GARDEN PATH PHENOMENA AND THE GRAMMATICAL BASIS OF LANGUAGE PROCESSING

BRADLEY L. PRITCHETT

Northwestern University

A central issue in the field of language processing concerns how grammatical theory and parsing are related. Evidence from processing breakdown (GARDEN PATH phenomena) reveals the conditions under which local ambiguity results in unprocessable sentences. These data provide evidence that the processor operates by admitting structure which maximally satisfies the principles of Government and Binding Theory locally at every point during a parse, and that the constraints on syntactic reanalysis during processing are also derived from grammatical theory. Alternative approaches to parsing are demonstrated to be incapable of accounting for the wide range of garden path effects.*

1. THE GARDEN PATH PHENOMENON. This paper investigates a fundamental issue at the interface of the fields of linguistics and natural language processing: how competence grammar and parser are related. Although a syntactic parser must, by definition, assign structures compatible with a postulated competence grammar, among those espousing syntax-based theories of natural language processing there has been a nearly universal assumption that the two components are nonetheless distinct. While some researchers have hypothesized that the relationship between the two is quite close (e.g., the parser is the grammar run backwards;[1] cf. Jenkins et al. 1965, Fodor et al. 1974), others have maintained that the two are essentially independent (with the parser merely being required to yield, in some fashion, structures compatible with the grammar; cf. Bever 1970, Fodor et al. 1974). Nevertheless, it should be quite uncontroversial that the grammar and the parser are related in some fairly direct way, as the structures they assign must be compatible. What this relationship is remains to be discovered.

During the past fifteen years, the role of grammatical theory within models of natural language processing has been continually reduced. Emphasis has shifted toward an attempt to discover independent processing principles which reflect fundamental human cognitive functions (whether or not these are specific to language). Recently, among those attempting to integrate modern generative grammars (including GPSG, LFG, and (R)EST) and parsing theory, this view has been taken to the extreme and there has arisen a common if sometimes implicit assumption that certain grammatical constraints should result automatically from a correctly designed parser (cf. attempts to derive notions of subjacency and c-command; Marcus 1980, Berwick & Weinberg 1984). The putative success of this endeavor has in turn been taken as evidence of the

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[1] This hypothesis misinterprets competence grammars as models of production. Parsers and grammars are in no sense inverses of each other; each has among its tasks the assignment of a structural analysis to a string.

parser's psychological reality (Gazdar et al. 1985, Berwick & Weinberg 1985). From this point of view grammar is held, to varying degrees, to be a derivative construct. It is clear, however, that this hypothesis cannot be taken to its logical extreme—that the parser wholly determines, or indeed is, the grammar, for the simple reason that this would prevent one from explaining language variation. If there is any content to the notion that parsing strategies reflect fundamental and automatic human cognitive processes, then we do not expect them to vary radically across the species. Regardless of the design and capabilities of the parser, one must also postulate a grammar if one's theory of language processing is to have any claim to universality. Thus the question of the precise relationship between grammar and parser remains unanswered.

In this paper, in an attempt to solve this problem, I examine evidence from processing breakdown and specify the conditions under which local ambiguity in the input string results in grammatical but virtually unprocessable (so-called 'garden path') sentences, as opposed to those cases where the ambiguity causes no processing difficulty. I will suggest that these differences in processability are firmly grounded in a theory of grammar rather than in performance, and hence that parsing itself must be characterized in terms of irreducible principles of grammatical theory. The following well-known example, originally due to Bever 1970, exemplifies the garden path (GP) phenomenon:

(1) GP: The boat floated down the river sank.
(The boat which was floated down the river sank.)
(cf. The boat ridden down the river sank.)

In the language processing literature in general, the potential difficulty in interpreting such sentences has been hypothesized to result from the existence of some type of ambiguity during processing. For example, before the verb *sink* is encountered in sentence 1, the string *the boat floated down the river* is ambiguous between a main clause and a complex NP interpretation:

(2) $_{IP}$[[The boat]$_{NP}$ [floated [down the river]$_{PP}$]$_{VP}$]
(3) $_{NP}$[[The boat]$_{NP}$ [$_{CP}$ [floated **e** [down the river]$_{PP}$]$_{VP}$]

Ambiguity is of course not uncommon in natural language, as well-known examples reveal:

(4) a. [[Feeding sharks]$_{S}$]$_{NP}$ can be dangerous.
= To feed sharks can be dangerous.
b. [[Feeding]$_{AP}$ [sharks]$_{N}$]$_{NP}$ can be dangerous.
= Sharks which are feeding can be dangerous.
(5) a. The woman [killed [the man]$_{NP}$ [with a gun]$_{PP}$]$_{VP}$.
b. The woman [killed [[the man]$_{NP}$ [with a gun]$_{PP}$]$_{NP}$]$_{VP}$.

These sentences are said to be GLOBALLY AMBIGUOUS, since there is more than one valid syntactic structure which may be assigned to the string as a whole. Though such global ambiguity is widespread, generally one of the possible interpretations is highly preferred, and speakers are typically unaware of the alternatives.

Both the globally ambiguous sentences in 4–5 and the garden path example in 1 may be characterized as displaying ambiguous attachment possibilities

DURING PROCESSING. That is, the identity and place of attachment of some constituent is locally indeterminate at some point during the parse. In sentence 5, for example, the PP *with a gun*, when initially encountered, might legitimately be attached either directly to the VP or incorporated into a larger NP—with either option ultimately proving to be grammatical. There is then one obvious factor which partially serves to distinguish garden path sentences from those which are globally ambiguous. In the case of GPs, a certain attachment decision which is locally tenable may ultimately lead to ungrammaticality. That is, the assignment of a particular structure which is legitimate AT A GIVEN POINT DURING PROCESSING ultimately proves to be unsupportable. For example, in 1, though the ambiguous string *the boat floated down the river* might locally be attached into the parse tree as a main clause S or alternatively as a complex NP in a relative construction, only the latter option will prove globally correct. This type of attachment ambiguity might then accurately be referred to as STRICTLY LOCAL. While only globally ambiguous sentences are truly ambiguous in the traditional sense, both they and garden path sentences are ambiguous with respect to processing.[2]

Crucially, however, this distinction neither explains nor predicts garden path phenomena in any sense. For example, both of the sentences in 6 display a strictly local ambiguity, but are completely unproblematic:

(6) a. I knew the man.
b. I knew the man hated me passionately.

At the point when *the man* is encountered it might be attached as the direct object of the verb, which will prove to be correct for 6a, or as the subject of a forthcoming clause, which will prove correct for sentence 6b. However, the local attachment of *the man* as the object of *know* in 6b would lead to a globally ungrammatical S with *hated me* dangling without a subject, and the alternative attachment as the subject of a forthcoming S in 6a would lead to an ungrammatical structure where the complement has a subject but no predicate. Each attachment proves correct in certain instances but untenable in others, but neither sentence presents any processing difficulty whatsoever. Processing difficulty then cannot be ascribed solely to the presence of strictly local ambiguity.

Consequently, an important question remains to be answered: why do certain locally ambiguous structures (as in 6) fail to result in processing difficulty, while others (as in 1) lead invariably to GP effects? An initial hypothesis might be that there exist processing strategies which are invariably pursued during parsing—thus leading to the correct analysis in certain instances and failing in others. The simple approach, however, obviously could not account for the lack of processing difficulty in both 6a and 6b. Furthermore, the following pair of sentences reveals even more strikingly the difficulty inherent in characterizing problematic versus unproblematic local ambiguity:

(7) I knew mother hated me for no reason.
(8) GP: I warned mother hated me for no reason.

[2] In saying this, I adopt the reasonable assumption that human processing is performed temporally 'left to right' in something resembling real-time.

In these perfectly grammatical examples (each structure is licensed by the principles of the grammar), the attachment of the NP *mother* is ambiguous between a verbal object and the subject of a forthcoming complement S. However, only in the latter case is the sentence problematic. The contrast in processing difficulty between 7 and 8 clearly demonstrates that it will be impossible to maintain a simple hypothesis which holds that the mere necessity of undoing initial misattachments (backtracking) is always problematic. Despite its surface similarity to example 7, sentence 8 is as difficult to process as the canonical garden path sentence in 1.[3] This important point—that backtracking in and of itself simply cannot be problematic—is reinforced by the following sentence:

(9) The woman kicked her sons' dogs' houses' doors.

Though 9, spoken, is locally ambiguous at several points, with each NP being interpretable as a plural NP object or a genitive determiner up through the occurrence of *doors,* no processing difficulty results. Below, I will demonstrate that local ambiguity only results in processing difficulty when it involves θ-theoretic difficulties of a very particular sort, and I will show that certain principles derived directly from grammatical theory are employed directly in parsing—that is, that there is a simple and direct link between grammatical theory and performance.

Without elaborating further for the moment, I will begin by postulating the following processing principle, which is derived directly from Government and Binding (GB) Theory:

(10) θ-Attachment: The θ-criterion attempts to apply at every point during processing given the maximal θ-grid.

This principle is meant to ensure that, when a θ-assigner is lexically identified during processing, its maximal θ-grid is recovered from the lexicon, and subsequently an attempt is made by the processor to match available θ-roles and potential arguments locally in accordance with the θ-criterion at every point throughout the parse. That is, the processor avoids having either undischarged θ-roles or non-θ-marked targets available locally at any stage during processing. Consequently, when a θ-role is available, it will be discharged onto any available target, and when a target is available, it will assume any available role. In other words, the target will be attached into the parse tree in an argument position so as to receive the θ-role in accord with independent principles of the grammar.[4] Consider very briefly how a simple non-garden path example is processed in accordance with this principle:

(11) Without her contributions we failed.

[3] See Pritchett 1987 for empirical evidence in support of this claim as well as a fuller discussion of all of the issues raised in this paper.

[4] For a general introduction to theta theory see Chomsky 1981. For a detailed a discussion of the structural conditions under which θ-roles are assigned, see Chomsky 1986. The term θ-grid is adopted from Stowell 1981, but is here intended in its most general sense only to specify the set of semantic roles, such as AGENT, PATIENT, or THEME, which may be assigned by a given θ-role assigner, typically a verb or preposition. The characterization of θ-Attachment in 10 is compatible with several common views of thematic role assignment, including Stowell 1981 and Williams 1981.

Initially, *without* is identified as a preposition and its θ-grid recovered from the lexicon. *Without* assigns a single θ-role, but no potential argument is at this point available, so the role cannot be discharged. Next, the element *her* becomes available and is identified as an NP. Since *without* has available a θ-role to assign and *her* is available as a target, the principle of θ-Attachment ensures that *her* is attached in a configurational position so as to receive the available θ-role, adopting perhaps the standard assumption that θ-roles are assigned to sisters under government. Consequently, *her* is attached as the object of the preposition. Next, *contributions* is identified as an NP. The processor then has two options: *contributions* could be left without a θ-role in local violation of the θ-criterion (as no additional roles are available), or a larger NP $[her\ contributions]_{NP}$ could be built. This latter option is selected in accordance with θ-Attachment as it locally fulfills the θ-criterion. *Without* is still able to discharge its role, and no NP is left roleless. *Contributions* receives its role from *without* as head of the NP and *her* receives its role from its structural position (or possibly from *contributions*). Next, the NP *we* is encountered. No θ-role is available, as *without* has already discharged its role onto *her contributions*; no grammatical NP $[her\ contributions\ we]_{NP}$ can be built, and no other θ-assigners are available. This results in an unavoidable local violation of the principle of θ-Attachment (with *we* remaining locally roleless), and, as such, is not costly. Finally, when the string *fail* is processed, a θ-role is made available and assigned to the NP *we*, which is attached as the subject, and the parse is completed without difficulty.

Initially it is tempting to hypothesize that all sentences which have interpretations inconsistent with the initial assignments forced by θ-Attachment present processing difficulty, and a garden path sentence very similar to 11 appears to provide evidence for this point of view:

(12) GP: Without her contributions failed to come in.[5]
(Without her the contributions failed to come in.)
(cf. Without him contributions failed to come in.)

It is not obviously compatible with an approach (such as that of Marantz 1984) in which the external argument role is assigned compositionally by VP and is thus unavailable until the point at which entire VP has been identified. I am indebted to John Whitman (personal communication, 1988) for this observation. Notice that, just as is increasingly true within GB theory, this approach to processing need make no reference to phrase structure rules (cf. Stowell 1981, Whitman 1986, and references therein).

[5] There is no doubt that garden path sentences can be disambiguated, to varying degrees, given intonational cues (or written punctuation). Thus, for instance, sentence 12 would be greatly improved with a strong pause between *her* and *contributions*. What is crucial is that in the absence of such cues certain locally ambiguous structures such as 11 never present processing difficulty, while others such as 12 do. Furthermore, although prosodic information may aid in the avoidance of garden path effects, it cannot force processing difficulty in what we will characterize as non-GP environments. For example, strong relative clause intonation (whatever it may be) may assist in disambiguating sentences such as (i), but that same intonation, misapplied to sentences such as (ii), will not result in a garden path.

(i) The mortician told [the mourners he was having trouble with] to get out.
(ii) The mortician told the mourners he was having trouble with the graves.

As in 11, *without* is first identified as a preposition and hence as a θ-role assigner. Next, *her* is identified as an NP. Since a θ-role is available from *without*, θ-Attachment ensures that *her* receives the role, as the alternative would produce an avoidable local violation of the θ-criterion with *her* left locally roleless. At the next stage, *contributions* is encountered. Again, this string could be analyzed as a full NP in itself or integrated into a larger NP, *her contributions*. If the former option were pursued, θ-Attachment would be violated, as *contributions* would be left without a θ-role. The alternative, however, satisfies the principle since the entire NP *her contributions* receives a θ-role and no NPs are left unassigned. At the next stage, *fail* is processed and an additional θ-role becomes available which must be assigned to subject position. No target is available, however, forcing syntactic reanalysis. The NP *her contributions* must be reanalyzed in order to obtain a subject for *fail* and in this instance this reanalysis indeed appears to result in processing difficulty. This contrasts with sentence 11, where the roleless NP *we* was available to receive the external argument role, and seems to support the hypothesis that any reanalysis inconsistent with the assignments initially determined by the principle of θ-Attachment is problematic. Notice, though, that we have ignored an important detail: 11 as well as 12 actually necessitated a syntactic reanalysis. In both of those sentences, the NP *her* was originally attached as the NP object of the preposition *without* but subsequently reanalyzed as the specifier of the NP *contributions,* receiving a new θ-role (POSSESSOR) in the process. If all reanalyses inconsistent with the structural assignments originally made in accordance with θ-Attachment were truly problematic, both sentences should have presented processing difficulty, but this was not the case.

Even more seriously, misattachment and reanalysis precisely parallel to what we considered the problematic case in 12 are required in the completely unproblematic example 13:

(13) We know her contributions failed to come in.

When *know* is encountered, its θ-grid is recovered, indicating that it assigns both an AGENT and a PATIENT role. The AGENT role is assigned to *we*, leaving only a single role, PATIENT, undischarged. Subsequently, *her* is encountered and assigned the PATIENT role in accord with θ-Attachment. Immediately thereafter *contributions* is processed and incorporated into the larger NP *her contributions* in order to avoid local violation of the θ-criterion, just as in the previous examples. The appearance of *fail* forces syntactic reanalysis, as above, with *her contributions* no longer attached as the object of *know* but as the subject of *fail*. However, the restructuring required here is not problematic. It seems clear that syntactic reanalyses inconsistent with the initial assignments made in accord with θ-Attachment are not necessarily problematic. This leads us to propose the following constraint on syntactic restructuring. Crucially,

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Crucially, no intonational cues are needed to interpret (ii), which is easily processed in neutral speech or even given the wrong prosodic pattern, while intonational cues are required to prevent GP effects in sentence (i). See Pritchett 1987 for a fuller discussion of such effects with respect to both prosodic and semantic information.

this constraint is based entirely on grammatical principles and not upon putative independent principles of performance.[6]

(14) Theta Reanalysis Constraint: Syntactic reanalysis which interprets a θ-marked constituent as outside of its current θ-domain is costly.

This in turn necessitates a simple definition of θ-domain:

(15) θ-domain: α is in the α θ-domain of β iff α receives the γ θ-role from β or α is dominated by a constituent that receives the γ θ-role from β.

Now reconsider our previous examples. In sentence 12, when *fail* is encountered, the reanalysis necessitated removes the NP *contributions* from the θ-domain of *without*: the NP no longer receives the θ-role from *without*, nor is it dominated by a constituent which receives the role. On the other hand, the reanalysis required in 13 does not violate the Theta Reanalysis Constraint. Though the NP *her contributions* is reinterpreted as the AGENT of *fail* rather than the PATIENT of *know,* it remains within the PATIENT θ-domain of *know* as it is the subject of a clause which itself receives the PATIENT θ-role. Crucially, it is not the assignment of a new θ-role which results in processing problems (this occurs in both the problematic 12 and the unproblematic 13), but reanalysis as outside a current θ-domain (this occurs only in 12). The domain in which syntactic reanalysis during processing is not problematic is therefore characterized in terms of notions derived directly from grammatical theory.

Consider now a sentence which is structurally parallel to 13 but which nevertheless is a GP:

(16) GP: I warned her mother loathed me.
(I warned her that mother loathed me.)
(cf. I warned him mother loathed me.)

Initially, *I* is identified as an NP. Since no θ-assigner is available, there is an unavoidable violation of θ-Attachment, which is not problematic. Next, *warn* is identified and its θ-grid recovered. It may assign maximally one external and two internal roles: AGENT, GOAL, and PROPOSITION. At this point, the AGENT role is assigned to *I*. Next, *her* is encountered and, in compliance with θ-Attachment, assigned the GOAL role.[7] Immediately thereafter, *mother* is iden-

[6] Specifically, it is based on the θ-criterion as extended to processing theory by 10 and upon the principle of θ-role assignment under government. The relation of θ-domain in 15 does not have a direct counterpart in grammatical theory.

[7] Within GB Theory itself, the relevance of the semantic content of θ-roles to syntax is controversial. In the case of *know* versus *warn,* for instance, *know* assigns an external role—call it AGENT—and one and only one internal role—call it PATIENT—which may be realized either as an NP (i.a) or as an S′ (i.b), but not as both simultaneously (ii):

(i) a. I know Bill.
b. I know Bill is a fool.
(ii) *I know Bill Mary is a fool.

The verb *warn*, on the other hand, assigns one external role and up to two internal roles—namely, GOAL as in (iii), and PROPOSITION as in (iv–v):

(iii) I warned Mary.
(iv) I warned that the criminal was after her.
(v) I warned Mary that the criminal was after her.

tified, and the larger NP *her mother* is constructed and marked as GOAL. Failure to build [*her mother*]$_{NP}$ would leave the NP *mother* without a θ-role in local violation of the θ-criterion. This reinterpretation of *her* as a specifier does not violate the constraint on reanalysis since *her* remains within the GOAL domain of *warn*, though as a POSSESSOR. The processing of *loathe* reveals the existence of an external argument role which must be assigned. This requires syntactic reanalysis, and *mother* must be moved outside the GOAL θ-domain of *warn* and attached as subject of the PROPOSITION *mother loathed me*. This S′ is of course not within the GOAL domain as it neither receives the GOAL role nor is dominated by any constituent which receives that role. The Theta Reanalysis Constraint is violated and the result is a garden path sentence.[8]

2. CURRENT APPROACHES TO ATTACHMENT AND GARDEN PATH PHENOMENA. Any psychologically valid model of human language parsing must predict processing breakdown in just those cases in which humans fail to obtain correct interpretations for grammatical input strings. In the previous section the GP phenomenon was defined and exemplified and an outline of a grammar-based treatment of this class of data was sketched. In this section I will demonstrate that existing approaches to processing are completely incapable of handling the range of GP data and hence are indefensible as models of human language

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It is the number of θ-roles assigned, not the content of these roles, that is the crucial distinction between these two verbs. However, in order to facilitate discussion, through §3 I will refer to θ-roles by their traditional labels, such as AGENT, PATIENT, and THEME. Furthermore, as a working assumption, I will assume that the role PROPOSITION may only be assigned to a sentence-like element, perhaps triggered by INFL or perhaps for semantic reasons as suggested by Chomsky 1986. The reader should be careful not to be confused, though, by the labelling of the S′ complement of *know* as PATIENT and that of *warn* as PROPOSITION. Nothing in the approach depends on the fact that a certain verb might actually assign a PATIENT rather than THEME, or an EXPERIENCER rather than AGENT role—it is the number of distinct roles (arguments) which is crucial. In §4, all reference to the content of θ-roles will be eliminated, and this will in turn motivate a very desirable and natural extension of the general parsing theory, which will be discussed in some detail.

[8] It has been suggested that sentences such as 16 are strange simply because *warn* might not allow deletion of the *that* complementizer, while verbs such as *know* and *believe* do permit this deletion. A sentential-complement interpretation of 16 is therefore difficult to obtain during processing simply because it would violate selectional features of the verb. Notice, however, that the absence of *that* does not invariably lead to GP effects:

(i) (?)I warned she would do it.
(ii) (?)I warned John Professor Smith was out to get him.

Even if there actually is a preference not to delete the *that* complementizer, these sentences are clearly not garden paths. Additionally, GP effects identical to those encountered with *warn* occur with verbs which do freely allow the deletion of *that*:

(iii) I convinced Bill Mary was a fool.
(iv) I persuaded Bill Mary was a fool.
(v) GP: I convinced her mother was a fool.
(vi) GP: I persuaded her mother was a fool.

Consequently, we cannot ascribe the GP effects encountered with *warn*-type verbs and the contrast with *know*-type verbs to simple surface violations of selectional features.

comprehension.[9] In §3 I will discuss in detail how these data are to be accounted for given the grammar-based approach outlined above.

2.1. PSYCHOLOGICAL ACCOUNTS. One pervasive approach to processing is characterized by the attempt to formulate human parsing strategies in terms of grammar-independent perceptual mechanisms—so-called attachment strategies—which determine the default or preferred locus for the connection of a constituent into the parse tree, given a local syntactic ambiguity. Well-known formulations of such attachment strategies include Bever's 1968 Canonical Sentoid Strategy, Kimball's 1973 seven surface structure parsing principles, and Frazier & Fodor's 1978 Sausage Machine, to name only a few. I will consider Frazier & Rayner's 1982 model, which is representative of approaches of this sort and is unusual only in postulating a rather explicit strategy for the recovery from initial misanalyses.

Frazier & Rayner 1982 recognize the fact that the parsing strategies discussed throughout the psycholinguistic literature fail to lead to the correct parse in a large number of instances—and could thus be said to lead the processor down the garden path. They further correctly note that not all of the sentences which are initially misanalyzed by processors employing these principles do indeed induce the garden path effect. Consequently, the authors suggest that there must be one or more independent principles which allow the parser to recover from the initial misanalysis in certain instances but not in others. The actual processing strategies that they adopt are Late Closure and Minimal Attachment. The former principle stipulates that the parser admit newly encountered terminal elements as members of the phrase currently being processed if this is syntactically permissible. For example, though a phrase such as *Mary sang* could be closed as an S, this principle maintains that there will be a preference to keep it open and to admit subsequently occurring material into the phrase. Consequently, if an NP (e.g. *a song*) were next encountered, it would be attached as object, yielding *Mary sang a song*. The second principle, Minimal Attachment, stipulates that ambiguous attachment possibilities are to be resolved in favor of attachment to the nodes already postulated in such a way that the smallest possible number of nonterminal nodes is introduced into the tree. Thus in a globally ambiguous example such as 5, the attachment of the PP directly to VP, rather than Chomsky-adjoined to NP (creating an additional node), is predicted to be preferred. The former option would introduce no new nodes beyond the PP, while the latter would introduce the additional higher NP node.[10]

[9] In this paper, for reasons of length, I will restrict my attention to theories of processing which may be roughly characterized as syntactic. There is of course also a tradition which attempts to characterize processing phenomena in terms of semantics, pragmatics, and real world knowledge (cf. Milne 1982, Crain & Steedman 1985, and Carlson & Tannenhaus 1988). See Pritchett 1987 for detailed arguments that such accounts are incapable of characterizing the class of GP phenomena.

[10] Informally, these principles are simply intended to ensure that newly encountered material is (1) attached to structure which has already been created (Late Closure), and (2) attached to that structure as directly as possible (Minimal Attachment).

Frazier & Rayner note that these strategies will correctly predict the garden path effect of 18 and its absence in 17:

(17) Since Jay always jogs a mile this seems like a short distance to him.
(18) GP: Since Jay always jogs a mile seems like a short distance to him.
(Since Jay jogs always a mile seems like a short distance to him.)
(cf. Since Jay never coughs a mile seems like a short distance to him.)

The NP *a mile* will be attached into the VP rather than into the as yet unpostulated S by a combination of Late Closure and Minimal Attachment. However, these same strategies make incorrect GP predictions (indicated by brackets) in many cases:

(19) The city argued the mayor's position forcefully.
(20) [GP:] The city argued the mayor's position was incorrect.
(21) [GP:] The linguists knew the solution to the problem would not be easy.
(22) [GP:] John suspected Bill was planning a murder.

The GP effect is predicted, but not present, in 20–22, since the NPs right-adjacent to the verbs will initially be attached as objects. Frazier & Rayner recognize this incorrect prediction and suggest that some independent principle of selective reanalysis must license recovery in these instances. They hypothesize that recovery is facilitated by the availability of an NP constituent to serve as the subject of the subsequently encountered clause, and that this renders the reanalysis unproblematic.[11] Consider how they would account for the paradigmatic GP:

(23) GP: The horse raced past the barn fell.

The strategies of Late Closure and Minimal Attachment initially provide an analysis of the phrase as a main rather than as a relative clause in order to avoid postulating the extra NP node required to dominate the relative construction. When *fall* is encountered, the correct NP constituent [*the horse raced past the barn*]$_{NP}$ is not available to serve as its subject, predicting the unrecoverable GP effect. In contrast, in examples such as 20–22, NPs are available to serve as subjects of the forthcoming clauses; they have simply been misattached as objects. Consequently, recovery is predicted to be possible, allowing the GP effect to be avoided.

However, contrast 20–22 with the following severe garden paths:

(24) GP: Without her contributions would be impossible.
(Without her, obtaining contributions would be impossible.)
(cf. Without him contributions would be impossible.)

[11] A similar procedure for recovering from initial misanalyses is implemented via the 'steal' action in Abney's 1986 very interesting 'licensing parser', where the same problems with respect to GPs are encountered.

(25) GP: While Mary mended a sock fell on the floor.
(A sock fell on the floor while Mary mended.)
(cf. While Mary coughed a sock fell on the floor.)
(26) GP: Mary warned Bill was planning a murder.
(Mary warned that Bill was planning a murder.)
(cf. Mary warned he was planning a murder.)

All three of these sentences will be initially misanalyzed following Frazier & Rayner's principles. However, in every single case here Frazier & Rayner's reanalysis strategy also predicts successful recovery from these attachments, in just the same way it does for sentences 20–22 and indeed for their own sentence, 18. In 24, *contributions* is available as a misattached NP to serve as the subject of the subsequent clause, just as *the solution to the problem* is available to serve as subject in 21 or *Bill* is available in 22. Frazier & Rayner's simple recovery strategy is clearly incapable of explaining these contrasts. From a surface-structure perspective, parallel misattachments and reanalyses result in processing difficulty in certain instances (24–26) but fail to do so in others (20–22).

Minimal Attachment is the generally accepted attachment strategy in the psycholinguistic literature. In addition to being stipulative, it clearly makes the wrong predictions in a wide variety of cases. Unfortunately, Frazier & Rayner's recovery procedure is incapable of correcting its defects. Clearly, these principles form an inadequate model of human language processing, as they fail to reflect actual human performance.[12]

2.2. DETERMINISTIC APPROACHES TO GARDEN PATH PHENOMENA. Marcus 1980 points out that it had generally been assumed, given the existence of linguistic ambiguity, that natural language must be parsed nondeterministically (or rather by simulated nondeterminism via either backtracking or parallel processing). In the case of parallelism, all possible parses of a particular sentence are built up simultaneously, and those which fail to be globally acceptable are discarded. In backtracking, the processor explores various hypotheses sequentially based on some heuristic (such as Late Closure and Minimal Attachment), abandoning those structures that fail and restarting at an earlier stage of the parsing process. Since, as has just been shown, humans are able to deal with much local ambiguity without difficulty, it would seem necessary that parsing be nondeterministic: there must be ways of altering structural assignments built during processing, of abandoning incorrect structure after it is formed. Otherwise, if local decisions could not be revoked, we would expect constant processing difficulties. Marcus, in contrast, hypothesized that natural language could indeed be parsed deterministically from left to right—that the assignment of structure, once made, could never be undone via backtracking. He maintained, in other words, that at every point during processing there would be a single

[12] Restricting her experimental data primarily to a limited set of coördinate constructions, Frazier 1987 claims to find evidence of the Minimal Attachment strategy in verb-final clauses in Dutch. See Pritchett 1988 for a detailed discussion of processing and garden path effects in Japanese, a true verb-final language, as well as for an analysis of Frazier's claims concerning Dutch.

legitimate path which the processor could follow. The primary computational motivations for favoring determinism are based on the memory and processing load imposed by parallelism and backtracking, as well as on the fact that deterministically processable languages form a proper subset of nondeterministically processable ones. In the discussion which follows, I will be more concerned with whether a version of the determinism hypothesis can provide an accurate model of human processing performance.

In order to account for the fact that some local ambiguity during processing is not problematic, Marcus claimed that a deterministic parser must have some look-ahead capability. It is crucial to note, as Marcus points out, that this look-ahead must be constrained in some fashion, for otherwise, if the parser can look ahead to the end of the sentence, there is obviously no content to the notion of determinism. The unique aspect of Marcus' parser is not merely that it incorporates look-ahead, but that the size of the look-ahead is constrained in terms of constituents rather than absolute elements. This look-ahead capability (or buffer) itself may hold up to three grammatical constituents whose place of attachment (or 'higher grammatical function') is still unknown. Marcus considered garden path sentences to provide evidence for his version of the determinism hypothesis. Garden paths, he claims, are problematic precisely because the determinism hypothesis is correct: they are sentences which cannot be parsed deterministically with a constituent buffer of three elements. Marcus claims that his parser, PARSIFAL, breaks down in GP contexts just as people do, providing evidence for the model's psychological reality. Consider first how Marcus' model would predict a GP effect in classical garden paths. According to Marcus, in a sentence such as *The boat floated down the river sank,* after *the boat* has been processed as an NP and attached to S, the buffer will hold the following three constituents:

(27) $\langle$floated$\rangle_{V}$ $\langle$down$\rangle_{P}$ $\langle$the river$\rangle_{NP}$

The final verb *sink* is not visible to the processor, and the rule which matches a main clause will be satisfied. When *sink* is subsequently encountered, reanalysis will be required. Since the abandonment of structure is not allowed, the processing which is required to obtain the correct interpretation will be conscious and nondeterministic (and beyond PARSIFAL's capacity), predicting great processing difficulty. Certain odd assumptions are involved even in this example. First, it is not at all clear why *down the river* does not enter the buffer as a constituent PP in the same way that *the boat* enters as an NP. Marcus' motivation for this actually seems to have been to account for the GP effect in these instances. He maintains that NPs enter the buffer as NPs because their 'leading edges' are usually clearly defined by determiners. However, this argument would seem to apply far more strongly to PPs, which always begin with one of the small class of prepositions. Consider further a variation of the above sentence:

(28) GP: The boat floated quickly sank.

After the subject NP has been processed, the buffer will contain 29:

(29) $\langle$floated$\rangle_{V}$ $\langle$quickly$\rangle_{ADV}$ $\langle$sank$\rangle_{V}$

Here the resolution of the ambiguity is clearly within the range of the look-ahead capability of PARSIFAL, as *quickly* doubtless occupies only a single buffer cell but the sentence is nevertheless a garden path. When we leave the realm of canonical GPs of the type Marcus focused on, the results are equally clear with other classes of GPs that we have seen:

(30) GP: Without ⟨her⟩$_{NP}$ ⟨money⟩$_{NP}$ ⟨would⟩$_{AUX}$ be hard to find.

(31) GP: While Tegan ⟨sang⟩$_{V}$ ⟨a song⟩$_{NP}$ ⟨played⟩$_{V}$ on the radio.

In 30, *would* is visible within the buffer while the NPs are being processed, revealing the need for a subject. In 31, after *while Tegan* has been processed, the buffer will contain the constituents shown, providing the disambiguating information. In all of these cases, the legitimate attachments are not ambiguous but processing difficulty results. It is therefore quite clear that Marcus' model cannot account comprehensively for garden path phenomena (see Briscoe 1983 and Fodor 1985 for further criticisms of the determinism hypothesis). In a variety of cases, it fails to predict processing difficulty which actually occurs. Given that there are GPs which should be parsable deterministically within Marcus' model, then at least this version of the determinism hypothesis is severely undetermined.[13]

2.3. LEXICAL APPROACHES TO GARDEN PATH PHENOMENA. Ford et al. 1982 propose an ostensibly simple account of garden path phenomena as part of their

[13] Building upon the framework of Marcus 1982, Marcus et al. 1985 outline a revised deterministic model for describing linguistic structures which they refer to as Description-Theory (D-theory). It shares several features with the monotonic dominance theory of Berwick & Weinberg 1985. Essentially, these theories allow the parser initially to encode less information concerning dominance relationships than do traditional tree-building parsers. The subsequent addition of information concerning dominance is not costly as long as previous structure is not destroyed. Consequently, recovery from certain structures which would lead a strictly deterministic tree-building parser down the garden path is possible. For example, due to ambiguities in PP attachment, the Marcus parser always attaches potential direct objects as objects and thus incorrectly predicts GP effects with sentential complements:

(i) a. [GP:] I know my aunt from Peoria died.
b. I know my aunt from Peoria.

However, when reanalysis of (i.a) occurs, information concerning dominance is added but no structure is destroyed, and the alteration is therefore not problematic for the D-theory parsers. Nevertheless, the D-theory and monotonic processors are incapable of accounting for contrasts of the following sort where the ambiguities in dominance are identical:

(ii) a. GP: I warned my aunt from Peoria died.
b. I know my aunt from Peoria died.

In both cases, when reanalysis occurs information concerning dominance is added, not lost, but the GP effect is present in only one of the cases.

Furthermore, we have seen that the primary problem with PARSIFAL is not that it fails to recover from garden paths, but that on the contrary it fails to correctly predict occurring GPs. The revisions introduced in D-theory do not alter the results on that data. For example, dominance predicate approaches to processing cannot explain the GP status of sentences such as *The doctor persuaded the patient that he was having trouble with to leave*. Initially, the *that* phrase is misanalyzed as a clause dominated by S. Reanalysis requires further domination by an NP but does not involve the loss of information, as it remains dominated by S. Recovery should not be problematic, but indeed it is.

more ambitious attempt to account for a variety of attachment preferences in English. The primary account of closure effects motivated by the authors is not extended to garden path phenomena. Indeed, they explicitly deny that reanalysis inconsistent with their primary attachment principles will be problematic (763): 'Reanalysis of phrasal structure without the need to recategorize a word may increase the complexity of local parsing decisions as measured by reaction times, but without perception of a garden path.' Rather, they propose the following specialized principle to account for GP phenomena: garden paths result when the stronger form of a lexical item must be rejected in favor of the weaker form in order to satisfy the functional compatibility requirements of the grammar. This is based upon their hypothesis that 'the various lexical forms of a given verb have different ''strengths'' or ''saliences'' ', and that 'the strongest form somehow determines the preferred syntactic analysis' (745). They state further that '[R]eanalysis which requires a new morphosyntactic analysis of a word within the functional structure of a completed constituent may cause a conscious garden path' (763). In other words, GPs result from certain forms of lexical (morphosyntactic) ambiguity, but the mere reanalysis of phrasal structure without the need to recategorize a word will not cause conscious GPs. For example, consider the following:

(32) GP: The boy got fat melted.

The initial functional structure is built based on *fat* as an adjective, its putative strong form, rather than as a noun. Subsequent recategorization as an N results in the GP effect. Similarly, in classic GPs of the type *The boat floated down the river sank,* the verb is first categorized as an active intransitive tensed verb (by stipulation) and this analysis must subsequently be rejected, requiring a new morphosyntactic (lexical) analysis of the verb. The garden path results from the necessity of this recategorization.

Though this approach is appealingly simple on the face of it, there are numerous problems. With respect to the canonical GP pattern, the sentence in 33 is a clear counterexample, as the lexical recategorization required is precisely the same as that necessitated in canonical GP structures, yet this sentence is not a garden path.

(33) The bird found in the store died.

Similarly, it is not clear why neither 34a nor 34b is a garden path sentence:

(34) a. I like green.
b. I like green dragons.

There are many other counterexamples where no obvious lexical recategorization is required:

(35) GP: I warned mother wielded an axe.
(I warned that mother wielded an axe.)
(cf. I warned he wielded an axe.)

(36) GP: While Mary was sewing the dress slipped to the floor.
(The dress slipped to the floor while Mary was sewing.)
(cf. While Mary was sewing she fell to the floor.)

(37) GP: The patient persuaded the doctor that he was having trouble with to leave.
(The patient persuaded the doctor with whom he was having trouble to leave.)
(cf. The patient expected the doctor that he was having trouble with to leave.)

Though none of the above examples involves the lexical recategorization of an argument—the NPs remain NPs and it is apparently their locus of attachment which is problematic—the garden path effects are strong. In response, Ford et al. might argue that lexical recategorization of the verb is involved and that it is this which is problematic. Supporting such a claim would require classifying each instance of a lexical item with a different complement structure as a different verb for these purposes. Ignoring the theoretical objections to such a move, it might be claimed, for example, that intransitive and transitive *sew* are different verbs, as are *warn* ⟨(SUBJ),(OBJ)⟩ and *warn* ⟨(SUBJ),(OBJ2),(SCOMP)⟩. Additionally, it would have to be stipulated that certain forms of the verb are preferred, just as the active intransitive interpretation of the verb *raced* is to be preferred over the past participle reading. As a result, recategorization which required a change in complement structure would be just as problematic as the recategorization of an active intransitive as a past participle.

This would be very similar to extending the authors' general account of attachment preferences to account for GP effects, a move explicitly rejected by Ford et al. Nevertheless, consider how this approach might be implemented. The authors maintain that the various lexical forms of verbs have different saliencies and that the form stipulated as 'strongest' determines the attachment preference. For example, the verb *want* putatively prefers the structure ⟨(SUBJ),(OBJ)⟩ over ⟨(SUBJ),(OBJ),(PCOMP)⟩ while in the case of *position* the situation is just the reverse.

(38) The woman wanted [the dress [on the rack]$_{PP}$]$_{NP}$.
(39) The woman positioned [the dress]$_{NP}$ [on the rack]$_{PP}$.

Such attachment preferences are to be accounted for by the interaction of the following two principles:

(40) LEXICAL PREFERENCES: If a set of alternatives has been reached in the expansion of a phrase structure rule, give priority to the alternatives that are coherent with the strongest lexical form of the predicate (Ford et al. 1982:747).
(41) FINAL ARGUMENTS: Give low priority to attaching to a phrase the final argument of the strongest lexical form of that phrase and to attaching any elements subsequent to the final argument. Low priority is defined here with respect to other options that arise at the end position of the element whose attachment is to be delayed (Ford et al. 1982:752).

The effect of these two principles is to keep the final argument (the rightmost argument specified in a lexical form) of the strong form of lexical items open

and its own higher attachment delayed, while closing nonfinal arguments earlier. The effects will vary by lexical item, since Lexical Preferences forces priority to be given to the strongest form. With respect to *want*, the principle of Lexical Preferences simply stipulates that ⟨(SUBJ),(OBJ)⟩ is the strong form. The Final Arguments strategy both delays the attachment of *the dress* to VP in 38 and attaches *on the rack* to the NP. In the case of *position*, ⟨(SUBJ),(OBJ),(PCOMP)⟩ is preferred: *the dress* in 39 is closed as a nonfinal argument and *on the rack* is attached to VP rather than NP.

Notice, however, that there are a number of empirical problems with this approach.

(42) The saleslady wanted [the dress]$_{NP}$ [on the rack]$_{PP}$.

Here the weaker interpretation ⟨(SUBJ),(OBJ),(PCOMP)⟩ appears to be favored simply due to a change in lexical item from *woman* to *saleslady*, and the sentence is certainly not problematic. If we equate the rejection of a stronger form in favor of a weaker form with morphosyntactic reanalysis, we make clear predictions concerning GP effects. Recall sentences 35–36. The approach which we are considering would claim that these GP effects result from rejecting stronger forms of the verbs in favor of weaker forms. Given the GP effects displayed, *warn* ⟨(SUBJ),(SCOMP)⟩, *sew* ⟨(SUBJ),0⟩ must be considered weak forms, but this will predict garden path effects in 43 and 44:

(43) [GP:] I warned he was wielding an axe.

(44) [GP:] Mary sewed for hours last Tuesday.

However, neither of these is a garden path. In these examples, a certain reading of Ford et al.'s principles drastically overpredicts GP effects. Additionally, there are examples in which strict adherence to their syntactic processing principles fails to predict occurring GP effects. Consider the sentence in 45:

(45) GP: I warned her mother was wielding an axe.

On the assumption that the strongest form of *warn* is ⟨(SUBJ),(OBJ2),(SCOMP)⟩, as in 46, sentence 45 should be processed without difficulty, according to Ford et al.'s established principles.

(46) I warned my friend they were out to get him.

The principle of Lexical Preferences stipulates that a parse consistent with ⟨(SUBJ),(OBJ2),(SCOMP)⟩ is to be pursued and in combination with Final Arguments should ensure the early closure of (OBJ2) and the early building of the final argument (SCOMP). When *mother* is encountered and its ambiguous attachment possibilities noted, Ford et al.'s strategies predict the closure of *her* and the attachment of *mother* as a constituent of (SCOMP), precisely the interpretation which people do NOT easily obtain. The correct parse should follow from the authors' principles; consequently, they wrongly predict that this sentence is not a garden path.[14] However, if their principles were altered and the (OBJ2) constituent closed late, explaining the incorrect inclusion of *mother*, sentences such as 47 could not be explained.

[14] Recall ex. 9, which clearly reveals that the determiner~argument ambiguity of *her* cannot itself be the source of the difficulty.

(47) GP: The patient warned the doctor he was having trouble with he should leave.

Again, if *warn* has a strong form ⟨(SUBJ),(OBJ2),(SCOMP)⟩, then the garden path is only predicted if *the doctor* is closed early and *he was having* parsed as an (SCOMP) rather than as a constituent of the NP. In 47 we wish the (OBJ2) of *warn* to be closed early in order to predict the GP effect, while in 45 it must be closed late in order to account for the processing difficulty. This contrast cannot be handled by this approach; hence, even when sentences are consistent with putative strong forms, parsing in accord with Ford et al.'s syntactic strategies remains incapable of accounting for the data. In light of these examples, there seems to be no coherent way of attributing the range of GP effects to lexical ambiguity.

3. A GRAMMAR-BASED ACCOUNT OF ATTACHMENT AND GARDEN PATH PHENOMENA. This paper has been concerned with examining the class of sentences in which the human language-processing mechanism suffers severe breakdown, to the point of being unable to assign a global grammatical interpretation to a grammatical input string. After sketching, in outline, a grammar-based approach to the garden path phenomenon, I turned to a survey of existing processing models and demonstrated how they were unable to account for the full range of garden path phenomena as any model of human processing must.

Recall now the principles of attachment and reanalysis, repeated here, which were suggested in §1:

(48) θ-Attachment: The θ-criterion attempts to apply at every point during processing given the maximal θ-grid.

(49) Theta Reanalysis Constraint: Syntactic reanalysis which reinterprets a θ-marked constituent as outside of its current θ-domain is costly.

(50) θ-domain: α is in the γ θ-domain of β iff α receives the γ θ-role from β or α is dominated by a constituent that receives the γ θ-role from β.

Let us now reconsider the data presented above in the discussion of alternative theories of parsing to see how the strategies advocated here, founded in grammatical theory, are capable of correctly predicting the data in a simple, direct, and unified fashion.

3.1. NP/PP~NP/S AMBIGUITY. Descriptively, the apparent problem with the sentences to be considered in this section is simply that what is initially postulated as an object of a preposition must later be reanalyzed as the subject of a subsequently encountered matrix clause. We begin by reconsidering an example originally discussed in §1.

(51) GP: Without her donations to the charity failed to appear.

(a) *Without* is recovered as a preposition. Its θ-role cannot at this point be discharged as no target is available. This is unproblematic.

(b) *Her* is identified as an NP and assigned a θ-role by *without*. The actual content of the role assigned is immaterial.

(c) *Donations* is admitted as an NP. At this point the processor could posit

either [*her*]$_{NP}$ [*donations*]$_{NP}$ or [*her donations*]$_{NP}$. Since *without* may only assign a single θ-role, the latter choice accords with the principle of θ-Attachment. It allows both *her* and *donations* to be θ-marked, as well as allowing the θ-role assigned by *without* to be discharged. Consequently syntactic reanalysis of *her* is required, and *her* is reinterpreted as the specifier of *donations*. However, this restructuring does not violate the Theta Reanalysis Constraint, as it does not involve reinterpreting *her* as outside its currently assigned θ-domain. Even though the NP *her* no longer receives its θ-role from *without,* it remains dominated by a constituent which does receive the θ-role from the preposition. Hence the reanalysis is not problematic.

(d) *To the charity* is admitted as a PP, with *the charity* receiving a θ-role from *to*, and Chomsky-adjoined to NP.[15]

(e) When *fail* is encountered, the previous analysis cannot be sustained, as no non-theta-marked NP is available to serve as its subject.[16] The only NP which, upon reanalysis, is able to fulfill this function is *donations to the charity*. The larger NP *her donations to the charity* is not available, since *her* must be left behind to serve as the object of *without*. Similarly, *the charity* is not available as it must remain as the object of *to*. Leaving either *without* or *to* without an object would result in each case in a global θ-criterion violation with neither preposition assigning a θ-role. Consequently, the only legitimate syntactic reanalysis must reinterpret *donations to the charity* as the subject of *fail*. This moves the NP completely outside of the θ-domain of *without,* since it will no longer receive a θ-role from that preposition nor be dominated by a constituent which receives the θ-role. This violates the Theta Reanalysis Constraint and results in a nearly unprocessable sentence. Notice that this example clearly demonstrates the contrast between syntactic ambiguity which is problematic and that which is not. The ambiguity of *her* as an NP or determiner does not lead to processing difficulty, while the subject~object ambiguity certainly does.

This point is made even more clearly by the lack of processing difficulty caused by sentences such as 9 or the following (punctuation omitted):

(52) I hate her sons dogs howling.

Here multiple syntactic reanalyses of specifiers and NPs are required during the parse, but the sentence is certainly not a garden path; the Theta Reanalysis Constraint is never violated.

The following sentence also presents no difficulty:

(53) Without her donations to the charity it failed to appear.

(a) *Without* is recovered as a preposition.

(b) *Her* is recovered as an NP and θ-marked by *without*.

(c) *Donations* is recovered as an NP and *her donations* is reanalyzed as an NP and θ-marked in keeping with θ-Attachment.

[15] How PP attachment is decided is not relevant to the GP phenomena to be discussed, though it too appears to be determined by grammatical principles. See Pritchett 1987 for a discussion of this issue.

[16] It would be more consistent with the general approach to say that no unmarked NP is available to receive the obligatory external argument role from *fail*, but for the remainder of this section I will generally continue to speak in more traditional and (I hope) neutral terms.

(d) *To the charity* is admitted as a PP and attached.

(e) *It* is admitted as an NP. There is no possible NP *[*her donations to the charity it*]$_{NP}$, and consequently *it* is not incorporated into the existing NP but left without a θ-role in a local and unavoidable violation of θ-Attachment (but crucially not of the Theta Reanalysis Constraint).

(f) *Fail* is encountered and *it* is assigned its θ-role. No violation of θ-Attachment occurs as *it* was never within another θ-domain.

Now consider a similar class of examples also involving subject~object ambiguities but displaying a set of more interesting contrasts.

3.2. NP/VP~NP/S AMBIGUITY. To begin again with a descriptive generalization, the sentences to be considered in this section involve ambiguous domination of NP by VP, as object, or by S, as subject.

(54) GP: Mary warned her mother hated her.

(a) *Mary* is identified as an NP. No θ-role is available and hence no further action can be taken. This is an unavoidable local violation of θ-Attachment and as such is not problematic.

(b) *Warn* is identified as a V and its maximal θ-grid is recovered. The verb may assign AGENT, GOAL, and PROPOSITION roles. *Mary* is assigned the external AGENT θ-role by *warn* at this point, in order to conform to θ-Attachment and not leave *Mary* locally without a role.

(c) *Her* is identified as an NP. It is assigned the GOAL role in accordance with our principles.

(d) *Mother* is identified as an NP. Rather than leaving *mother* without a θ-role in violation of θ-Attachment, syntactic reanalysis builds *her mother* as an NP to which the GOAL role is then assigned.[17] This does not violate the Theta Reanalysis Constraint as *her* remains within the GOAL θ-domain of *warn*.

(e) *Hate* is encountered and its θ-grid, indicating that it assigns AGENT and PATIENT roles, is recovered. Syntactic reanalysis is required as no NP is available to serve as subject (or, more accurately, no non-theta-marked NP is available to receive the AGENT role from *hate*). This syntactic reanalysis must reinterpret *mother* as outside of the GOAL θ-domain of *warn*, thus violating the Theta Reanalysis Constraint and producing the garden path effect.

Consider now a sentence which exhibits ambiguity exactly parallel to 54 but which is nonetheless not a garden path:

(55) Mary knew her mother hated her.

(a) *Mary* is identified as an NP but at this point can receive no θ-role.

(b) *Know* is identified as a V and its maximal θ-grid is recovered. This verb assigns at most two roles; call them AGENT and PATIENT.

(c) *Her* is identified as an NP and assigned the PATIENT role.

[17] It is important to note that the building of [*her mother*]$_{NP}$ as a constituent cannot be attributed to the statistical likelihood that *her* serves as a determiner. The garden path effect seen in 54 occurs in precisely the same fashion in sentences such as (i) (punctuation omitted), where *the boys* is clearly not more likely to be a determiner than an argument of the verb.

(i) GP: I warned the boys mother hated them.

(d) *Mother* is identified as an NP and, rather than violating θ-Attachment and leaving this NP locally without a role, syntactic reanalysis constructs [*her mother*]$_{NP}$, which is then assigned the PATIENT role. This reanalysis is unproblematic as *her* is not removed from its current θ-domain, still being dominated by a constituent which receives the PATIENT role.

(e) *Hate* is identified and its θ-grid is recovered. No NP is available to serve as its subject. Syntactic reanalysis must reanalyze *her mother* as the subject of *hate* rather than the object of *know*.

Syntactically, this is exactly parallel to the situation in 54 above in which *mother* was reanalyzed as the subject of *hate* rather than as the object of *warn*, as initially hypothesized. However, in this instance reanalysis is not problematic. While in 54 the reanalysis involves reinterpreting *mother* as outside of the GOAL domain of *warn* and within its PROPOSITION domain, here the NP *her mother* remains within the PATIENT θ-domain of *know* after the restructuring, as the entire clause receives that θ-role. Though *her mother* itself no longer receives the PATIENT role from *know,* it remains dominated by a constituent which receives that role. Notice too that the fact that *her mother* itself comes to receive a different θ-role (it becomes an AGENT) from a different θ-role assigner (*hate*) is NOT itself ruled problematic by the Theta Reanalysis Constraint. Crucially, upon reanalysis *her mother* remains within its current θ-domain, and there is consequently no garden path effect.[18]

Now consider the following examples, which also involve subject~object ambiguity, but where the ambiguity is between object of a lower clause and subject of a higher clause—rather than object of a higher clause and subject of a lower clause, as in the examples just considered.

(56) GP: While Mary was singing a song played on the radio.

(a) *Mary* is identified as an NP.

(b) *Sing* is identified as a verb and its θ-grid is recovered. It may assign AGENT, GOAL, and THEME roles.[19] *Mary* is assigned an AGENT θ-role.

(c) *A song* is identified as an NP and in accordance with θ-Attachment is assigned a role (THEME) by *sing*.

(d) *Play* is encountered and found to lack a subject. *A song* must be rean-

[18] It might be claimed that there is another difference between this pair of sentences which accounts for their varying status. In the reanalysis of [*her mother*]$_{NP}$ in 54, that NP must be split, *her* remaining the GOAL of *warn* and *mother* entering the AGENT domain of *hate*. In 55, on the other hand, the NP *her mother* remains a constituent under reanalysis. Thus it might be hypothesized that it is this syntactic splitting of an NP that is problematic. Since wherever there is such a splitting of NPs there will be also be a violation of the Theta Reanalysis Constraint, I cannot provide an example of unproblematic split. However, examples such as the following duplicate the GP patterns displayed in 54–55 and unequivocally demonstrate that such restructuring in itself cannot be the cause of the unprocessability.

(i) GP: Mary warned mother hated her.

(ii) Mary knew mother hated her.

[19] Since in §4 I will demonstrate that simple θ-role mislabellings such as GOAL for THEME or vice versa cannot be problematic, we will ignore here the possibility that GOAL is initially misassigned to *a song*.

alyzed as the subject of *play*. This reanalysis reinterprets *a song* as outside of the THEME domain of *sing*, since it neither receives a role from *sing* nor is dominated by a constituent which receives a role from *sing*. *A song* is reinterpreted as within a θ-domain of *play*, violating the Theta Reanalysis Constraint and resulting in a garden path.

Of course, the following sentence is not a garden path:

(57) While Mary was sleeping a song played on the radio.

(a) *Mary* is identified as an NP.

(b) *Sleep* is identified as a verb and its θ-grid is recovered. *Mary* is assigned an AGENT θ-role.

(c) *A song* is identified as an NP, but as *sleep* assigns no internal role, no θ-role is available to be assigned to *a song*.

(d) When *play* is encountered, *a song* is placed within a θ-domain of *play* as subject. There is no violation of the Theta Reanalysis Constraint. Though the point seems trivially obvious, this example does provide additional evidence that the parser is steered by lexical information, which is not a priori true.

There is a notion which sometimes appears implicit in the literature that raisings (in a processing sense) are more difficult than lowerings. This might be taken to predict the contrast between sentences such as 58 and 59:

(58) GP: While Mary sang a song played on the radio.

(59) Mary recognized her friends were fools.

Although, as discussed above, both sentences involve subject~object ambiguity, in the first case the syntactic reanalysis required involves raising an NP from a subordinate into a matrix clause, while the second example involves lowering an NP from a higher matrix clause into the subject position of a subordinate clause. It is clear that the differing behavior of the *warn* type versus *know* type verbs as in exx. 54–55 makes this impossible to maintain as the account of processing difficulty, since both cases involve simple lowerings but reveal an extremely strong contrast in processability.[20]

[20] The contrast in processability between sentences of the *know* and *warn* types reveals that the Theta Reanalysis Constraint cannot easily be restated simply in terms of government without reference to θ-marking, although such a move would be entirely consistent with the approach outlined in this paper. For example, one might hypothesize that the constraint on reanalysis should actually maintain that a constituent not be reanalyzed as no longer governed by its current governor. However, perfectly unproblematic reanalyses do violate this constraint:

(i) I hate the boys' dogs.

The NP *the boys* is first analyzed as a PATIENT which is governed by *hate,* but upon reanalysis it becomes the specifier of *dogs*, which is not governed by *hate,* given certain common definitions of government. Similarly, in tensed clauses *the boy* is first governed by *know* as an object but is reanalyzed as a subject governed by INFL:

(ii) I know the boy likes chess.

Since the lower clause is tensed, this is not an S′ deletion context, and *the boys* is arguably no longer governed by *know*. This point can be made even more clearly with predicates that never permit S′-deletion:

(iii) I doubt her story could be correct.

3.3. MAIN CLAUSE~RELATIVE CLAUSE AMBIGUITY. In this section we consider various examples of the canonical garden path pattern. Descriptively, of course, the problem with such sentences appears to result from the initial misanalysis of the first several words of the sentence as a matrix clause. Subsequently, syntactic reanalysis as a reduced relative is required, and this restructuring turns out to be costly. Consider then how the most famous example of a garden path sentence is parsed according to our principles:

(60) The horse raced past the barn fell.

(a) *The horse* is identified as an NP. Since no θ-role assigner is available, θ-Attachment cannot be satisfied at this point during processing.

(b) *Race* is recovered as a V along with its maximal θ-grid. It may assign both an AGENT and a PATIENT role. Two possible θ-role assignments could grammatically be made at this point during processing. *The horse* could receive the AGENT role from *race*, resulting in a main clause analysis, or the PATIENT role could be discharged on an empty category, leading to a reduced relative clause structure. For the moment, simply assume that the AGENT role is discharged and hence that a main clause analysis is pursued. We return below to the crucial issue of why this is so.

(c) The PP is processed: *the barn* receives its θ-role from *past*, and is attached to VP.

(d) At this point, the verb *fall* is encountered and its θ-grid is recovered. It assigns a single θ-role. The presence of *fall* is not compatible with the θ-role assignments which have been made up to this point, leading to the main clause analysis. Reanalysis is necessary and the result is extremely problematic. *The horse,* originally assigned an AGENT θ-role and hence within the AGENT θ-domain of the V (or possibly VP), must be reanalyzed as within a θ-domain of *fall*. As head of the relative clause, *the horse* will eventually receive the same θ-role as is assigned to the entire complex NP. Note that this NP does not receive the PATIENT role from *race*. The role is assigned to the empty category and hence to the chain which consists of the empty category and the (null) WH-

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This sentence shows no GP effects despite the fact *doubt* does not govern *her story* upon reanalysis, under many definitions. On the other hand, if one adopts the revisions of Chomsky 1986, then specifier position is governed and hence subjects of tensed clauses are governed by the governor of the clause. However, this crucially fails to capture the contrast between the *know* and *warn* types of cases, since, given this, in (iv) *the boys* would still be governed by the verb after reanalysis. The same point is also made by examples such as (v–vi):

(iv) GP: I warned the boys liked to play chess.
(v) GP: I sent the boys food to John.
(vi) GP: I sent the boys food some utensils.

In both of these cases (to be discussed in §4), upon reanalysis an NP will be moved to a position which is arguably governed by the verb; but these sentences are nevertheless GPs. It is also unclear what an analysis based solely on government would say about the GP status of sentences such as (vii):

(vii) GP: The boy persuaded the girl that he was having trouble with to leave.

Government seems to be crucial to the Theta Reanalysis Constraint insofar as it is relevant to θ-marking, but the constraint cannot obviously be formulated in terms of government alone.

word.[21] The interpretation of *the horse* as the entity being raced is derived through the coindexing of that NP and the WH-word in COMP. Thus, if the role assigned by *fall* is THEME, then *the horse*, originally within the AGENT domain of *race,* must be reanalyzed as within the THEME domain of *fall*. Bear in mind that it is not the necessity of receiving a new θ-role which is problematic, as I will further argue below, but the necessity of syntactic reanalysis which moves an NP out of its current θ-domain. In this example, *the horse* is reanalyzed as outside of the AGENT domain of *race* and within the THEME domain of *fall*. This violates our Theta Reanalysis Constraint and consequently results in a garden path.

We have seen how, on the assumption that the θ-role assignments consistent with a main clause analysis rather than a reduced relative clause analysis are initially pursued, a violation of the Theta Reanalysis Constraint results when the verb *fall* is ultimately encountered. What remains to be accounted for is why the main clause analysis rather than the relative clause analysis is initially pursued. If an independent principle were required to force this, the account would be vacuous and stipulative, but in fact, the principle of θ-Attachment as stated accounts for the preference for the main clause over the relative clause interpretation. Consistent with that analysis, if the PATIENT role were discharged on an empty category after *race,* the AGENT role could not be assigned to any NP, and consequently there would be no gain with respect to θ-Attachment versus the main clause analysis. In both cases only one of the available θ-roles would be discharged: AGENT in the case of the main clause and PATIENT in the case of the reduced relative. However, the θ-assignments consistent with the reduced relative clause analysis would also necessitate the building of a complex NP, consisting of the relative clause and its head, for which no θ-role is available. This would be a violation of the principle of θ-Attachment, which attempts to maintain a one-to-one mapping between NPs and θ-roles. Consider the structures and θ-assignments of each alternative analysis before *fall* is encountered.

(61) Main Clause Analysis:
[[The horse]$_{\text{NP-AGENT}}$ raced past the barn ...]
race: ⟨AGENT = discharged, PATIENT = unassigned⟩
NP = All NPs θ-marked.

(62) Complex NP Reduced Relative Analysis:
[[The horse]$_{\text{NP}=?}$ raced $\mathbf{e}_{\text{NP}=\text{PATIENT}}$ past the barn]$_{\text{NP}=?}$ ...]
race: ⟨AGENT = unassigned, PATIENT = discharged⟩
NP = *The horse,* unmarked. Complex NP = unmarked.

Clearly the main clause analysis, which leaves only a single role unassigned, is more consistent with θ-Attachment than the reduced relative analysis, which leaves one unassigned role and two unassigned NPs (the complex NP and its head). Consequently, in those instances when no θ-role is available and a phrase

[21] This point may be made even more clearly if one adopts an adjunct analysis of these structures. It then becomes the lack of a role for what we have been calling the head rather than for what was considered the complex NP itself which is crucial. I am indebted to Steve Abney for this observation.

may be analyzed as either a main clause (which need not itself be θ-marked) or a complex NP (which must be), the main clause analysis will be pursued. This is predicted by the principle of θ-Attachment.

Of course, in the case of parallel non-garden path sentences, the morphology on the first verb prohibits a main clause analysis, thus forcing an unavoidable violation of the θ-criterion attachment principle and interpretation as a reduced relative. This prevents the initial θ-role misassignments:

(63) The horse ridden past the barn fell.

(a) *The horse* is admitted as an NP.

(b) *Ride* is recovered as a V along with its maximal θ-grid, which allows the assignment of both an AGENT and a PATIENT. Given the morphological shape of *ridden, the horse* may not receive any θ-role, but the PATIENT role may be discharged on an empty category sister of *ridden*. The assignment of an AGENT role to *the horse* is not a locally grammatical possibility, given the morphology of the verb. A complex NP containing a reduced relative clause, *the horse ridden past the barn,* is built, though no θ-role is available either for it or for its head.

(c) The PP is processed with *the barn* receiving its θ-role from *past*, and it is attached to the VP.

(d) *Fall* is encountered and its θ-grid is recovered. Both the complex NP, *the horse ridden past the barn,* and the head of the relative, *the horse,* receive the THEME-role from *fall*. Since *the horse* was neither assigned a θ-role nor dominated by a constituent which received a θ-role, there is no violation of the Theta Reanalysis Constraint and the sentence is unproblematic.

Now consider a more complicated example which displays the ambiguous morphology of examples such as 60 but is nevertheless not a garden path:

(64) The bird found in the store died.

(a) *The bird* is admitted as an NP.

(b) *Find* is recovered as a V. For reasons identical to those discussed for 60, θ-role assignments consistent with a main clause rather than a reduced relative clause analysis are pursued. Postulating a reduced relative would leave the AGENT role undischarged, as well as leaving the complex NP and its head without a θ-role. On the other hand, assigning the AGENT role to *the bird* leaves only a THEME role undischarged and no NPs without roles.

(c) *In the store* is admitted as a PP. Here a crucial difference between *find* and *race* emerges; *find* is obligatorily transitive. Furthermore, this must be represented in the verb's θ-grid, as it is the only way of ruling out ungrammatical sentences such as **John found in the store*. *Find* must be transitive, and independent principles of the grammar locally recognize that no object will be forthcoming.[22] The crucial point is that the need for reanalysis becomes evident at the point that *in the store* is encountered. This contrasts strongly with the situation involving *race*, which, since it is not obligatorily transitive, does not have reanalysis forced upon it—reanalysis which would yield a local θ-theoretic

[22] As we will see in §4, it is likely that this can be ascribed to the application of principles of Case Theory, in particular the Case Adjacency Principle, at every point during processing.

loss. Consequently, it is at this stage that *the bird,* which has been assigned an AGENT θ-role by *find* and is thus within the AGENT θ-domain, must be reanalyzed as outside of that domain. This requires syntactic restructuring and appears to violate the Theta Reanalysis Constraint in a way similar to 60 above, which does result in a garden path.

(d) The verb *die* is encountered and both *the bird found in the store* and its head, *the bird,* receive a θ-role from *die*.

This initially appears problematic: we evidently incorrectly predict this sentence to be a garden path, as the reanalysis required is of the same type as in the unprocessable 60 above. However, there is a clear difference between the reanalyses required in 60 and in 64. In the latter example, when the reanalysis occurs the reanalyzed NP, *the bird,* is not reinterpreted as being within any existing θ-domain. At the point when *in the store* is encountered and reanalysis is forced, *the bird* will not immediately receive a new θ-role; nor will it be attached as dominated by a constituent which currently receives a θ-role, because the verb of the matrix clause, *die*, has yet to be encountered. *The bird* itself does not receive a role from *find* immediately upon reanalysis. Eventually it will receive a role as the head of the relative clause, but crucially that role is not available at the point when reanalysis occurs. This prompts a minor revision in the Theta Reanalysis Constraint:

(65) Theta Reanalysis Constraint (revised): Syntactic reanalysis which reinterprets a θ-marked constituent as outside of its current θ-domain and as within an existing θ-domain of which it is not a member is costly.[23]

A θ-domain is considered to exist if the θ-assigner responsible for the domain has been encountered. Consequently, sentence 64 is not predicted to be a garden path, since, at the point when reanalysis occurs, *the bird* is not moved into an existing θ-domain. Notice that this account of 64 correctly predicts 66 to be a garden path sentence, as reanalysis is forced by *die,* and *the bird* therefore is moved into an existing θ-domain. And, even though reduced relative clauses which are this light are only marginally grammatical in English, 66 is certainly far more difficult to process than 67:

(66) GP: The bird found died.

(67) ?The bird eaten died.

Consider now how a related sentence involving heavy NP shift is to be handled:

(68) The bird found in the store a hundred pound sack of seed.

(a) *The bird* is admitted as an NP.

(b) *Find* and its grid are recovered, making AGENT and THEME roles available.

The structure is ambiguous, but the ambiguity is resolved in favor of assignment

[23] The clause 'of which it is not a member' is necessary to account for non-garden path sentences such as *I remember the bird found in the store died.* At the point when *in the store* is encountered, *the bird* will be reanalyzed as outside of the previously assigned AGENT domain of *find* and within an existing θ-domain—that of *remember*. However, this is not costly as *the bird* is already a member of that domain.

of the agent role to *the bird* for reasons identical to those given for the previous examples.

(c) *In the store* is processed and, as in the previous example, independent principles of the grammar (most likely the Case Adjacency requirement) determine that no object is forthcoming. Since *find* requires an obligatory PATIENT, reanalysis takes place. However, *the bird* does not enter into an existing θ-domain (it becomes the roleless head of the relative), and the Theta Reanalysis Constraint is not violated. The THEME role is assigned to an empty category adjacent to *find*.

(d) An NP is processed, making an object available, and re-analysis is required. Though *the bird* is again reinterpreted, this time as within the AGENT domain of *find*, it is not analyzed as outside of any existing θ-domain at this point, since both it and the relative clause of which it is the head lack a θ-role. The NP *a hundred pound sack of seed* receives its θ-role through the chain it forms with the empty category adjacent to *find*. There is no violation of the Theta Reanalysis Constraint and no garden path effect even upon this second reanalysis.

3.4. COMPLEMENT CLAUSE~RELATIVE CLAUSE AMBIGUITY. In the examples to be considered here, the descriptive problem is apparently the initial misanalysis of an NP ...S′ sequence as an object NP followed by a complement clause rather than as a relative clause.

(69) GP: The patient persuaded the doctor that he was having trouble with to leave.

(a) *The patient* is admitted as an NP, but at this point no θ-role is available to be assigned to it.

(b) *Persuade* is identified as a V and its θ-grid is recovered. It maximally assigns AGENT, GOAL, and PROPOSITION roles. The AGENT role is assigned to the NP *the patient*.

(c) *The doctor* is identified and receives the GOAL role in accord with the principle of θ-Attachment.

(d) The string *that he was having trouble with* is locally ambiguous and could be attached as either a complement clause or the clausal component of a relative clause whose head is *the doctor*. However, the principle of θ-Attachment forces the discharge of the PROPOSITION role and consequently the attachment of the S′ as a complement. In this fashion, θ-Attachment is maximally satisfied, since a role (PROPOSITION) which would otherwise remain locally unexpressed is assigned. The relative clause attachment would yield no gain with respect to θ-Attachment, since the ambiguous string would merely enter the already existing GOAL domain of *persuade*.[24] The relative clause analysis is avoided in this instance not because a locally non-theta-marked NP would be constructed but

[24] Notice that this example clearly reveals the contrast between my approach, which attempts to satisfy principles of grammar such as the θ-criterion, and an approach which attempts to interpret each local substring as grammatical (such as might be implemented via pattern matching, for example). In that case, one would expect the relative clause interpretation to be primary, as the string *the doctor that he was having trouble with* is a grammatical relative clause, though not a grammatical NP ... S′ sequence. This is clearly the wrong prediction.

because a θ-role which could otherwise be assigned would be left locally undischarged.

(e) When *to* is encountered, *with* is left without an object and hence cannot discharge its θ-role. The complement clause analysis cannot be maintained and the previous structure must be reanalyzed as a relative clause. This reanalysis reinterprets the θ-marked PROPOSITION *that he was having trouble with* as outside of its original PROPOSITION θ-domain and within the existing GOAL θ-domain, thus violating the Theta Reanalysis Constraint and yielding the garden path effect. The very similar garden path sentence in 70 demonstrates that the GP effect is not somehow tied to problems of control, as here the reanalysis is forced by a tensed complement clause.

(70) GP: The patient persuaded the doctor that he was having trouble with that he should leave.

Examples such as 71 are of course unproblematic, as they involve a single internal θ-role:

(71) The patient expected the doctor that he was having trouble with to leave.

(a) *The patient* is admitted as an NP lacking a θ-role.

(b) *Expect* is identified and its θ-grid is recovered. *Expect* may assign only a single internal θ-role in addition to the external EXPERIENCER role.

(c) *The doctor* is marked as THEME.

(d) In contrast with our examples above, *that he was having trouble with* is not ambiguous between a complement and relative clause in this example, since *expect* has no PROPOSITION role to assign in addition to its THEME role. Consequently, the string is attached as the clausal component of a relative clause headed by *the doctor*. This attachment does require syntactic reanalysis, but the restructuring does not reinterpret *the doctor* as outside of its current THEME θ-domain; it remains the head of a relative clause which receives the THEME θ-role as *the doctor* itself originally did (and will also inherit as head of the complex NP).

(e) When *to leave* is processed, the entire complex NP, including the relative clause and its head, must be reinterpreted as its subject (and as receiving its θ-role from *leave,* though it receives Case from *expect* on an Exceptional Case Marking analysis). However, parallel to the examples discussed above involving verbs like *know,* the entire constituent *the doctor that he was having trouble with to leave* receives the THEME role from *expect*, and hence both the relative clause and its head remain within the THEME domain. Consequently, there is no violation of the Theta Reanalysis Constraint.

Now consider another example which again involves *persuade* but which displays no garden path effects:

(72) The patient persuaded the doctor that he was having trouble with his feet.

(a) *The patient* is admitted as an NP.

(b) *Persuade* is identified as a V and its θ-grid is recovered. An AGENT role is assigned to *the patient*.

(c) *The doctor* receives the GOAL θ-role.

(d) In accord with the principle of θ-Attachment, the PROPOSITION role is discharged on the ambiguous string *that he was having trouble with,* which is therefore attached as a complement.

(e) *His feet* receives a θ-role from *with*. This is consistent with the previous assignment of the PROPOSITION role and hence with the attachment as a complement clause. No restructuring is required, so there is no violation of the Theta Reanalysis Constraint.

Examples such as the following reveal even more strikingly that it is the initial pursuit of a complement clause analysis which is problematic.

(73) GP: The patient persuaded the doctor that he was taking great pains with.

The eventual lack of a target for the θ-role assigned by *with* forces reanalysis, and the string *that he was taking great pains with,* initially marked as PROPOSITION, must be reanalyzed as within the existing GOAL θ-domain, resulting in a garden path sentence.

3.5. DOUBLE OBJECT AMBIGUITIES. The sentences to be considered here involve a variety of ambiguities found when one of the arguments of a ditransitive verb[25] is a relative clause, which may itself contain a transitive verb. GP effects vary, depending on whether an object or a subject relative is involved.

(74) GP: I gave the boy the dog bit a bandage.

(a) *I* is identified as an NP.

(b) *Give* is identified as a V and its maximal θ-grid is recovered. The verb may assign AGENT, GOAL, and THEME roles.

(c) *The boy* is identified as an NP. It is assigned a θ-role, GOAL.

(d) *The dog* is identified as an NP. It must be assigned the THEME role. Thus the parser has now identified this structure: I_{AGENT} *gave the boy*$_{\text{GOAL}}$ *the dog*$_{\text{THEME}}$.

(e) *Bite* is encountered and its θ-grid is recovered; it may assign both an AGENT and a PATIENT role. Since *give* does not allow an S′ complement, the only grammatical θ-role assignments will result in the string where *the boy the dog bit* is a relative construction with *the boy* as its head. The required syntactic reanalysis removes *the dog* from the THEME θ-domain of *give* and reinterprets it as within the GOAL θ-domain which is assigned to the entire relative clause. Additionally, *the dog* also enters the AGENT domain of *bite* within the relative clause construction. This too is a violation of the Theta Reanalysis Constraint,

[25] I will assume the initial assignment of the correct θ-role to the initial NP object of a ditransitive verb. It is clear that initial assignments cannot be problematic:

(i) Mary gave the dog a bone.
(ii) Mary gave the dog to John.

Crucially, if *the dog* were initially incorrectly assigned a THEME role in (i) or a GOAL role in (ii), the resulting reanalysis would not require syntactic restructuring, but only the relabelling of the content of a semantic role. We return to this issue in §4.

since *the dog* has been removed from the THEME domain. The garden path effect consequently results.

It does not appear significant for the GP effect that certain informants report interpreting *a bandage* as the object of *bite*. It is quite clear that the garden path effect is obtained before that NP is encountered, as sentences such as 75 reveal.

(75) GP: Sue threw the vase the ball broke.

Of course, verbs which are not ditransitive do not produce parallel GP effects:

(76) Sue kicked the ball the dog chewed.

(a) *Sue* is recovered as an NP.

(b) *Kick* is recovered and found to assign AGENT and PATIENT roles maximally. *Sue* is marked as AGENT.

(c) *The ball* is marked as PATIENT.

(d) *The dog* is identified as an NP, but no θ-role is available, resulting in a temporary but unavoidable local violation of the θ-criterion.

(e) *Chew* is encountered and found to assign AGENT and PATIENT roles. *Kick* accepts no S′ complement, so syntactic reanalysis is required. The string *the ball the dog chewed* is reanalyzed as a relative NP. As head of the relative clause which is assigned a PATIENT role, *the ball* remains within the PATIENT θ-domain of *kick*. *The dog* is marked as PATIENT, but as it previously was neither θ-marked nor dominated by a constituent which was θ-marked (that is it was within no θ-domain), this assignment is unproblematic. There is no violation of the Theta Reanalysis Constraint, and the sentence presents no processing difficulty. A similar analysis obtains in the unproblematic sentence *Sue threw Mary the ball the dog chewed.*

The above examples involved ditransitive verbs and object relative clauses and were handled directly by our principles. Now consider the case of double object verbs and subject relatives.

(77) GP: Sue gave the man who was reading the book.

(a) *Sue* is identified as an NP.

(b) *Give* is identified as a verb and its θ-grid is recovered. It may assign AGENT, GOAL, and THEME roles.

(c) Assume that, after it is identified, *the man* is correctly assigned the GOAL role.

(d) *Who was reading* is unambiguously identified as the clausal component of a complex NP containing a subject relative clause with *the man* as its head. The entire NP, *the man who was reading,* is assigned the GOAL role originally assigned to *the man,* which continues to receive that role by inheritance as head of the relative clause. Of course, this is not problematic, as *the man* remains in its current θ-domain. However, also at this point, *read* is identified as a verb and its θ-grid is recovered (it may assign AGENT, GOAL, and PATIENT). An AGENT role is available and is assigned to the unambiguous subject gap. A PATIENT role also becomes available (ignoring for now the GOAL).

(e) When *the book* is identified as an NP, an interesting situation results. A

single target (the NP *the book*) is available, as well as two θ-roles: the THEME and PATIENT θ-roles assigned by *give* and *read,* respectively. The principle of θ-Attachment makes no prediction in this instance about which role will be assigned first since either assignment will provide the NP *the book* with a θ-role, discharging a role from one grid and stranding another. Each equally satisfies the attachment principle.

One interesting fact immediately becomes apparent. Though the THEME role of *give* is obligatory, and the PATIENT role of *read* is not, the garden path status of this sentence clearly demonstrates that the choice of which θ-role to assign is not based on this criterion. If the NP *the book* is initially assigned the PATIENT role by *read,* the subsequent reanalysis, motivated by the global absence of a THEME of *give,* removes *the book* from the PATIENT domain of *read* and interprets it as within *give*'s THEME domain, violating the Theta Reanalysis Constraint. In contrast, the initial assignment of *give*'s THEME role to *the book* would result in the grammatical interpretation, with no need for reanalysis. Local ambiguity in this case thus has two resolutions. One resolution is predicted to be unproblematic; the other is predicted to result in a GP by my account. I therefore predict that subject response to the potential GP context should be more sporadic than in the cases we have examined up to this point.[26]

Consider now a contrasting case in which the assignment of the PATIENT role by *read* is globally grammatical due to the appearance of a subsequent NP.

(78) GP: Susan gave the man who was reading the cereal box the magazine.

(a) *Susan* is identified as an NP.

(b) *Give* is identified as a verb and its θ-grid is recovered.

(c) *The man* is assigned a GOAL role.

(d) *Who was reading* is identified as the coda of the relative clause construction whose head is *the man*. The entire complex NP is assigned the GOAL role, which is inherited by *the man* as the head of the relative. *Read* is identified; its θ-grid is recovered, and its AGENT role is assigned to the subject gap. Its PATIENT role also becomes available.

(e) *The cereal box* is identified as an NP, and both a PATIENT role from *read* and a THEME role from *give* are available to be assigned to it.

(f) *The magazine* is identified.

Attachment of the NP *the cereal box* as the PATIENT of *read* will yield the globally grammatical interpretation, since at stage (f) *the magazine* may be assigned the obligatory THEME role by *give*. No reanalysis is necessitated. On the other hand, if *the cereal box* is attached as the THEME of *give,* reanalysis will be required when *the magazine* is identified, since otherwise it could not receive a θ-role. This reanalysis removes *the cereal box* from the THEME domain of *give* and reinterprets it as within the PATIENT domain of *read*, violating the Theta Reanalysis Constraint. Like the previous example, this sentence is a sporadic garden path. People apparently either severely garden-path on this

[26] The judgments concerning the garden path status of the sentences discussed in the text are based not solely upon intuition but also upon experimental data. See Pritchett 1987.

sentence or find it unproblematic. The resolution of the θ-assignment ambiguity appears essentially random. Furthermore, it is striking that the obligatory nature of the THEME role of *give* apparently does not influence θ-assignment in such environments. This may be attributed, however, to the fact that θ-Attachment merely requires that the θ-criterion be maximally satisfied at every point during processing where more than one role is available; it does not choose between them on the basis of the 'obligatoriness'. Unlike the other sentences we have seen, exx. 77–78 lead to garden path effects only about half the time. I have attributed this to the random resolution of θ-assignment in cases involving more θ-roles than targets. Notice that psychological heuristics such as Minimal Attachment will have great difficulty accounting for these examples, as they should treat them identically in terms of attachment, predicting GP effects in one but not the other.

4. EXTENDING THE THEORY. By focusing on the role of the θ-criterion in processing, we have succeeded in formulating highly specific processing strategies and in capturing the relationship between grammar and parser. Because our principles are derived from grammatical theory but are nevertheless independent from grammatical rules, they may be hypothesized to be universal. In this final section I propose a very natural extension of my parsing theory, which incorporates grammatical principles beyond the θ-criterion. I then examine how this revision allows us not only to simplify the account of the data we have previously considered but also to explain certain processing phenomena which are otherwise potentially problematic for my account. Consider the following sentences:

(79) I believe her professors hate me.
(80) GP: I convinced her professors hate me.
(81) I gave the dogs to Mary.
(82) I gave the dogs some bones.

Recall the account of the contrast exhibited by sentences such as 79 and 80. I have proceeded on the assumption, as discussed in the introduction, that the sentential complements of verbs such as *warn, convince, tell,* and *persuade* are PROPOSITIONS, while those of *know, believe, expect,* etc., are THEMES or PATIENTS—or, alternatively, that they too are PROPOSITIONS but that the relabelling of the semantic content of a domain without syntactic reanalysis is not costly. The crucial contrast between these two classes of verbs is that the former may assign a single internal θ-role, while the latter may assign two such roles. The same assumption is required to account for sentences such as 81 and 82, since otherwise one of the pair would be expected to yield garden path effects—because locally, when the first argument is processed, the semantic content of the role will not be ascertainable. That the actual semantic content of roles cannot be important for our purposes is made even clearer by examples such as the following:

(83) John loaded the truck onto the boat.
(84) John loaded the truck with bananas.

When the NP *the truck* is encountered, the content of the semantic role associated with that argument is locally indeterminate. It may receive either a THEME or a LOCATIVE role, depending on the nature of the following PP. Its configurational position is arguably identical in both instances. Since the syntax in general and the θ-criterion in particular make no reference to the semantic content of thematic roles under most commonly-accepted assumptions, I propose to eliminate all such reference from the parsing theory. What is relevant, as I have stressed, is the number of distinct roles a verb may assign (i.e. the number and configuration of argument positions). Consider how this approach will work with respect to a familiar example.

(85) I know her professors hate me.

(a) *I* is identified as an NP.
(b) *Know* is identified as a verb. Its θ-grid indicates that it assigns one external and one internal role: ⟨EXT,INT⟩. *I* is assigned the external role.
(c) *Her* is identified and assigned the internal role.
(d) *Professors* is identified. In accordance with the θ-criterion, the NP *her professors* is built and assigned the internal role.
(e) *Hate* is recovered. It assigns an external role and a single internal role. *Her professors* receives the external role from *hate* but remains within the θ-domain of the internal role of *know*, which is assigned to the entire clause. Thus the Theta Reanalysis Constraint is not violated. Quite clearly, whether the content of the internal role is actually spelled out as PATIENT on NPs and PROPOSITION on sentential elements is irrelevant to this approach.

Though the revision proposed above is desirable, it initially appears to introduce certain complications:

(86) GP: I convinced her mother hated me.

(a) *I* is identified.
(b) *Convince* is recovered. It assigns one external and two internal roles: $\langle \text{EXT},\text{INT}_1,\text{INT}_2 \rangle$.
(c) *Her* is identified and assigned the role INT_1.
(d) *Mother* is identified and the constituent $[\textit{her mother}]_{\text{NP}}$ is assigned the role INT_1.
(e) *Hate* is processed and syntactic reanalysis which moves *mother* outside the domain of INT_1 and into the INT_2 domain is required, violating the constraint on Theta Reanalysis and resulting in processing difficulty.

An immediate problem arises in this account, however. The question is why, when *mother* is first encountered, the role INT_2 is not immediately discharged upon it in accord with θ-Attachment. Subsequently, the entire clause of which *mother* becomes subject would receive the INT_2 role. Just as in the case of *know*, this would not be predicted to violate the Theta Reanalysis Constraint, as *mother* would remain within the INT_2 domain of *convince* and the sentence would not be predicted to be a garden path. Previously, of course, we prevented this by the stipulation that the second role assigned by *convince* was PROPOSITION, and that that role could only be assigned to sentential complements—

and hence not to the NP *mother,* whether for syntactic or semantic reasons. However, this is no longer defensible, given that we have eliminated reference to role content. Furthermore, there is good reason to suppose that our previous assumption simply is not supportable:

(87) I convinced her of Mary's hating her.

(88) I warned her of the vampire.

As is well known, the second argument of a verb such as *warn* may indeed be an NP rather than an S′ if that NP is in a position to receive Case. Sentences such as 89–90 are ruled out only because the second NP argument lacks Case, not because the PROPOSITION role may not be assigned to that position.

(89) *I convinced her Mary's hating her.

(90) *I warned her Bill.

If *of* as a semantically empty case marker is made available to assign Case to these NPs, the second internal role of these verbs may be discharged on them. Given that we no longer have recourse to role-content as an explanation, we must seek an alternative account of why the second arguments of verbs like *warn* and *convince* are not initially assigned the INT_2 role, leading to an unproblematic parse. The above array of facts indicates that we were correct in abandoning reference to role content, and it also suggests a natural extension of this approach to processing which will handle these facts:

(91) Σ-Attachment: Every principle of the Syntax attempts to be satisfied at every point during processing.

Now, rather than simply maintaining that the θ-criterion attempts to be satisfied at every point during processing, I wish to ensure that all principles of grammar (θ-Theory, Binding Theory, Bounding Theory[27], Case Theory, etc.), viewed as conditions on representations rather than as rules, are maximally satisfied locally at every stage of the parse. To handle the now problematic sentence 86, we appeal to Case Theory. We associate thematic roles with configurational positions so that INT_1 is always assigned to the first sister of V and INT_2 is assigned to the second sister (or perhaps simply to the sister of V′). Consequently, INT_1 is associated with a position which is always Case-marked, while INT_2 is associated with a position which typically is not, except for the small class of ditransitive verbs. In example 86, although *mother* (when initially encountered) could be assigned the INT_2 role, satisfying θ-criterion at that point, this would locally violate Case Theory, as *mother* would be left without Case,

[27] There is much to be said about how Bounding Theory is locally satisfied. Sentences such as (i) exhibit several potential gaps which prove not to exist, but the sentence is unproblematic. However, sentences such as (ii)–(iii) do yield GP effects.

(i) John, I like (e) to tell (e) jokes to e.

(ii) GP: Who did you warn (e) [e hated me].

(iii) GP: Who did you warn (e) John [e hated me].

This might indicate (a) that the processor does attempt to satisfy Bounding Theory at every point by freely postulating gaps; and (b) that empty categories, like overt NPs, are subject to the Theta Reanalysis Constraint; but (c) that incorrectly postulating gaps, as in (i), does not violate the constraint—since the gap is not syntactically reanalyzed as within a new domain, but rather is deleted.

since *convince* cannot assign Case to its second argument.[28] The alternative possibility of building the NP *her mother* allows both the θ-criterion and Case Theory to be satisfied with respect to the input string. This is therefore the analysis pursued, as principles of the grammar are maximally satisfied at this point during processing. When reanalysis is required, it will violate the Theta Reanalysis Constraint by moving *mother* from the INT_1 into the INT_2 domain. Now consider how this revised account handles other (by now familiar) examples.

(92) GP: The doctor persuaded the patient he was having trouble with to leave.

(a) *The doctor* is admitted as an NP.

(b) *Persuade* is identified and found to assign one external and two internal roles.

(c) *The patient* is encountered and assigned INT_1. It also receives Case from *persuade*.

(d) Next, *he* is encountered. It cannot be incorporated into an NP *[*the patient he*]$_{\text{NP}}$, and hence it cannot receive Case at this point—because *persuade,* like *warn,* cannot assign Case to its second argument. Since there is no local manner in which the Case Filter may be satisfied (either by direct Case-marking by *persuade* or by incorporation into a larger NP), *he* is simply assigned the INT_2 θ-role from *persuade*.

(e) The string *was having trouble with* is processed. The INT_2 role is reassigned to the entire clause and *he* is reassigned the EXT role within the S′. This is not costly, as *he* remains within the INT_2 θ-domain.

(f) Reanalysis is necessitated when *to leave* is encountered, and the string *he was having trouble with* must be reinterpreted as outside of the INT_2 domain and within the INT_1 domain. This of course violates the Theta Reanalysis Constraint, and the sentence is a garden path.

Consider, in contrast to the examples we have already seen, how Case and Theta Theory are reconciled locally, given a verb which may assign Case to both of its arguments:

(93) GP: I sent the boys dogs some bones.

(94) GP: I sent the boys dogs to Mary.

In both cases, when *the boys dogs* is encountered, the principles of the grammar may be maximally satisfied by interpreting the string as [*the boys*]$_{\text{NP}}$ [*dogs*]$_{\text{NP}}$ rather than [*the boys' dogs*]$_{\text{NP}}$ and assigning one of the two internal θ-roles available from *send* to each NP. Case Theory does not prevent this, as it would in the case of *warn* or *persuade*, since *send* may of course assign Case to both of its NP objects, as in *I sent the dog a steak.* Consequently, in both sentences, when either *some bones* or *to Mary* is encountered, one of the NPs, *the boys* or *dogs,* must be reinterpreted as within the other internal θ-domain, violating the Reanalysis Constraint.[29] This contrasts with examples 81–82,

[28] See Stowell 1981 for evidence that S′ complements are not Case marked.

[29] Amy Weinberg has noted (personal communication, 1988) that this theory makes the following predictions concerning the primary interpretations of examples such as (i)–(iii):

which do not involve syntactic reanalysis but simply the relabelling of the semantic content of a θ-position. All of these data are now handled under assumptions consistent with my approach, where the content of θ-roles is irrelevant and where all principles of syntax, not just θ-Theory, apply during processing.

Notice also that the revisions account for certain otherwise problematic sentences whose status as garden paths was not clearly predicted by our previous account.

(95) GP: I told the boy the dog bit Sue would help him.

Consider first how our original account would handle this sentence:

(a) *I* is identified as an NP.

(b) *Tell* is identified as a verb and its θ-grid is recovered. It may assign AGENT, GOAL, and PROPOSITION roles.

(c) *The boy* is identified and assigned a GOAL role.

(d) *The dog* is admitted as an NP, but cannot itself be assigned a role.

(e) When *bite* is encountered, two possibilities arise. First, a PROPOSITION θ-role might be assigned to *the dog bit* ... (as its sentential status has become clear) and an AGENT role assigned to *the dog*. This leaves only the PATIENT role of *bite* undischarged. However, the surface string *the boy the dog bit* could also be legitimately analyzed as a relative clause receiving the GOAL role, with *the boy* also receiving the GOAL role from *tell* as the head of the relative, and *the dog* receiving an AGENT role. The PATIENT role would be discharged on the gap. This leaves only the PROPOSITION role unsatisfied. The principle of θ-Attachment would not appear to select between these two options, as each strands a single role. Pursuit of the latter analysis would not lead to a garden path effect, since *the boy* remains in the GOAL θ-domain of *tell,* though it itself receives a new role; and the sentence would therefore not be expected to yield processing difficulty. This certainly cannot be the analysis pursued, as the sentence is an unequivocal GP. Clearly the PROPOSITION role is discharged.

(i) I read her$_{\text{GOAL}}$ books$_{\text{THEME}}$

(ii) I told her$_{\text{GOAL}}$ stories$_{\text{THEME}}$

(iii) I gave her$_{\text{GOAL}}$ mother$_{\text{THEME}}$

While this seems to be accurate for sentences (i) and (ii), it does not appear to be the case for (iii), which seems like a fragment. There are at least two possible explanations. First, it may simply be true that strong pragmatic factors (or possibly statistical factors; cf. Kuno 1986) can override syntactic processing strategies in certain cases. While possible, this does not appear accurate, since sentences such as (iv) display GP effects despite strong semantic influence to the contrary.

(iv) GP: While Mary sang a rock fell on her head.

If pragmatic information prevented the attachment of *a rock* as an object of *sing*, the processing difficulty encountered with this sentence could not be explained. Alternatively, it may be that (iii) is indeed the primary interpretation of the string but that this reading is rapidly rejected based on pragmatic knowledge. One might then claim that syntactic reanalysis that is forced by real world knowledge rather than by syntactic factors is not subject to the same reanalysis constraint. Sentence (iv) could still be explained, since it is not pragmatics but syntax (the appearance of the verb *fall*) which triggers the restructuring. See the discussion of semantics- and pragmatics-based approaches to parsing in Pritchett 1987 for a more detailed discussion of the interaction of real world knowledge and processing strategies, with reference to both local and global ambiguity.

This, however, is predicted by my revised approach, as the following analysis of 95 shows:

(a) *I* is identified as an NP.

(b) *Tell* is identified as a verb and its θ-grid is recovered. It may assign one external and two internal roles. *I* is assigned the EXT role.

(c) *The boy* is identified and assigned INT_1.

(d) *The dog* is admitted as an NP and assigned the remaining internal role.

(e) *Bite* is encountered and its θ-grid is recovered. Already at this point, reinterpretation as a relative clause would violate the Theta Reanalysis Constraint, since it would remove *the dog* from the INT_2 domain, placing it in the domain of INT_1—precisely the same reanalysis as is forced by *would help him*.

These revisions also allow us to account for otherwise unexplained garden path sentences such as 96:

(96) GP: The cotton fields produce makes warm coats.

(a) *The cotton* is identified as an NP, but can be assigned no θ-role or Case.

(b) *Fields* is identified as an N. In keeping with Σ-Attachment, the single NP $[\textit{the cotton fields}]_{\text{NP}}$ is built, requiring the admission of only a single roleless and Caseless NP.

(c) *Produce* is recovered and found to assign one external and one internal role. Assigning the EXT role to *the cotton fields* would leave only the INT role unassigned, and all NPs would have Case. On the other hand, the reduced relative analysis would discharge both θ-roles, with *fields* receiving the external role and the gap the internal role; but this analysis would leave the NP *cotton* unmarked and also without Case. Consequently, the former analysis is pursued, as it produces only a single violation (an unassigned INT role), while the latter results in two local violations (an NP without a θ-role and an NP without Case). Our previous account does not make a clear prediction in this case, since the main clause analysis would have left one undischarged role, while the relative analysis would have left one roleless NP. Notice that this provides an additional argument for pursuing a main clause rather than a relative clause analysis in canonical garden path structures too, as the head of the relative would lack Case.

(d) *Make* is encountered and reanalysis is necessitated. *The cotton* is removed from the EXT domain of *produce* and put into the EXT domain of *make,* as head of the relative clause, violating Theta Reanalysis. The revised approach thus clearly predicts the GP effect.[30]

5. CONCLUSIONS. This paper has been concerned with the central issue of language processing: how input strings are assigned structures compatible with

[30] It may also be that the matrix clause analysis is pursued because the maximum number of conditions is satisfied with respect to the string rather than the grid. Under the main clause analysis a role is left in the grid undischarged, while in the relative clause analysis an argument is left unmarked. This account would hold true even if one were to argue that, because it is the SAME NP (*cotton*) which lacks both the thematic role and Case, this should not count twice against that attachment option.

a competence grammar, and, more generally, how grammatical theory and parsing are related. Evidence from processing breakdown was examined and an attempt was made to specify the conditions under which ambiguity in the input string resulted in grammatical but unprocessable sentences. Globally ambiguous sentences (wherein more than one local syntactic analysis proves well-formed) were contrasted with sentences characterized as strictly locally ambiguous (wherein certain local structural assignments prove to be globally untenable). A further crucial contrast—between instances of local ambiguity which result in processing difficulty and other instances which do not—was revealed, and the central task became the characterization of problematic versus unproblematic local ambiguity.

It was suggested that theories of parsing which fail to take principles of grammar into account were incapable of accounting for processing phenomena of the relevant type, and it was argued in detail that no existing approach could account for the wide range of GP phenomena. In contrast, two principles derived directly from grammatical theory were postulated, the θ-Attachment principle (which determines attachments) and the Theta Reanalysis Constraint (which imposes a grammar-based bound on the domain of syntactic restructuring during a parse). Subsequently, it was demonstrated that these principles succeed in accounting for the relevant class of processing effects. Finally, the approach was extended to involve all principles of grammar, in addition to the θ-criterion, and it was suggested that processing theories which do not make reference to grammatical principles are not only insufficient but also unnecessary. Human language processing can be characterized in terms of grammatical theory, where the grammar is viewed not as a system of rules but as a set of conditions on representation, and where parsing is simply the application of grammatical principles locally at every point during the processing of the input string.

Thus, in the theory developed here, both processing phenomena and grammaticality are accounted for by the same principles, though in somewhat different fashions. Ungrammatically results from the GLOBAL violation of some grammatical constraint. Unprocessability, on the other hand, is attributable to certain LOCAL violations of grammatical principles which necessitate reanalysis beyond the bounds of the parser, bounds which are also characterized in terms of grammatical theory. The theory's success in accounting for an extremely wide range of processing phenomena in a simple and unified fashion has demonstrated that the core of parsing theory is derived from the theory of grammar.

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Department of Linguistics
Northwestern University
2016 Sheridan Road
Evanston, IL 60201

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