be of particular relevance to the autonomy question because the variety of information available to the scanner should indicate whether it is relatively modular and specialized or able to accept diverse influences on a more or less equal footing.

The strategy of the experiment is based on the observation that some of the factors that can influence the reference of they can be used to block or inhibit possible coreference relations. Given this, it is possible to construct pairs of sentence fragments similar to (1) in which one member permits a coreference relation between they and a following VERBing NOUNs expression while the other minimally distinct member of the pair will not permit the same relation. Differences in performance evident with the two fragments should indicate whether the kind of information that is used to interfere with the coreference relation is considered by the scanner when it interacts with the selector.

Apart from the more complex materials set, the form of Experiment 4 was much like Experiment 3.

3.5.1 Materials. The sample materials in (6) - (8) illustrate three ways of interfering with the potential coreference relation between they and a following VERBing NOUNs expression. In each pair, the fragment labeled a permits the coreference relation and the fragment labeled b interferes with it.

(6) (a) If they want to save money, visiting uncles...
(b) If they want to believe that visiting uncles...

(7) (a) Even though they use very little oil, frying eggs...
(b) Even though they eat very little oil, frying eggs...

(8) (a) Whenever they smile during the procedure, charming babies...
(b) Whenever they lecture during the procedure, charming babies...

Coreference is blocked by principles of logical form in (6b) because they c-commands visiting uncles, which is an R-expression and therefore free (see Chapter 2, especially Section 2.2, for further discussion and definitions of technical terms used in this section). This allows the rule of Disjoint Reference to apply between visiting uncles and they. In (6a) neither visiting uncles nor they c-commands the other. Thus the Disjoint Reference rule cannot relate these two noun phrases and they are potentially coreferential in (6a). In (7b) the relation is much less direct. Eat takes animate subjects and thus the they in this fragment seems to acquire the property of animacy via the verb. This renders (7b) anomalous with coreference between they and frying eggs in the same way that The egg ate the oil is anomalous. The relevant linguistic principles are selection restrictions. In (8b) there is a problem arising from pragmatic or real-world knowledge; it seems unlikely that charming babies will be found lecturing during any procedure.

With all three types of material the essential assumption is that the first member of each pair permits (but does not require) assignment of a coreference relation between they and the VERBing NOUNs expression and will show the PBE demonstrated in Experiments 1 - 3. The second fragment will be in some way anomalous if the same coreference assignment is made. Pairs such as (6) will be referred to

as LF cases, pairs such as (7) as selection cases, and pairs such as (8) as pragmatic cases. The b member of each pair will be termed anomalous and the a form nonanomalous.

The materials in the non-anomalous cases were designed to conform to the formula given in (9a) and exemplified in (9b).

(9) (a) (Initial subordinating conjunction)(Subject noun phrase)(Verb phrase), (VERBing NOUNs expression)...
(b) (If)(they)(want to save money),(visiting uncles)...

Distinctions between the three anomaly types were always produced by alternations in the verb phrase. The LF cases have nonanomalous verb phrases including VERB+NOUN or VERB+ADJECTIVE sequences. The anomalous fragments were produced by replacing these verb phrases with VERB+that sequences where the verbs accept that-complements. Both the selectional and pragmatic cases were based on single-word verb substitutions in the subordinate clause. In the anomalous selection cases the verb in the subordinate clause selects for either (+HUMAN) or (+ANIMATE) subjects and the VERBing NOUNs expression is (-HUMAN) or (-ANIMATE), respectively. All of the selection cases for this experiment turn on the use of these same two features. The pragmatic anomalies arise because, when they is taken as coreferential with the VERBing NOUNs expression, the fragment attributes something unlikely to the referent of the VERBing NOUNs expression, e.g., keys suppressing noise, babies lecturing, etc. These cases may be analyzed by reference to features such as (± ADULT) or (± MATURE). The practical difference between the latter features and those mentioned in connection with the selection cases is simply that the latter did not figure in the account of selection restrictions in Chomsky (1965)(see Chapter 2 for further

discussion).

Certain additional structural constraints were imposed in order to rule out various possible confounding variables. The appendix includes a listing of these additional constraints and lists all of the materials for Experiment 4.

Each materials type was represented by 24 items, with each item based on one VERBing NOUNs expression. Four sentence fragments using the same VERBing NOUNs expression were defined by the interaction of two pairs of alternating elements: they vs. its control (you) and the alternation in the verb phrase that produced the anomalous form. Using you as the control noun phrase made the materials somewhat easier to construct.

The four versions of each materials item were distributed among four materials sets. Each materials set contained equal numbers of items representing each anomaly type and equal numbers of the four forms that items could take. In brief, the four materials sets were fully counterbalanced.

Mixed with the 72 experimental items in each materials set was an equal number of filler items. There were three types. One third of the fillers included VERBing NOUNs expressions but the fragments were not interrupted until one or more words beyond this expression. Another third of the fillers were interupted immediately after a VERBing NOUNs expression but the probe verb associated with these items was never a form of be. Finally, one third of the filler items used non-ambiguous VERBing NOUNs expressions. Apart from the specific deviations enumerated above, each filler was designed to resemble the experimental cases as nearly as possible.

3.5.2 Design. The design incorporated three within-subjects factors: Anomaly Type (three levels: LF, Selection, Pragmatic), Anomaly (two levels: assuming coreference between they and the VERBing NOUNs expression, some degree of referential anomaly is either Present or Absent), and Context (two levels: with Pronoun they is present in the subordinate clause and with Control it is not). A between-subjects Groups factor was fully crossed with the preceding three. Each subject was represented in the by-subjects bias analysis by 12 mean bias values, one for each cell of the Anomaly Type by Anomaly by Context interaction. Each of these mean bias values was based on RTs obtained on six trials (apart from cases of missing data). Three of the RTs that went into each bias value were obtained with the probe verb is and three with are. This factor was also crossed with all the others. The mean bias values entered into the ANOVA were obtained by subtracting the mean RT of the are trials from the mean RT of the is trials. A similar approach was applied to the by-items bias analysis except that here the Anomaly Type factor became a between-subjects factor and each materials item was therefore represented by the four mean bias values obtained with its four variants.

For the analysis of millisecond RTs each bias value in the analyses described above was replaced by a pair of RT values representing the two levels of the Verb Type factor, Is and Are. Otherwise, the design was unchanged.

3.5.3 Subjects and procedure. Thirty-six Queens College undergraduates participated in the experiment. The experimental plan called for 40 subjects but scheduling difficulties made this impossible. In

order to have equal numbers of subjects in each materials condition, the data from four subjects were excluded from the analysis. The subjects excluded were selected according to the number of missing scores. Data from two additional subjects were excluded because the experimental sessions were ended early due to equipment failure or experimenter error. All subjects were volunteers recruited from various linguistics and communication courses. Each was paid $4 in partial compensation for his or her participation.

The experimental procedure was the same as in Experiment 3 except that the materials were presented in four blocks of 36 trials each.

3.5.4 Results. A measure of the mean raw pronoun bias effect was obtained by comparing the mean bias obtained with *they* with the mean bias obtained with *you* within each cell of the Anomaly Type by Anomaly interaction (see Table 3-12). The RTs from which these bias values are derived are summarized in Table 3-13. An analysis of variance showed a significant main effect only for the Context factor ($F(1,28)=5.46$, $MS_e=.02$, $p<.05$). One-tailed t-tests using error terms derived from the ANOVA also showed significant Context effects in the LF and Selection Nonanomalous conditions ($t(28)=1.82$, $p<.05$, and $t(28)=1.84$, $p<.05$, respectively) and in the Selection and Pragmatic Anomalous conditions ($t(28)=2.20$, $p<.05$, and $t(28)=2.49$, $p<.01$, respectively). There were no significant differences in the LF Anomalous and Pragmatic Nonanomalous conditions.

These results should be viewed with some caution because the ratio between those cells of the Anomaly Type by Anomaly by Context

TABLE 3-12

EXPERIMENT 4, By-subjects analysis using millisecond data: The values in the Bias columns are means of 24 item bias values obtained by subtracting the are mean for a given cell from the is mean for the same cell. The pronoun bias effect values were obtained by subtracting the Control bias values from the corresponding Pronoun bias values. Large positive values indicate a strong effect. The values in this table are related to the means shown in Table 3-13.

	Anomaly					
	Nonanomalous			Anomalous		
	Context			Context		
Anomaly Type	Control Bias	Pronoun Bias	Pronoun Bias Effect	Control Bias	Pronoun Bias	Pronoun Bias Effect
LF	-5.4	34.9	40.3	3.4	26.5	23.1
Selection	-5.5	35.3	40.8	-7.9	40.8	48.7
Pragmatic	7.2	21.0	13.8	-1.1	54.0	55.1

TABLE 3-13

EXPERIMENT 4, By-subjects analysis using millisecond data: Interaction between Context and Verb Type factors within levels of the Anomaly Type by Anomaly interaction. The values in the Pronoun Effect column were obtained by subtracting values in the Pronoun column from corresponding values in the Control column using more precise values than those shown here.

Anomaly Type	Anomaly	Verb Type	Context		Pronoun Effect
			Control	Pronoun	
Logical Form	Non-anomalous	Is	587	615	28
		Are	592	580	-13
	Anomalous	Is	610	611	1
		Are	607	585	-22
Selectional	Non-anomalous	Is	570	593	23
		Are	576	558	-18
	Anomalous	Is	559	621	62
		Are	567	580	13
Pragmatic	Non-anomalous	Is	592	601	9
		Are	584	580	-4
	Anomalous	Is	573	622	50
		Are	574	568	-5

interaction with the most extreme within-cell variance values is nearly 1:6. Thus, the above results may be distorted by a departure from the assumption of homogeneity of variance. Something nearer to homogeneous within-cell variances was obtained by replacing each subject's millisecond RT bias values with transformed scores based on the mean and standard deviation for that subject on the experimental trials. These standardized scores have a mean of three and a standard deviation of one. These are arbitrary values chosen for the sake of computational convenience.

The Context effect within the cells of the Anomaly Type by Anomaly interaction shows roughly the same pattern with the transformed RTs as appeared with the raw scores (see Table 3-14). However, the relative size of the differences in the two cells that did not show significant differences in the raw RT data is much smaller. That is, evidence of the Context effect nearly disappears in both the LF Anomalous condition and the Pragmatic Nonanomalous condition. An ANOVA on the transformed RTs showed a significant effect only for the Context factor ($F(1,28)=5.20$, $MS_e=.77$, $p<.05$). One-tailed t-tests using error terms derived from the ANOVA showed significant Context effects in the LF ($t(28)=1.79$, $p<.05$) and Selection ($t(28)=2.50$, $p<.01$) Nonanomalous conditions. Smaller differences appeared in the Selection ($t(28)=1.49$, $p<.10$) and Pragmatic ($t(28)=1.65$, $p<.10$) Anomalous conditions. The Context effect in the LF Anomalous and Pragmatic Nonanomalous conditions did not approach significance. The Context effect was significant in the Pragmatic Anomalous condition according to a one-tailed t_{pair} test ($t_{pair}(32)=1.72$, $p<.05$).

There are two concerns about the results of Experiment 4 that

TABLE 3-14

EXPERIMENT 4, By-subjects analysis using standard scores transforms of millisecond data: The values in the Bias columns are means of 24 item bias values obtained by subtracting the are mean for a given cell from the is mean for the same cell. The PBE values were obtained by subtracting the Control bias values from the corresponding Pronoun bias values. Large positive values indicate a strong effect.

	Anomaly					
	Non-anomalous			Anomalous		
	Context			Context		
Anomaly Type	Control Bias	Pronoun Bias	Pronoun Bias Effect	Control Bias	Pronoun Bias	Pronoun Bias Effect
Logical Form	-.0146	.2760	.291	.0512	.0678	.017
Selection	.1053	.5119	.407	-.0446	.1987	.243
Pragmatic	.1896	.1867	-.003	.0687	.3382	.270

the by-subjects analyses reported above cannot resolve. First, the overall pattern of results may be determined by relatively few atypical examples among the materials. Second, as was demonstrated in the discussion of Experiment 3, the PBE is sensitive to the inherent bias of the materials within which the pronoun alternation is implemented. Thus it would be useful to correct for bias in the various cells of the Anomaly Type by Anomaly interaction. Note that the by-items analyses reported below are not intended to assess prospective generalizations to any linguistic population.

The by-items ANOVA on the transformed bias data yielded results similar to those obtained on the by-subjects tests reported above. Only the Context factor was significant ($F(1,69)=7.31$, $MS_e=.34$, $p<.01$). One-tailed t-tests using error terms derived from the ANOVA showed significant Context effects in the LF ($t(69)=1.73$, $p<.05$) and Selection ($t(69)=2.45$, $p<.01$) Nonanomalous conditions. The same contrast in the Pragmatic Anomalous condition was not significant ($t(69)=1.45$, $p<.1$).

Sign tests indicated that the PBE appeared with 19 of 24 sentence fragments in the LF Nonanomalous condition (see Table 3-15). This proportion is significantly larger than .5, ($p=.003$). In the Anomalous condition 12 sentences showed the PBE and 12 did not. A χ^2 test, with the Yates correction (Siegel, 1956, pp. 63-67) indicates that the shift between the Nonanomalous and Anomalous conditions was significant ($p<.025$, one-tailed). In the Selection condition the proportion of sentence fragments showing the PBE in the Nonanomalous condition, 18 of 24, was also significantly larger than .5, $p=.01$, but the χ^2 test did not show a significant change from the Nonanomalous to the

TABLE 3-15

EXPERIMENT 4, By-items sign tests: Each of the six rows of the table partition 24 items into those that did and did not show the PBE. If a given kind of anomaly can interfere with the PBE, then the Nonanomalous row for that type should show an imbalance in favor of the Items Showing PBE column and this imbalance should disappear in the Anomalous row.

Anomaly Type	Anomaly	Items Showing PBE	Items Not Showing PBE
Logical Form	Nonanomalous	19	5
	Anomalous	12	12
Selection	Nonanomalous	18	6
	Anomalous	14	10
Pragmatic	Nonanomalous	11	13
	Anomalous	16	8

Anomalous condition. Sign tests yielded no further significant contrasts, though 16 of 24 fragments showed the PBE in the Pragmatic Anomalous condition, p=.08.

A covariance analysis was used to assess the effects of inherent item bias (cf., Section 3.4.5 above). The results for the 24 fragments at each level of the Anomaly Type factor revealed substantial mean differences in inherent bias (as measured by bias in the Control (you) context condition) across the Nonanomalous and Anomalous cells (Table 3-16). The pronoun effect results are parallel to those reported for the by-subjects analysis (cf. Table 3-12 and 3-14). The pronoun effect values in Table 3-16 correspond to the differences reported in Table 3-12. The covariance analysis showed a significant adjusted pronoun effect for the Anomaly Type factor ($F(2,69)=9.01$, $MS_e=.40$, $p<.005$). Adjusting the pronoun effect measures shown in Table 3-16 according to their respective inherent bias measures, reveals that the pattern of the pronoun effect measures may in fact be substantially distorted by the inherent bias of individual items. Two features of the matrix of adjusted pronoun effect measures are of particular interest. First, there is a substantial change in the value in the Pragmatic Non-Anomalous cell. The change suggests that the PBE may have been present in this condition but was obscured by the inherent bias of the materials. The second interesting change is in the Selection Anomalous condition. Here the adjustment indicates that the unadjusted value probably overstates the size of any PBE that may have appeared in this cell. Pairwise comparisons of the adjusted Anomalous and Nonanomalous pronoun effect cells within various levels of the Anomaly Type factor show significant differences in the LF and Selection conditions

TABLE 3-16

EXPERIMENT 4, Covariance adjustment of the pronoun effect measures: The values in the Inherent Bias columns are mean bias values for the Control context condition. The values in the PBE columns show the difference between the bias values obtained in the Control and Pronoun context conditions, i.e., these values measure the effect of introducing the arbitrary pronoun into the context. The Adjusted Pronoun Effect columns show revised PBE values computed on the basis of an analysis of covariance. Cells in which the pronoun effect worked should show relatively larger negative values.

	Non-anomalous			Anomalous		
Anomaly Type	Inherent Bias	Pronoun Bias Effect	Adjusted Pronoun Effect	Inherent Bias	Pronoun Bias Effect	Adjusted Pronoun Effect
Logical Form	-.015	.2887	.2069	.051	.0322	.0178
Selection	.102	.4100	.4477	-.041	.1977	.0887
Pragmatic	.226	-.0086	.1552	.069	.2418	.2454

($F(1,23)=5.61$, $MS_e=.03$, $p<.05$ and $F(1,23)=10.52$, $MS_e=.03$, $p<.005$, respectively).

As with Experiments 2 and 3, a further by-subjects analysis of variance test was performed on the raw millisecond RTs in order to partition the observed overall Context effect into its facilitation and inhibition components. This analysis revealed significant main effects for Context ($F(1,24)=7.28$, $MS_e=2827$, $p<.05$) and Verb Type ($F(1,24)=8.54$, $MS_e=6422$, $p<.01$), as well as a significant interaction between these two factors ($F(1,24)=5.13$, $MS_e=12764$, $p<.05$). However, as is evident from Table 3-17, these results flow from only some of the pairwise contrasts subsumed under the interaction. In particular, the reduced RT to _are_ in Pronoun contexts is not significant ($t(24)=.81$), though the increase in RT to _is_ in the same contexts is significant ($t(24)=2.88$, $p<.01$). Though the difference between the two verb types is obviously insignificant in Control contexts ($t(24)=.17$), the parallel difference in the Pronoun condition is highly significant ($t(24)=3.92$, $p<.001$). These results indicate that the overall difference between RT to _is_ and _are_ is entirely attributable to the difference in the Pronoun condition and that this difference arises mostly from inhibition of RT to _is_ in the Pronoun context.

There were also unexpected significant interactions, some involving two between groups factors related to the organization of the experimental materials. Subjects were categorized on a Tapes factor according to which of four materials tapes they heard and on a Trays factor according to which of two sequences of probe words they saw. The Tapes by Trays by Anomaly Type by Anomaly interaction was significant ($F(6,48)=2.79$, $MS_e=2809$, $p<.05$) as was the Tapes by Trays by

TABLE 3-17

EXPERIMENT 4, By-subjects analysis on millisecond RTs: The values in the Pronoun Effect column were obtained by subtracting each value in the Control column from the corresponding value in the Pronoun column. Each Bias value is the difference between *is* and *are* values for that column.

Verb Type	Context		Pronoun Effect
	Control	Pronoun	
Is	582	610	29
Are	583	575	-8
Bias	-2	35	

Anomaly Type by Verb Type by Anomaly interaction ($F(6,48)=2.44$, $MS_e=2528$, $p<.05$). The Anomaly Type by Context by Anomaly interaction was also significant ($F(2,48)=3.26$, $MS_e=757$, $p<.05$). A parallel ANOVA used a log transform of the data in order to correct for possible non-normalcy of the distribution of RT values. In this analysis none of the effects reported above in this paragraph achieved significance. The ANOVA on the transformed data also showed a significant interaction between the Anomaly Type and Context factors ($F(2,48)=3.69$, $MS_e=.001$, $p<.05$).

The Anomaly Type factor was significant in the millisecond RT analysis ($F(2,48)=8.46$, $MS_e=3172$, $p<.001$) as well as in the analysis of the log RTs. Though apparently reliable, this effect is of no interest.

3.5.5 Discussion. These results indicate clearly that LF anomalies can interfere with the PBE. The nonparametric tests indicate that there was a strong PBE in the Nonanomalous condition, that this effect disappeared in the presence of anomaly and that the pattern of change from the Nonanomalous to the Anomalous condition was itself significant and in the direction predicted by the assumption that LF anomalies can block or impede the PBE. All of the parametric tests show that the pronoun effect in the Nonanomalous condition is significant at the .05 level. No test shows a significant difference in the Anomalous condition and the covariance analysis shows a significant contrast between the Nonanomalous and Anomalous conditions.

The results in the Selection case are less clear. Parametric tests on the raw RTs show significant pronoun effects in the Anomalous

condition and in the Nonanomalous condition. By contrast, nonparametric tests show a significant pronoun effect in the Non-anomalous condition but not in the Anomalous condition. Similarly, parametric tests on the transformed RTs show no significant Context effect in the Anomalous condition and the covariance analysis shows a significant reduction in the adjusted pronoun effect going from the Nonanomalous to the Anomalous condition. These results suggest that the pronoun effect may have appeared in the Nonanomalous cases and been reduced or eliminated in the Anomalous cases. For the purposes of further discussion, however, it will be assumed that selctional anomalies did not interrupt the PBE. Though this seems to be the most straightforward interpretation of the results obtained here, more conclusive evaluation of the effects of selectional anomalies must await further research.

The Pragmatic results are complicated by the apparent absence of the PBE in the Nonanomalous condition. The results of the covariance test suggest that this unexpected finding reflects a strong advantage for the <u>are</u> reading in the Nonanomalous cases. The alternative interpretation, that there is in fact no pronoun effect, contradicts the overall results of Experiment 4 as well as the results of Experiments 2 and 3. The assumption that the PRE was present but obscured in the Nonanomalous cases also has the advantage of being consonant with the finding that this effect appeared in the Anomalous cases. Here there were indications of a significant difference by every test. Though these data are not conclusive, they provide no support for the view that pragmatic anomalies can impede the PBE.

In overview, the results of Experiment 4 support the claim that

LF anomalies can block the PBE but that Pragmatic anomalies cannot. Selectional anomalies may be able to diminish the PBE, but the present results do not support any firm conclusion.

In terms of the expository framework presented in Section 3.1.1 the results of Experiment 4 indicate that when the scanner interacts with the selector it has made some use of knowledge about the logical form properties of the input, but has not tapped pragmatic knowledge. It may not have used knowledge of selection restrictions either.

The results of Experiment 4 closely parallel those of Experiment 3 in that the overall PBE is clearly the result of an inhibition of RT to <u>is</u>, not the facilitation of RT to <u>are</u>.

Notes for Chapter Three

[1]One subject did not do the task as instructed. The tachistoscope began to behave erratically while another subject was working. Since disturbances related to the equipment problem interrupted the experimental routine, the data from this subject were considered suspect. A third subject was excluded because there were many missing RTs (10 of 48, or 21%). The exclusion of this subject forced the exclusion of three more subjects in order to maintain an equal number in each subject group. The other three excluded subjects were selected at random within the appropriate groups.

[2]The ANOVA on RTs (rather than bias indices) for Experiment 2 showed several unexpected significant effects.

The main effect of Verb was significant ($F(1,12)=7.78$, $MS_e=7849$, $p<.05$), indicating that mean RT to forms of be (628 msec.) was faster than mean RT to forms of have (659 msec.). This difference is, however, almost entirely due to a large difference between RT to is (603 msec.) and the other three verb forms used, which were all in the 653-665 msec. range. An ANOVA using log transforms of the RTs indicated that the Verb by Verb Type interaction was significant ($F(1,12)=6.21$, $MS_e=.002$, $p<.05$).

There was a very neatly patterned interaction among the Control Type, Context and Tapes factors (see Table 3i)($F(1,12)=7.37$, $MS_e=9757$, $p<.05$). Tapes was a between-subjects factor with the two subject groups exposed to one materials tape representing one level and the two groups exposed to the other tape representing the other level. Unfortunately, this interaction is quite unintelligible. Though there was no control for intonation in this experiment, it is difficult to imagine that intonational differences between the materials tapes could produce such tidy contrasts. Yet it is only some unintended

TABLE 3i

EXPERIMENT 2: Mean RTs in milliseconds for the cells of the Control Type by Context by Tape interaction.

Control Type:	you		Noun Phrase	
Context:	Control	Pronoun	Control	Pronoun
Tape				
Tape 1	620	659	654	612
Tape 2	664	638	638	665

contrast in the materials tapes, or some feature of the subjects nested within levels of the Tapes factor that can explain this result.

There were also significant but uninterpretable interactions involving the Tray factor (there were two sequences, "trays," of slides). The interaction among the Tray, Control Type and Verb factors was significant ($F(1,12)=21.80$, $MS_e=1255$, $p<.001$) as was the interaction among the Tray, Verb and Verb Type factors ($F(1,12)=5.61$, $MS_e=6248$, $p<.05$). The ANOVA using the log transform of the raw RT values produced results generally parallel to those of the ANOVA on the raw RT values except that the Verb by Verb Type interaction mentioned above, and the Tape by Tray by Control interaction ($F(1,12)=5.05$, $MS_e=.002$, $p<.05$) were also significant.

Given the presence of several unexpected statistically significant interactions, it should be stressed that the theoretically critical interaction, Context by Verb Type, did not enter into any significant higher order interaction. In particular, the interaction among Control Type, Context and Verb Type and among Verb, Context and Verb Type were not significant ($F(1,12)<1$, $MS_e=3508$ and $F(1,12)<1$, $MS_e=4386$, respectively). Of the 12 higher order interaction terms involving the Context by Verb Type interaction, there were two that approached significance, the Tape by Control by Context by Verb Type interaction ($F(1,12)=3.95$, $MS_e=3508$, $p<.10$) and the Tape by Tray by Verb by Context by Verb Type interaction ($F(1,12)=4.45$, $MS_e=4387$, $p<.10$). Each of these interactions may be viewed as defining a set of replications or partitions of the Context by Verb Type interaction. In the former case there were four replications corresponding to the various levels of the Tape and Control factors, etc. In the first of these interactions, the PBE is evident in all four replications, while in the second it is evident in six out of eight. That is to say, apart from the two exceptions, the replications of the Context by Verb Type interaction within these higher order interactions show a greater difference between singular and plural verbs in the Pronoun condition than in the Control condition, with the plural forms being faster than the singular forms.

CHAPTER FOUR

An Account of the Pronoun Bias Effect

The results described in Chapter 3 will be discussed in relation to three questions about language processing: 1) When and how does the processing system select an antecedent for they?, How might the presence of they in prior context influence the syntactic analysis of a VERBing NOUNs expression?, and 3) How might the preferred syntactic analysis of the VERBing NOUNs expression affect naming performance on a following verb? The results will also be considered in relation to possible general models of the processing system and the contrasting results of Frauenfelder, et. al. (1980, see discussion in Chapter 1) will be examined.

The linguistic theory assumed in this chapter, and elsewhere in this thesis, is Chomsky's government binding theory (Chomsky, 1981). This of course is not the only linguistic theory. Its employment here is motivated by the assumption that best practice in psycholinguistics is to reference every study to some particular linguistic theory or theories and by the opinion that this theory has achieved greater depth of explanation than others. Since the object of study here is the processing system, there seems to be little to be gained from surveying other linguistic theories and their possible bearing on the findings. If a more convincing account of the results reported here can be built by reference to some other linguistic theory, that will be a project for proponents

of the other theory.[1]

Names for components of a processing theory are standardly derived from the names of putatively related components of a linguistic theory, e.g., "syntactic component." The reader should bear in mind that all such labels are assumed here to mean something like "the processing component (or components) that implements the principles encoded in the _____ component of the linguistic theory." The use of such terms should not prejudice the question whether there is any unified processing module that relates to a particular component of the linguistic theory in some way, nor any other empirical questions about the relation between the theories of language and language processing.

One of the principle values of assuming a particular linguistic theory in doing psycholinguistic research is that the linguistic theory, where it is sufficiently developed, provides unambiguous answers to at least some questions of the kinds shown in (1).

(1) (a) Do the phenomena X and Y 'fall together?'

(b) Are the phenomena X and Y both (choose one) [phonological, syntactic, interpretive,...]?

(c) Can the phenomena X and Y both be understood by reference to a consistent set of principles expressed in a uniform vocabulary?

Such questions can only be answered by reference to some theory. For now, the only theories that can answer any very rich class of such questions where language behavior is concerned are linguistic theories. Eventually it may be possible to answer some such questions by reference to a processing theory. At all times it will

be important to bear in mind the particular identity and type of the theory on which any particular answer is based. For the purposes of the following discussion it is important to note that in the government binding theory the principles that construct logical form representations are part of the syntactic component of a grammar.

Turning to the empirical results described in Chapter 3, the schema in (2) provides a framework within which they may be summarized.

(2) $[_S$ CONJ $[_{NP}]$ $[_{VP}$ VERB ...X... VERBing NOUNs // VERB

Experiments 2 and 3 demonstrated that, holding all other elements constant, alternations in the subject noun phrase between they and other noun phrases that do not have similar referential properties affects the relative speed of naming with the probe verbs is and are when everything up through the VERBing NOUNs expression is presented auditorily and the probe verb visually. Specifically, is and are are read in about the same time when noun phrase subjects other than they appear, but is is significantly slower (relative to itself and are) when the subject of the fragment is they. This is termed the pronoun bias effect (PBE). Experiment 4 demonstrated that this effect is blocked when the material in the variable ...X... in (2) introduces a complement sentence that includes the VERBing NOUNs expression, thus making coreference between the latter expression and they impossible. However, the PBE is evidently unimpaired when the verb following they implicitly assigns properties to the pronoun, by virtue of the verb's selectional or pragmatic specification, that result in some degree of anomaly when the pronoun is taken as coreferential with the VERBing NOUNs expression.

To summarize the summary, this study has uncovered three facts: 1) the PBE exists, 2) it is sensitive to syntactic influences on coreference, but not selectional or pragmatic influences, and 3) the effect on naming is purely inhibitory. These findings are, as usual, much in need of reconsideration and refinement in further experiments. Nevertheless, the role of this chapter is to estimate what the facts, if they are facts, might mean. Questions of their credentials are not considered here.

4.1 Selecting an antecedent for *they*

The results indicate that when *they* appears in a discourse context that provides no established entity for *they* to refer to, the processing system begins searching for a logical antecedent for the pronoun in subsequent context. Deciding the reference of *they* is not deferred to the next clause boundary. The VERBing NOUNs expressions used in these experiments always appeared at the beginning of a clause and the reference-related effect was evident on the next word. In this respect these results support proposals of Marslen-Wilson and others to the effect that the process of constructing an interpretation of an utterance begins at the beginning and runs continuously as the utterance is heard.

If there is a component of the processing system that implements only the principles represented in the syntactic component of a grammar, that component cannot implement the PBE by itself. Recall that one of the control contexts that alternated with *they* was *you*. These two pronouns, however, have exactly the same properties up through the level of a logical form representation. So far as

coreference is concerned, both must be free in their governing categories (see Chapter 2). In (3), considering the object forms, neither pronoun can be interpreted as coreferential with the subject of the sentence.

(3) (a) *You saw you in the mirror.

(b) They saw them in the mirror.

Neglecting many complications not relevant here, you is interpreted as a kind of referential constant with all instances in one direction in a dyadic exchange somehow inherently referring to the same individual. The conflict between this nonsyntactic principle and the syntactic requirement that the two you's in (3a) be disjoint in reference renders that sentence anomalous. In brief, to implement the PBE it is necessary to distinguish the reference properties of you and they. Thus the PBE appears to involve some processor that can at least 1) recognize that they needs an antecedent, and 2) recognize that it can't be interpreted by reference to a constant antecedent, as with you. On the government binding theory, this is not syntactic information.

Once the processing system has established that they needs an antecedent on non-syntactic grounds, the evidence is very good that candidate noun phrases in subsequent context are selected primarily by syntactic criteria. This is the most important result of Experiment 4. The contexts following they contained plural noun phrases in most of the materials used. Introspectively, it seems very unlikely that any of these, prior to the VERBing NOUNs expression, is ever even tentatively considered a possible antecedent for they.

The results of the LF condition in Experiment 4 unambiguously support this conclusion. Holding they and some particular VERBing NOUNs expression constant, the PBE worked when the VERBing NOUNs expression was outside the initial subordinate clause and disappeared when it was inside. In other terms, when the position of the VERBing NOUNs expression was syntactically eligible for coreference with they, the presence of the PBE suggested that such a relation was at least temporarily constructed. But when the VERBing NOUNs position was syntactically inelligible for coreference with they the PBE disappeared.

Furthermore, it appears that the mechanisms that implement the PBE select candidate antecedents by syntactic criteria alone. At least, the extrasyntactic information types tested in Experiment 4 showed no reliable ability to impede the PBE. Though listeners readily notice that they are left with an anomalous interpretation with fragments such as those in (4), whatever mechanism detects the anomalies in these cases leaves the PBE intact.

(4) (a) As they stroll in the afternoon sun, flying kites...

(b) Since they drink lots of water, melting glaciers...

(c) However little they chirp when the sun comes up, waking kittens...

Those parameters of the situation that do seem likely to affect the PBE, apart from the structural one tested in Experiment 4, are those marked in the pronoun itself. For example, the PBE will probably disappear if he, she, etc. replace they in these materials. This sort of evidence, however, if it is available, is ambiguous. The number

property reflected in the they/he contrast is a syntactic parameter, the one that is involved in subject/verb agreement in English. Thus, if it can block the PBE, this is conceivably a syntactic effect like the demonstrated effect of logical form. However, it may be important that there appear to be no syntactic rules in English that block coreference between he and, say, managing directors solely because they differ in number. Such rules appeared in many early transformational grammars (for instance, Jacobs and Rosenbaum, 1968) but have now generally been abandoned. If, as recent analyses indicate, the number property of pronouns is nonsyntactic for the purposes of coreference, then the proper analysis of the PBE might be that the extrasyntactic factors it is sensitive to are just those that are morphologically explicit in the pronoun, plus the fact of the pronoun needing an antecedent. Another very interesting case would be a pronoun that is morphologically marked for some property that does not become involved in syntactic rules in any language. If such a property could be used to block the PBE, that would suggest that the facts relevant to the PBE are those that are morphologically explicit in the pronoun, regardless of their status relative to syntax. If the only parameters that affect the PBE are those that are involved in syntactic rules (in the language in question, or in any language) then this will argue for an account of the PBE that relies on syntactic processing systems. Unfortunately, English presents opportunities to test this question only for parameters that are not syntactically involved in English itself. Gender is such a parameter. Though it plays a syntactic role in other languages, in English there are no syntactic rules whose output is affected by this parameter.

There are many models that might accomodate these facts and possible facts. The key difficulty in constructing such a model is to account for the particular pattern of information types that the PBE is sensitive to. Two models will be considered here.

The first possibility is to assume that the PBE is implemented by an enriched syntactic processor. Selectional and pragmatic information don't become involved because they are implemented by a separate interpretive component. The enriched syntactic processor would have to deal in some information about reference and it would have to have added to it means for positively specifying tentative coreference relations. Coreference relations assigned by such an enriched syntactic processing module would be subject to reconsideration by various interpretive processes. Such a model has several drawbacks. It moves away from a modular theory by making the syntactic component more complex and somewhat less coherent. Looking at the details of such a theory might also suggest more interaction between syntactic phenomena and reference matters than can actually be demonstrated. If further research is able to answer some of the questions mentioned earlier, this may have a bearing on the attractiveness of an enriched syntactic component. If possible antecedents indicated by previous sentences, especially those that are less explicit, are able to shut off the PBE, this would make the syntactic component a less likely candidate for implementing the effect. If such antecedents block the PBE it would seem to be necessary to have those interpretive components that construct, evaluate and use such antecedents communicate with the enriched syntactic component about matters of reference. This would effectively defeat the original purpose of putting some

reference handling capability in the syntactic component. The point of that move was to isolate the mechanisms that implement the PBE from those that deal with selectional and pragmatic information. If the interpretive component has knowledge of these matters and communicates with the enriched syntactic component on matters of reference, it is not clear why the selectional and pragmatic information the interpretive processor has could not then affect the PBE through the interpretive component's link with the syntactic component. Finally, the question whether pronoun parameters that affect the PBE are syntactic or morphological, if it can be answered, should bear on the plausibility of this model. If only syntactically active pronoun parameters affect the PBE, this will support, though weakly, the enriched syntax model.

The second model isolates the PBE from selectional and pragmatic information by partitioning the interpretive resources of the processing system between two components: 1) a reference processor, and 2) a general interpretive processor. The task of the reference processor is essentially to determine what entities are 'in play' at a given moment in a discourse and to identify certain of the relations among these entities. Its most basic capability is to distinguish referring expressions (such as the men, you, each other, etc.) from other kinds and to make certain distinctions among referring expressions. In particular the reference processor distinguishes three kinds of referring expression: 1) those such as I and you which have 'constant' reference, 2) those such as they and he which tend to be linked to elements in the universe of discourse via some other referring expression, and 3) those such as a woman or the books that,

by hypothesis, don't take linguistic antecedents (at least not in the same sense that they does; cf. Clark and Sengul, 1979). The reference processor uses two kinds of information in doing this work. First, it uses outputs of the syntactic component as they bear on coreference. Either the reference processor assigns reference relations and the syntactic processor checks them or the reference processor reads coreference possibilities and restrictions off the output of the syntactic processor. Second, the reference processor uses morphological information and can recognize and exploit distinctions of definiteness, number and gender, possibly among others. The second processor is a general interpretive processor that is responsible for any interpretive problem not covered by the reference processor. Most importantly for present purposes, it is assumed to have the capacity to extract information about entities from the linguistic contexts in which they are mentioned, e.g., the information that the referent of they is animate in They ate the corn. This model, though for now impossible to specify in any depth, is generally more attractive than the first. It enhances modularity by attempting to isolate in one module what seems like a natural class of processing activities. It suggests predictions about how the PBE might be affected by morphological parameters of the pronoun and by other expressions appearing ahead of the pronoun in cases like those used in the experiments reported above. However, since it rests so heavily on speculation, there is little to be gained by elaborating it or defending it further here. For the moment it solves one of the key theoretical problems posed by the results reported in Chapter 3; it provides a mechanism by which they might be linked to a reading of the

VERBing NOUNs expression without involving selectional and pragmatic knowledge that should tend to block this relationship.

4.2 Influences on the syntactic analysis of the VERBing NOUNs expression

The next problem is, given that some relation between they and the VERBing NOUNs expression has been established somewhere in the processing system, how might that relationship come to affect the syntactic interpretation of the VERBing NOUNs expression? Had the enriched syntactic component been preferable, this problem would not arise. Then the question would have been only how does the syntactic processor affect the syntactic processor, which doesn't seem like so deep a mystery. The second model proposed in Section 4.1, however, gives rise to a special case of a general problem in modular processing theory; how do structurally distinct processors communicate without compromising their distinctiveness?

Unfortunately there is very little that can be said about this problem on the strength of the present study. It does appear that the syntactic processor is in fact alerted to the reference processor's preference for one reading of the VERBing NOUNs expression because a syntactic rule (subject/verb agreement) plays a crucial role in the PBE. If this analysis is correct, the PBE involves a "downward" influence of interpretive processing on syntactic processing. There is, however, nothing about the PBE to indicate that the mechanism involved requires a 'broad band' communication channel. A system in which the syntactic processor displays alternative analyses for the reference processor and merely detects an instruction to prefer one is sufficient. This is an example of a proposal that contradicts the

autonomy proposal of Forster (1979) and yet preserves modularity.[2] Furthermore, there is nothing in the evidence at hand to support the suggestions of Tyler and Marslen-Wilson (1977) to the effect that the syntactic component is being guided in any sense other than that mentioned above. There certainly is no indication of interpretive processes anticipating syntactic analyses and directing the syntactic processor to pursue some and ignore others.

4.3 Factors affecting naming time

The raw fact that the presence or absence of they in prior context can affect relative naming time on is and are is interesting from two points of view. First, even assuming the analysis of the PBE outlined above, there is no logical necessity that naming time, a task with a major production component, will be sensitive to compehension processes. The fact that it is argues for a relatively intimate relation between production and comprehension. Secondly, the PBE is plainly intelligible only on the assumption that the naming task involves lexical access, an issue on which there has been some uncertainty (cf., West and Stanovich, 1982, and Forster and Chambers, 1973).

The more complex fact that the PBE is an inhibition effect that bears on is is of some importance. There are various proposals in the literature that suggest the possibility that syntactic context might facilitate the lexical access process (cf., Goodman, McClelland and Gibbs, 1981, Marslen-Wilson and Welsh, 1978, and see Chapter 1). The results reported in Chapter 3 deal with a situation where a forward-reaching syntactic influence, if it is possible, might arise.

Fortunately, the PBE provides an excellent opportunity to discriminate facilitory context effects from inhibitory effects. If syntactic context were facilitory it should have the effect of reducing the search space (or time or difficulty) for recognizing the verb form that is directly compatible with the selected interpretation of the VERBing NOUNs expression. In other words, if syntactic context facilitates lexical access in these cases, _are_ should be faster when _they_ appears in prior context. This is not what happened. The facts that the non-preferred verb form, _is_, showed the effect, and that the effect was inhibitory are consistent with a post-access account of the effect. Apparently the verb form the subject saw on the screen was retrieved from the mental lexicon on orthographic grounds and only then considered in relation to syntactic context.

It's also worth noting that this inhibition effect appears to bear little resemblance to the lexical inhibition effects that have been widely discussed in relation to various "priming" experiments. In general, those effects appear only with relatively long delays between the context stimulus and the word the subject responds to. For example, West and Stanovich (1979) observed significant inhibition effects in their task only with delays on the order of 700 msec. Because of this contrast, the phenomena described in Chapter 3 do not seem to be compatible with the much discussed proposals of Posner and Snyder (1975). These authors attributed the context effects they considered to two mechanisms, a fast one and a slow one. The fast mechanism, generally thought to be some kind of spreading activation system in the lexicon, is taken to be purely facilitory. The slow mechanism is attentional and has both facilitory and inhibitory

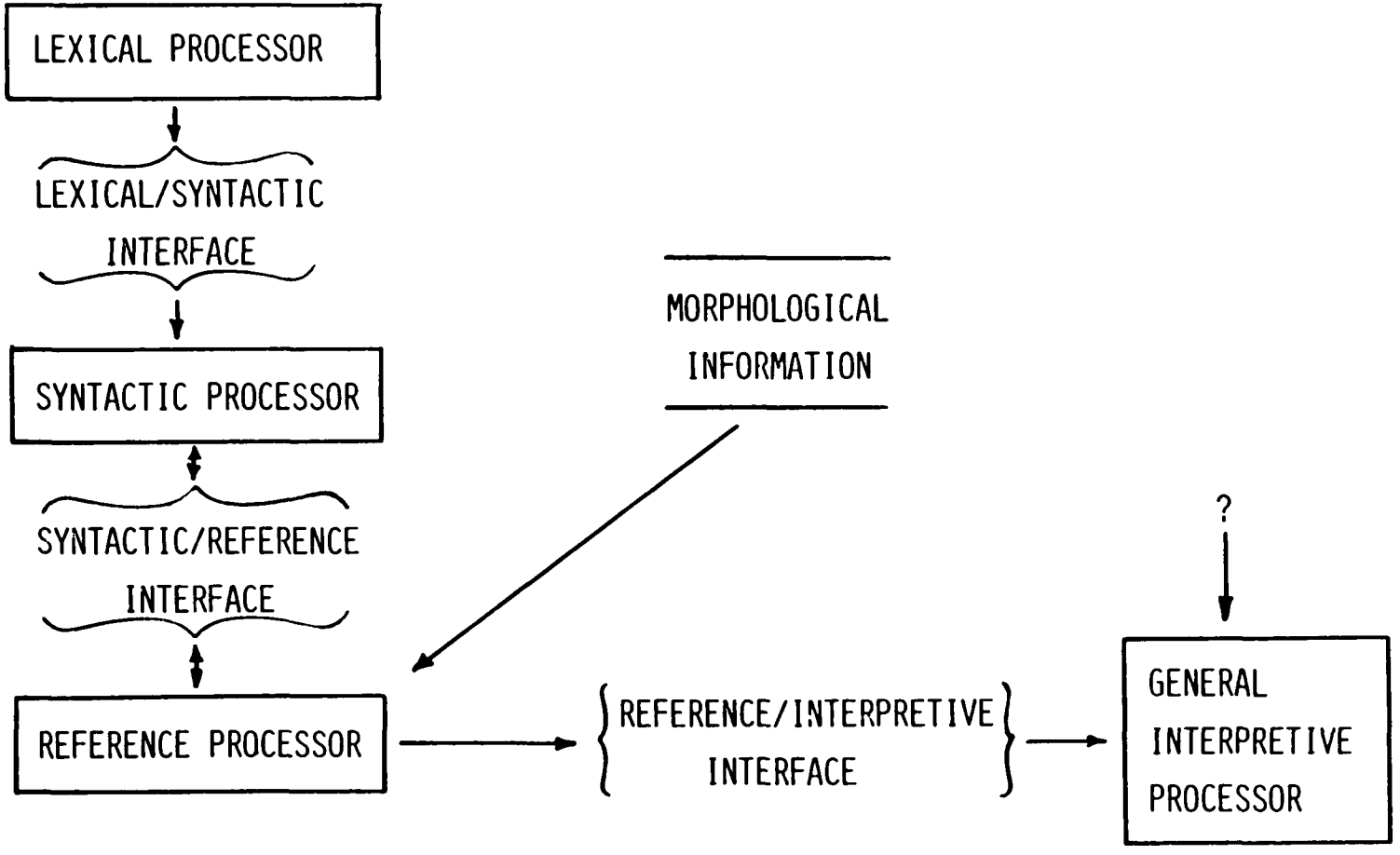
effects. Thus only the slow attentional mechanism is available to produce inhibition. This mechanism is generally thought to be engaged only when the critical stimulus is first presented at about the time subjects were responding in Experiments 2 - 4.

4.4 The model

The theoretical proposals made in this chapter are summarized in Figure 1. The only novel feature of this model for which there is clear empirical evidence in this study is the distinction between the reference processor and the general interpretive processor. Though Section 4.1 suggests various ways that the relation between the syntactic processor and the reference processor might be assessed, this study provides no empirical justification for distinguishing these two devices. The class of reference-related issues assigned to the reference processor is neither the minimum necessary to implement the PBE nor the full set of reference problems. Rather, these tasks represent merely a guess about what will turn out to be a natural class of problems. The point of indicating the interfaces in the model is simply to emphasize that developing a modular theory of the language processing system involves both the differentiation of the components of the system as well as the specification of interfaces between the components.[3] In any case, the role of the model is not to encode established truth but to focus attention on those points where an investigator's labors have some hope of being rewarded.

Viewed from a somewhat broader perspective, the central claim the model represents is simply that there is a language module. It

FIGURE 4: A MODEL OF THE LANGUAGE PROCESSING SYSTEM



asserts that there is an ensemble of processors that respond only to those properties of an utterance that figure in a linguistic theory (e.g., the government binding theory). Though it acknowledges the roles of other kinds of human knowledge in sentence interpretation, it also asserts that the mechanism that implements these other kinds of knowledge can be distinguished from those that implement strictly linguistic knowledge.

As noted briefly above, the model contrasts with Forster's (1979) proposals in that it permits some interaction between the reference processor and the syntactic processor. The limited character of this interaction, as it is described above, would not, however, compromise the fundamental goal of modularity. The proposed interaction does nothing to complicate the resources of the syntactic processor, nor does it seem likely to extend the expressive power of the processing theory as a whole. On the contrary, it avoids requiring nonsyntactic components to determine the syntactic consequences of choices between alternate interpretations and thus probably reduces overall expressive power relative to such a theory. Note that these are all plausibility arguments. None of the results in Chapter 3 in themselves motivate a distinction between the syntactic and reference processors described above.

Where lexical processing is concerned, the results of this study support the claims of Forster (1976, 1979). The experiments presented a clear opportunity for syntactic context to affect lexical processing in some facilitory way and no such effect appeared. Thus this study supports Forster's claims that during comprehension there is only a one-way flow of information between the lexical and syntactic

processors. This of course does not prejudice the question whether syntactic context may have some effect in other circumstances.

The "on-line interactive" model discussed in Marslen-Wilson and Tyler (1980), Marslen-Wilson, Tyler and Seidenberg (1978), Tyler and Marslen-Wilson (1977) and elsewhere is consistent with the proposals made here only in so far as this study supports the suggestion that relatively deep levels of analysis become involved in utterance interpretation from the outset. Apart from this, the fundamental goal of this research contradicts the blurring of distinctions between processing types associated with the on-line interactive model. Expectations derived from the on-line interactive model are clearly violated by the results of Experiment 4. Most particularly there is no evidence here to support Tyler and Marslen-Wilson's suggestion that the processing system may anticipate the syntactic form of the second clause via the interpretation of the first. Indeed, the presence of they as the subject of the initial subordinate clause seems to constrain the syntactic form of the following clause hardly at all. Rather they seems to serve merely as evidence upon which a choice is made between two independently provided syntactic alternatives. The proposal that syntactic context can contribute to lexical processing (cf., Marslen-Wilson and Welsh, 1978, Marslen-Wilson and Tyler, 1980) also finds no support, as noted above.

The results of Frauenfelder, Segui and Mehler (1980, see Chapter 1) appear to contradict the outcome of Experiment 4 fairly directly. Frauenfelder, et. al. found that phoneme monitor RTs were lengthened immediately after a clause boundary when the noun phrases in the clause appeared in noncanonical order, i.e., the noun phrase following

the verb was the grammatical subject of the clause. However, when selectional information (in the sense of Experiment 4) was manipulated to make the clause "nonreversible ," this putatively syntactic effect on phoneme monitoring disappeared. In brief, the result suggests that syntactic processing exploits selectional information. This of course is not consistent with the processing model outlined above. Since selectional information is exploited by the general interpretive processor it would be available at best indirectly through the reference processor. Looking at the matter the other way around, if selectional information is involved in syntactic processing intimately enough to remove the difficulty of dealing with noncanonical order, it is at least a little surprising that it cannot affect the PBE. One possible account of this apparent conflict is based on the difference between exploiting selection information for its relevance to syntactic structure as opposed to its implications for reference. To use selectional information to facilitate syntactic processing in the Frauenfelder, et. al., case it would only be necessary to compare the selectional properties of a noun and verb with some structural information provided by the syntactic component itself. To use selectional information to block the PBE in the Selection condition in Experiment 4 it would be necessary to attribute a property to the referent of they on the strength of the selectional properties of a verb in construction with it. These are two different tasks and it is conceivable that selectional information could be exploited in these two different ways by different components of the processing system.[4]

Another account of the conflict between these findings may be built on contrasts between the tasks. Cairns, Cowart and Jablon

(1981) argue that the phoneme monitor task, even though it logically requires nothing beyond a phonological analysis of the input, in fact involves and is sensitive to integrational processes involved in discovering the discourse theme, context, actors, etc., intended by the speaker of some utterance. If this analysis is correct, then the model proposed in Section 4.4 may be correct for the relation between syntactic processing and selectional information. The phoneme monitor task detected a role for selectional information in the Frauenfelder, et. al., study because the task taps into linguistic processing at its "top" end, at least at the level of the general interpretive processor. Experiment 4 did not detect selectional effects because the naming task taps into the processing system at a "lower" level, i.e., at the output side of the reference processor.

The conflicting results present a clear experimental agenda when considered in relation to the model proposed above. If the Frauenfelder, et. al., study were replicated using the naming task used in Experiments 2 - 4, the effect of selectional information ought to disappear. By contrast, if the naming task on Experiment 4 were modified to involve some conscious criterion, the effects of selectional information should be evident (cf., the discussion of tasks in Chapter 1).

4.5 A comment on methods

Advocates of "autonomous" theories of language processing have generally made certain assumptions about the character of such processing (e.g., it proceeds "bottom-up") and about the relation between the processing system and a grammar (e.g., each component

of the linguistic theory is realized by a distinct component of the processor).

The strategy of this project has been different (at least as it is reconstructed and rationalized here at its end). This work is more tentative in that it assumes nothing about the relation between components of a grammar and components of a processing system, or about the character of the interfaces between these components. It is more aggressive about modularity because it takes for granted that the best theory of how the language processing system works will be somehow modular. The question is not whether but how. The role of linguistic theory in this enterprise is to provide an account of the function the processing system computes. It specifies what the processor is up to in the same sense that Peano's axiomatization of arithmetic specifies what a pocket calculator is up to when it adds two and two.[5] There is no more reason to expect a neat relation between the logical machinery of the linguistic theory and the mental machinery of language processing than there is to assume a neat relation between Peano's axioms and the machine language programs a pocket calculator covertly runs. They are different logical types and their designs are driven and constrained by distinct (though overlapping) sets of concerns. Nevertheless, it seems to be impossible to learn much about language processing without a linguistic theory. For the time being at least, the only way to study language processing is to analyze the gross behavior of more or less intact humans. This is hard. The system is complex almost beyond comparison, noisy and adept at keeping its secrets. Nothing could be more useful in studying it than a good account of how it sees the world, what distinctions it makes, what

differences it ignores, what objects it sees, what relations they enter and what structures they form. That is just the story that a linguistic theory tells.

The strategy of this study has been to use a linguistic theory as a guide to the world the language processing system sees. The gamble is that the best way to find the joints in the processing system will be to probe the joints in the language it knows.

Notes for Chapter Four

[1]There is no contradiction in asserting both that psycholinguistic theories ought to be referenced to particular linguistic theories and that there is little value in considering the results of this study from the viewpoints of other linguistic theories. In the approach to language processing research employed here, the principal roles of a linguistic theory are 1) to provide a systematic and coherent account of the descriptive terms needed to identify and delimit the range of linguistic stimuli under study, and 2) to provide suggestions as to what linguistic phenomena are and are not related to each other. For the kinds of results obtained here only the first of these roles is crucial to the interpretation of findings. However a linguistic theory may partition linguistic phenomena, the processing results are what they are; if they indicate a contrast the linguistic theory does not make, that contrast must still be respected in the processing theory. Thus considering other linguistic theories that make other distinctions than the ones the government binding theory makes cannot change the interpretation of the present results in a fundamental way; it can only affect the linguistic vocabulary within which they are described.

[2]The evidence of this study is particularly damaging to Forster's (1979) claim that there is no "downward" influence on the syntactic processor. The PBE involves a choice between syntactic alternatives, each of which has distinct syntactic consequences for subsequent material. If the choice between possible analyses of the VERBing NOUNs expression is controlled by nonsyntactic factors, then either those nonsyntactic mechanisms must have a way to communicate their decision to the syntactic processor so that it can work out the syntactic consequences of this choice, or syntactic knowledge must be (redundantly) attributed to further mechanisms that can work out the syntactic consequences of the choice without exerting any downward influence on "the" syntactic processor. Thus to deny that postsyntactic processing can influence the syntactic processor seems to work against modularity by requiring syntactic knowledge to be distributed through the system.

[3]Note that the arrows in Figure 1 are not to be read as claims about the order in which various components operate, but only as claims about what components provide inputs to what other components. Thus the model would be falsified by evidence that pragmatic information could affect the PBE but not by evidence that the general interpretive processor (where pragmatic information resides) is active prior to or simultaneously with the reference processor.

[4]Evidence reviewed in Section 3.4.5 indicates that the inherent bias of VERBing NOUNs expressions interacted with the PBE. If there was a strong inherent bias toward the plural noun phrase reading, this may have diminished or eliminated the PBE. There is no way to tell from this study what factors influence inherent bias, but selection restrictions are an obvious possibility. Thus the role of inherent bias in the present study might be weak evidence in favor of Frauenfelder, et. al.'s claims.

[5]Peano's arithmetic was an attempt to describe the fundamental ideas of traditional mathematics in the simplest possible terms. It was already known that arithmetic, algebra and other mathematical systems based on the natural numbers (1,2,3...) could be derived from the properties of the natural numbers themselves. Therefore, Peano's aim was to describe the natural numbers with the barest minimum of primitive concepts and axioms. He found that, apart from some machinery borrowed from formal logic, he needed only three primitive terms (zero, number, successor) and five axioms. The five axioms are given in (A).

(A) (1) Zero is a number.
(2) The successor of any number is a number.
(3) No two numbers have the same successor.
(4) Zero is not the successor of any number.
(5) If P is a property such that (a) zero has the property P, and (b) whenever a number *n* has the property P, then the successor of *n* also has the property P, then every number has the property P.

Peano demonstrated in effect that all of the "operations" of traditional mathematics could be defined in terms of this system. Obviously, the relation between this set of principles and the procedures people employ in paper and pencil addition is very abstract. The relation between these primitives and the internal procedures of a calculator is at least as obscure.

See Russell (1919) and Hempel (1956) for further discussion of Peano's accomplishment and its significance.

APPENDIX

Experimental Materials

A.1 Materials for Experiments 1 and 2

The experimental materials for the first two experiments were divided into two major groups, those that used a nonpronominal noun phrase such as the birds as the control context and those that used you as the control context. The materials are presented below in their control version. The experimental version is derived in each case by replacing the underlined control material with they.

A.1.1 Materials using nonpronominal controls.

1. As the birds soar gracefully above the field, flying kites...
2. When the men use a machine to do the work, drying clothes...
3. If the newlyweds want to take a cheap vacation, visiting relatives...
4. Since the better animals seem obedient and docile, riding horses...
5. When the entertainers don't feel like putting on a show, amusing people...
6. Although the runners must rely on a dedicated coach, training athletes...
7. Since the darker types don't look very appetizing, frying eggs...
8. Even though the daisies often become quite attractive, growing flowers...
9. Since the predators benefit from newly enacted conservation laws, hunting eagles...
10. While the expensive models usually come with several internal partitions, packing cases...
11. In that the basic equipment can work in many different situations, adapting devices...

12. Supposing that the big cats won't actually try to do fatal harm, battling lions...

13. However much people may smile on some occasions, deceiving relatives...

14. Whether Christmas shoppers mean to or not, hurrying people...

15. Although the marks might not all fit a familiar pattern just yet, identifying symbols...

16. Unless the ideas amount to a definite proposal, inviting suggestions...

17. Once the coins start to make noise, jangling keys...

18. Because a few individuals sometimes behave very rudely, jostling shoppers...

19. In that well-designed implements can greatly improve productivity, manufacturing tools...

20. Before the outer parts really begin to turn soft, marinating onions...

21. That the newborn lack teeth presents no real problem, nursing infants...

22. Until the enemies become fully involved in the contest, overpowering opponents...

23. Whereever in the show such fine performers will appear, parading horses...

24. Considering that old acquaintances may never know when to expect another encounter, parting friends...

A.1.2 Materials using you as a control.

1. If you can handle the intense competition, racing cars...

2. Since you presume that basic needs are not being met, starving children...

3. Although you don't need much time, cooking apples...

4. Even though you need well-trained crews, sailing ships...

5. Because you may appear unexpectedly during the meeting, folding chairs...

6. If you keep watch during the courtship rituals, breeding pigeons...

7. When you fall into a familiar pattern, playing cards...

8. If you try to thread a needle, shaking hands...

9. When you get stuck in deep snow, moving cars...

10. Although you can never tell what will happen, alarming monsters...

11. Given that you will probably begin to fall apart, banging doors...

12. Except that you must deal with a lot of mud, bathing elephants...

13. Except that you may get too hot too quickly, boiling vegetables...

14. If you continue to interfere, centralizing controls...

15. Unless you show signs of great genius, challenging ideas...

16. Assuming that you use the right technique, charging bears...

17. Since you don't represent what matters on this issue, circulating petitions...

18. So that you can disguise the fact of an impoverished childhood, dazzling friends...

19. Unless you manage to appear extremely gruff, enchanting children...

20. Granting that you will play a central role in the research project, engaging assistants...

21. Unless you make a habit of boring people, entertaining guests...

22. Although you imply that any school can maintain a long winning streak, losing games...

23. While you cannot always achieve a perfectly helpful attitude, pleasing associates...

24. Once you begin to examine the matter, prosecuting attorneys...

A.2 Materials for Experiment 3

The VERBing NOUNs expressions for the first 28 items are drawn from the materials used by Tyler and Marslen-Wilson (1977). Each item is shown in its control version. The experimental version is derived from this form by replacing the underlined material with they.

1. As the birds soar gracefully above the field, flying kites...
2. When the men use a machine to do the work, drying clothes...
3. If the newlyweds want to take a cheap vacation, visiting relatives...
4. Since the animals seem obedient and docile, riding horses...
5. When the entertainers don't feel like putting on a show, amusing people...
6. Although the runners must rely on a dedicated coach, training athletes...
7. Since the donuts don't look very appetizing, frying eggs...
8. Even though the daisies can often become quite attractive, growing flowers...
9. Since the predators benefit from newly enacted conservation laws, hunting eagles...
10. While the boxes usually come with several internal partitions, packing cases...
11. If the engines can handle the intense competition, racing cars...
12. Since the officials presume that basic needs are not being met, starving children...
13. Although the vegetables don't take up so very much time, cooking apples...
14. Even though the captains need to rely on well-trained crews, sailing ships...
15. Because the evaluators may appear unexpectedly during the meeting, folding chairs...

16. As long as the birds stay reasonably close to the nest, breeding pigeons...

17. When the results fall into a familiar pattern, playing cards...

18. If the beginners try to thread too small a needle, shaking hands...

19. When the wheels get stuck in very deep winter snow, moving cars...

20. Because the poems usually require careful pronunciation, rhyming words...

21. Although the fires do enormous ecological damage, burning trees...

22. Since the fragments sometimes cut people standing nearby, breaking glasses...

23. Since the noise can become extremely irritating, ringing bells...

24. Because the saws contribute most of the noise in the carpentry shop, cutting boards...

25. Since the runoff can provide a valuable supply of cold water, melting glaciers...

26. When the passengers arrive at better-designed airports, landing planes...

27. Since the colors affect the entire appearance of a living room, moving pictures...

28. Although the toys once brought endless amusement to children, spinning tops...

29. Supposing that the cats won't do any very serious harm, battling lions...

30. Whether the customers mean to or just can't do otherwise, hurrying people...

31. Unless the ideas amount to a definite proposal, inviting suggestions...

32. Once the coins start to make any kind of noise, jangling keys...

33. Because the clerks sometimes behave very offensively, jostling shoppers...

34. That the newborn lack teeth presents no major problem, nursing infants...

35. Except that the trainers must deal with an enormous amount of mud, bathing elephants...

36. Except that the potatoes may get very hot too quickly, boiling vegetables...

37. Although the coaches imply that few schools can maintain a long winning streak, losing games...

38. For all the fear the sounds provoke on typical occasions, clanking chains...

39. Because the freshmen may overburden existing facilities, enrolling students...

40. Before the situation gets completely out of control, nagging adolescents...

A.3 Materials for Experiment 4

Each item in the materials listed below represents a set of four sentence fragments. The four members of each set are generated by substitutions involving the underlined material and the subject of the initial subordinate clause. The subject of all the cases shown below is they. This gives the experimental versions of each item. The control versions are derived by replacing they with you. This alternation is crossed by alternation between the two underlined segments. The first of these implements the Nonanomalous condition. When it is in place there should be no bar to the subject taking they and the VERBing NOUNs expression as coreferential. However, when the second alternative is used, there should be some bar to this relation. Thus, the second underlined alternative implements the Anomalous condition.

A.3.1 Materials implementing logical form anomalies. In each of the following items there is a bar to relating they and the VERBing NOUNs

expression when the second underlined alternative is in place. This impediment to the potential coreference relation derives from principles of logical form. There should be no influences arising from selection restrictions or pragmatic factors that affect possibilities of coreference in these cases.

1. If they want to save money visiting uncles...
   believe that
2. Granting that they often feel insecure starving workers...
   pretend that
3. Though they seem to require clarification demanding tests...
   imply that
4. Once they begin to consider details prosecuting officials...
   accept that
5. So long as they sometimes move suddenly feeding infants...
   expect that
6. Providing they intend to avoid trouble pleasing associates...
   agree that
7. However much they may want to express annoyance pestering
   assume that
   children...
8. Considering that they often want to avoid scenes parting
   proclaim that
   friends...
9. Supposing that they like to frighten children battling lions...
   hope that
10. Just because they frequently reduce costs boiling vegetables...
    require that
11. Granting that they like to speak plainly worrying mothers...
    think that
12. Even though they sometimes work quietly investigating
    anticipate that
    officers...
13. While they may interest passersby moving displays...
    declare that

14. Now that they occasionally live alone / insist that admiring grandparents...

15. Because in some instances they may do anything / claim that jostling shoppers...

16. Whenever they might doubt something / deny that incriminating witnesses...

17. In that they might seem to encourage disorder / suggest that developing ideas...

18. If they sometimes strive to satisfy expectations / find that accomodating people...

19. Although most times they won't want to cause trouble / propose that assisting coaches...

20. Supposing they sometimes regret misbehavior / say that loving fathers...

21. In that they occasionally seem uncertain / hint that shaking hands...

22. While they often fear losses / state that prodding salesmen...

23. Often when they begin play / predict that deceiving opponents...

24. Except that they may fear retaliation / discover that threatening strangers...

A.3.2 Materials implementing selectional anomalies. In each of the following items the second underlined verb has the effect of implicitly assigning some property, such as animacy, to the subject of the initial subordinate clause. If the subject, they, is referentially related to the VERBing NOUNs expression, an anomaly results. As before, they alternated with you to form the control cases.

1. Even though they use / eat very little oil, frying eggs...

2. Just because they make / expect a lot of scary noise in the dungeon, rattling chains...

3. Admitting that they rarely disturb / observe the rule of quiet in the library, turning pages...

4. Whatever they may reveal / believe about personal wealth, accumulating investments...

5. Except that they need / prefer relatively little spice, cooking apples...

6. Providing that they start / speak from reliable information, narrowing differences...

7. Because they may encourage / dislike an atmosphere of genuine excitement, challenging ideas...

8. Even though they seem / hope to benefit directly, growing flowers...

9. As they sail / stroll in the afternoon sun, flying kites...

10. Whenever they appear / sing during the procession, parading horses...

11. Whether or not they may demonstrate / conceive an important concept, spinning tops...

12. When they encourage / anticipate confusion among the general public, changing laws...

13. Since they require / drink lots of water, melting glaciers...

14. Seeing that they aggravate / respect my Uncle George, ringing buzzers...

15. In that they rarely improve / manufacture a high quality product, warping boards...

16. Unless they attack / shout quite vigorously, overpowering animals...

17. Assuming that they don't approach / talk before Harry makes his move, charging bears...

18. If they can provide / describe an ample source of food, breeding pigeons...

19. Although they may go / ache from dawn to dusk during the harvest working tractors...

20. While they should detect / report any possible disturbance, watching dogs...

21. Even though they may work / gossip throughout every shift at the factory, operating machines...

22. Now that they benefit from / disagree with the expansion of the conservation program, hunting eagles...

23. Considering that they need / enjoy the improvements in acceleration, passing trucks...

24. While they may irritate / like everybody in town, clanking bells...

A.3.3 Materials implementing pragmatic anomalies. The form of these cases is identical to that of the preceding selectional examples except that the anomalies invoked by the second verb derive from pragmatic knowledge, not selectional restrictions.

1. Once they begin making / suppressing any sort of noise, jangling keys...

2. Whenever they smile / lecture during the procedure, charming babies...

3. Since they often add / pulsate to the sound of the music, popping corks...

4. Because they emphasize / analyze every figure of speech, rhyming phrases...

5. Supposing they will insult / arrest some of the witnesses, burning witches...

6. However little they wiggle / chirp when the sun comes up, waking kittens...

7. Although they may greet / baptize each new member of the team, training atheletes...

8. Whereas they often replace / enclose the actual gold bars in some bank vault, circulating coins...

9. Sometimes when they step / leap right into the water, bathing elephants...

10. Presuming that they continuously lose / absorb water during the process, drying clothes...

11. As long as they talk / complain all of the time, entertaining guests...

12. Considering that they rehearse / direct each overture with great care, leading orchestras...

13. When they respond / hold to the flight controls, landing planes...

14. Whereas they move / grow rapidly in times like these, decreasing expenditures...

15. However much they may resist / bend when the pressure increases, breaking glasses...

16. Given that they jangle / calm most people's nerves, irritating adolescents...

17. When they describe / grow long white beards, amusing boys...

18. Unless they interest / repel every member of the committee, inviting suggestions...

19. Since they usually avoid / attack major enemy positions, withdrawing troops...

20. Whether or not they go / stroll near to the cash register, hurrying clerks...

21. Unless they laugh / grouch all the time, enchanting youngsters...

22. Assuming that they don't shake / twist the shift levers out of position, racing cars...

23. Because they consider / grade certain assignments very rigorously, enrolling students...

24. Unless they accept / deny the existence of God, teaching nuns...

A.4 Materials criteria for Experiment 4

Enumerated below are some of the more important design criteria that guided the development of materials for Experiment 4. In a few cases minor divergences from these criteria were accepted where this did not seem to threaten the interpretability of the experiment.

A.4.1 Criteria bearing on the VERBing NOUNs expressions.

1. Each ambiguous VERBing NOUNs expression should be unique and there should be no repetition of any of the constituent participial forms or nouns.

2. Each VERBing NOUNs expression should be ambiguous with stress on the noun.

3. The stem verb in each VERBing NOUNs expression should fit into both of the following frames:
   a. the NOUNs are VERBing
   b. somebody is VERBing the NOUNs

A.4.2 Structural criteria bearing on all sentence fragments.

1. Neither fill-in should exhibit any associative or pragmatic relation to the VERBing NOUNs expression.

2. The gerundive nominal of each VERBing NOUNs expression in context should not be odd or implausible when the they of the first clause is taken as the implicit subject of the gerundive nominal itself.

3. The following criterion applies with:
   a. both fill-ins of the LF cases, and with
   b. only the first fill-in in the other cases.

   When the VERBing NOUNs expression is taken as a plural noun phrase it must be useable as the subject of the item whether is or are is the probe verb.

A.4.3 Criteria bearing only on some parts of the materials.

1. In the LF forms there are no repetitions among the verbs used in the second fill-ins, i.e., those that induce the complement structure to the right.

2. Except in the LF cases, there should be no plural noun phrases appearing between the fill-ins and the ambiguous expressions.

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