Recency Preference and Garden-Path Effects

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Abstract

Following Fodor (1983), it is assumed that the language processor is an automatic device that maintains only the best of the set of all compatible representations for an input string. One way to make this idea explicit is to assume the serial hypothesis: at most one representation for an input string is permitted at any time (*e.g.*, Frazier & Fodor (1978), Frazier (1979), and Pritchett (1988)). This paper assumes an alternative formulation of local memory restrictions within a parallel framework. First of all, it is assumed that there exists a number of structural properties, each of which is associated with a processing load. One structure is preferred over another if the processing load associated with the first structure is markedly lower than the processing load associated with the second. Thus a garden-path effect results if the unpreferred structure is necessary for a grammatical sentence.

This paper presents three structural properties within this framework: the first two– the Properties of Thematic Assignment and Reception– derivable from the θ-Criterion of Government and Binding Theory (Chomsky (1981)); and the third– the Property of Recency Preference– that prefers local attachments over more distant attachments. This paper shows how these properties interact to give appropriate predictions– garden-path effects or not– for a large array of local ambiguities.

1 Introduction

Perhaps the best-known theory of garden-path effects is that developed by Frazier and her colleagues (Frazier & Fodor (1978), Frazier (1979), Frazier & Rayner (1982)). This theory assumes the serial hypothesis: that at most one representation can be maintained for the input string at each parse state. In order to decide which structure to choose at a given parse state, the principles of Minimal Attachment and Late Closure are invoked. These principles are given in (1) and (2) respectively (from Frazier & Rayner (1982)):

(1) Minimal Attachment: Attach incoming material into the phrase-marker being constructed using the fewest nodes consistent with the well-formedness rules of the language.

(2) Late Closure: When possible, attach incoming lexical items into the clause or phrase currently being processed (*i.e.*, the lowest possible nonterminal node dominating the last item analyzed).

The principles of Minimal Attachment and Late Closure inside a serial processing model correctly predict a large array of garden-path effects and preferred readings of ambiguous input. Consider the following well-known examples:[1]

(3) # The horse raced past the barn fell.

(4) a. # Since she jogs a mile seems light work.
b. Bill thought John died yesterday.

Minimal attachment predicts the garden-path effect in (3). At the point of parsing the word *raced*, fewer nodes need to be constructed for the matrix verb reading than for the reduced relative clause reading, so the matrix verb reading is preferred. Since it is the reduced relative reading that is necessary for (3), a garden-path effect results.

Late Closure predicts the garden-path effect in (4a) and preferred reading in (4b). In (4a), there is a syntactic ambiguity at the point of parsing the noun phrase *a mile*: this NP may attach as either direct object of the verb *jogs* or as subject of the matrix clause to follow. Since the direct object attachment is within the same clause as the preceding words, this attachment is preferred by the principle of Late Closure. However, the matrix subject attachment is the attachment that is necessary for a successful parse of (4a). Thus a garden-path effect is correctly predicted.

Similarly, the nominal adverb *yesterday* can attach to either the embedded clause or to the matrix clause in (4b). Since the embedded clause occurs more recently in the input string, this attachment is preferred. Thus there is a preferred reading of (4b): that which associates *yesterday* with the embedded clause.

Although the principles of Minimal Attachment and Late Closure correctly account for numerous other garden-path effects, they also make a number of incorrect predictions, as noted in Pritchett (1988). For example, it is predicted that (5) should induce a garden-path effect:

(5) John knew Bill liked Sue.

[1] I will prefix sentences that are difficult to process with the symbol "#".

The NP *Bill* may attach in one of two locations: as direct object of the verb *knew* or as subject of the complement clause of the verb *knew*. Since the direct object attachment requires fewer nodes, it is preferred because of the principle of Minimal Attachment. Thus when the verb *liked* is processed, reanalysis must take place and a garden-path effect results. Since people have little difficulty parsing sentences like (5), Frazier's principles are in error in this case.

As a result, Pritchett proposes an alternative processing theory which collapses the Principles of Minimal Attachment and Late Closure into a single parsing principle:

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

The syntactic principles that Pritchett assumes are those from Government and Binding Theory (Chomsky (1981), Chomsky (1986a)). In particular he appeals to the θ-Criterion:

(7) The θ-Criterion: Each argument bears one and only one θ-role (thematic role) and each θ-role is assigned to one and only one argument (Chomsky (1981) p. 36).

The garden-path effect in (3) is derived in Pritchett's theory as follows. When the word *raced* is input it can attach either as matrix verb or as a reduced relative clause modifier of *the horse*. In the matrix verb attachment, the NP *the horse* receives a thematic role from the verb *raced*. No such thematic role is assigned to *the horse* in the modifier attachment. Thus the matrix verb attachment is locally preferred since it better satisfies the θ-Criterion than does the modifier attachment. When the word *fell* is processed, no attachments are possible and reanalysis is necessary to obtain a parse for the sentence. Thus the garden-path status of (3) is predicted.

In order to account for the non-garden-path status of (5), Pritchett hypothesizes the existence of the Theta Reanalysis Constraint:

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

(9) 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.

Consider (5) with respect to the Theta Reanalysis Constraint. At the point of parsing the word *liked*, reanalysis is necessary. The NP *Bill* initially receives its θ-role from the verb *knew*; after reanalysis this NP receives its θ-role from the verb *liked*. Pritchett hypothesizes that this reanalysis is not costly because of the Theta Reanalysis Constraint: after reanalysis the θ-marked constituent *Bill* is still within its original θ-Domain since the θ-role initially assigned to *Bill* is now assigned to a constituent dominating *Bill*, the complementizer phrase *Bill liked*.[2,3]

Note that the definition of the Theta Reanalysis Constraint still predicts a garden-path effect in (3). At the parse state just before the word *fell* is input, the NP *the horse* receives the θ-role AGENT from the verb *raced*. When the word *fell* is input, the NP *the horse* must be reanalyzed as THEME of *fell* rather than as AGENT of *raced*. Since this reanalysis interprets the NP *the horse* as outside its original θ-Domain, this reanalysis is expensive and a garden-path effect results.

In addition, Pritchett's theory predicts a garden-path effect in (4a), thus partially collapsing Frazier's principles of Minimal Attachment and Late Closure. However, Pritchett's theory does not predict the preferred reading in (4b): no principle of the syntax is better satisfied by attaching the adverb *yesterday* to the embedded rather than to the matrix clause. Thus the preferred reading of (4b) is unexplained in Pritchett's theory: his theory will be forced to include a principle like Late Closure in order to account for examples like (4b).

Furthermore, both the theories of Pritchett and Frazier make incorrect predictions with respect to the data in (10):

(10) a. I gave her earrings on her birthday.

b. I gave her earrings to Sally.

Although the input string *I gave her earrings* is ambiguous between two possible readings, neither is difficult to process, as is demonstrated by the lack of garden-path effects in either of the sentences in (10). Since both Frazier's and Pritchett's models are serial models, there can be at most one representation for the input string *I gave her earrings*.

[2] The category complementizer phrase (CP) is the equivalent of the traditional S' node (Chomsky (1986b). Furthermore, tense and agreement information are assumed to reside in the category *Infl*. The category IP (Infl phrase) is the modern equivalent of the traditional S node.

[3] It turns out that there are difficulties with Pritchett's analysis when Case Theory is considered. If the Theta Reanalysis Constraint is not to be stipulative, then it should follow from (6). Since Pritchett appeals to Case Theory in many of his garden-path derivations, there should be a corresponding Case Reanalysis Constraint. However there cannot be such a constraint because of examples like (5). If the Case Filter is to be locally satisfied, then the preferred attachment of the NP *Bill* is as direct object of the verb *knew* so that it receives accusative Case. Case reanalysis is necessary when the verb *liked* is encountered: the noun *Bill* now receives nominative Case. Since this sentence is not difficult to process, this reanalysis should not be costly. Thus either (5) violates the Case Reanalysis Constraint or there is no Case Reanalysis Constraint and hence the Theta Reanalysis Constraint is stipulative.

Frazier's model therefore predicts a garden-path effect for one of the two sentences. Since Pritchett's model allows reanalysis as long as the Theta Reanalysis Constraint is not violated, it is necessary to check whether or not this constraint is violated by the parse of one of the sentences in (10). Consider the state of the parse after the input *I gave her earrings* has been processed. Since the verb *give* assigns two thematic roles, the representation that would best satisfy the θ-Criterion has both of these roles assigned. Thus Pritchett's theory predicts that the preferred reading at this parse state represents *her* and *earrings* as separate noun phrases, each receiving thematic roles from *gave*. Hence reanalysis is necessary in order to parse (10b). Furthermore, this reanalysis violates the Theta Reanalysis Constraint, since the NP *earrings* must be reanalyzed as within a new θ-Domain. Thus it is incorrectly predicted that (10b) should induce a garden-path effect.

I propose here that the difficulties encountered by these models can be overcome by the use of similar principles inside a constrained parallel model (*cf.* Gibson & Clark (1987), Clark & Gibson (1988)). By including a principle like Late Closure within a constrained parallel model, two structures can be maintained in parallel for the sentences in (10). Thus neither of these sentences will cause a garden-path effect.

2 A Parallel Model of Sentence Processing

Following Fodor (1983), it is assumed that the language processor is an automatic device that maintains only the best of the set of all compatible representations for an input string. One way to make this idea explicit is to assume the serial hypothesis: at most one representation for an input string is permitted at any time (*e.g.*, Frazier & Fodor (1978), Frazier (1979), and Pritchett (1988)). This paper assumes an alternative formulation of local memory restrictions within a parallel framework.[4] First of all, it is assumed that there exists a number of structural properties, each of which is associated with a processing load, in Processing Load Units or PLUs.[5] One structure is preferred over another if the processing load associated with the first structure is markedly lower than the processing load associated with the second.[6] That is, I assume there exists some preference quantity P corresponding to a processing load, such that if the processing loads associated with two representations for the same string differ by load P, then only the representation associated with the smaller of the two loads is pursued. Given the existence of a preference factor P, it is easy to account for garden-path effects and preferred readings of ambiguous sentences. Both effects occur because of a local ambiguity which is resolved in favor of one reading. In the case of a garden-path effect, the favored reading is not compatible with the whole sentence. Given two representations for the same input string that differ in processing load by at least the factor P, only the less computationally expensive structure will be pursued. If that structure is not compatible with the rest of the sentence and the discarded structure is part of a successful parse of the sentence, a garden-path effect results. If the parse is successful, but the discarded structure is compatible with another reading for the sentence, then only a preferred reading for the sentence has been calculated. Thus if we know where one reading of a (temporarily) ambiguous sentence becomes the strongly preferred reading, we can write an inequality associated with this preference:

(12)

$$\sum_{i=1}^{n} A_i x_i - \sum_{i=1}^{n} B_i x_i > P$$

where:

P is the preference factor in PLUs,
x_i is the number of PLUs associated with property i,
A_i is the number of times property i appears in the unpreferred structure,
B_i is the number of times property i appears in the preferred structure.

Three structural properties will be presented within this framework: the first two– the Properties of Thematic Assignment and Reception (Gibson (1990))– derivable from the θ-Criterion of Government and Binding Theory (Chomsky (1981)); and the third– the Property of Recency Preference– that prefers local attachments over more

[4] See Kurtzman (1985), Gorrell (1986) and Carlson & Tanenhaus (1989) for psycholinguistic evidence in favor of parallel processing.

[5] I also assume the existence of semantic and pragmatic properties that require processing load, but I will only consider structural properties here. The existence of further properties may help to explain the data presented in Crain & Steedman (1985) and Ni & Crain (1989).

[6] See Gibson (1990) for a description of how these same properties can be used to predict processing overload in sentences like (11):
(11) # The man that the woman that the dog bit likes eats fish.

distant attachments (*cf.* Frazier & Fodor (1978), Frazier (1979), Frazier & Rayner (1982)).

3 The Properties of Thematic Assignment and Reception

Recall the θ-Criterion:

(7) The θ-Criterion: Each argument bears one and only one θ-role (thematic role) and each θ-role is assigned to one and only one argument.

Note that the θ-Criterion can be violated in one of two ways: an argument can be missing a thematic role or a thematic role can be left unassigned. Thus I propose that the θ-Criterion has two corresponding parsing properties, each of which requires processing load:

(13) The Property of Thematic Reception (PTR):
Associate a load of x_{TR} PLUs of short term memory to each thematic element that is in a position that can receive a thematic role in some co-existing structure, but lacks a thematic role in the structure in question.

(14) The Property of Thematic Assignment (PTA):
Associate a load of x_{TA} PLUs of short term memory to each thematic role that is not assigned to a node containing a thematic element.

Note that the Properties of Thematic Assignment and Reception are stated in terms of *thematic* elements.[7] Thus the Property of Thematic Reception doesn't apply to functional categories, whether or not they are in positions that receive thematic roles. Similarly, if a thematic role is assigned to a functional category, the Property of Thematic Assignment does not notice until there is a thematic element inside this constituent.

Since the Properties of Thematic Assignment and Reception are both derived from the θ-Criterion, it is reasonable to assume as a default that the loads associated with these two properties is the same:

(15) $x_{TR} = x_{TA} = x_\theta$

Consider (5) with respect to the Properties of Thematic Assignment and Reception:

(5) John knew Bill liked Sue.

As pointed out earlier, the verb *knew* is ambiguous: either taking an NP complement or a CP complement. Thus the NP *Bill* may attach as either the direct object of the verb *knew* or as subject of the CP to come.[8]:

(16) a. $[_{IP}$ $[_{NP}$ John $]$ $[_{VP}$ knew $[_{NP}$ Bill $]]]$

b. $[_{IP}$ $[_{NP}$ John $]$ $[_{VP}$ knew $[_{CP}$ $[_{IP}$ $[_{NP}$ Bill $]$ e $]]]]$

In (16a) the NP *Bill* is attached as the NP complement of *knew*. In this representation there is no load associated with either of the Properties of Thematic Assignment or Reception since no thematic elements need thematic roles and no thematic roles are left unassigned. In (16b) the NP *Bill* is the specifier of a hypothesized IP node which is attached as the complement of the other reading of *knew*. This representation is associated with at least x_θ PLUs since the NP *Mary* is in a position that can be associated with a thematic role (the subject position), but does not yet receive one in this structure. No load is associated with the Property of Thematic Assignment, however, since both thematic roles of the verb *knew* are assigned to nodes that contain thematic elements.

Since there is no difficulty in processing sentence (5), the load difference between the structures in (16) cannot be greater than P PLUs, the preference factor assumed in inequality (12). Thus the inequality in (17) is obtained:

(17) $x_\theta \leq P$

Since the load difference between the two structures is not sufficient to cause a strong preference, both structures are maintained. Note that this is a crucial difference between the theory presented here and the theory presented in Frazier & Fodor (1978), Frazier (1979) and Pritchett (1988). In each of these theories, only one representation can be maintained, so that either (16a) or (16b) would be preferred at this point. As noted earlier, Pritchett's theory accounts for the lack of difficulty experienced in parsing (5) by appeal to the Theta Reanalysis Constraint, (8). However, no such stipulation is required in the theory presented here: all reanalysis is assumed to be expensive.

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[7] Following early work in linguistic theory, two kinds of categories are distinguished: *functional* categories and *thematic* or *content* categories (see, for example, Fukui & Speas (1986) and Abney (1987) and the references cited in each). Thematic categories include nouns, verbs, adjectives and some prepositions; functional categories include determiners, complementizers, and inflection markers. There are a number of properties that distinguish functional elements from thematic elements, the most crucial being that functional elements mark grammatical or relational features while thematic elements pick out a class of objects or events.

[8] I assume some form of hypothesis-driven node projection so that noun phrases are projected to the categories that they specify (Gibson (1989)).

Now consider once again (3):

(3) # The horse raced past the barn fell.

The structure for the input *the horse raced* is ambiguous between at least the two structures in (18):

(18) a. $[_{IP}$ $[_{NP}$ the horse] $[_{VP}$ raced]]

b. $[_{IP}$ $[_{NP}$ the $[_{N'}$ $[_{N'}$ horse$_i$] $[_{CP}$ O_i raced]]] $[_{I'}$]]

Structure (18a) has no load associated with it due to either the PTA or the PTR. Crucially note that the verb *raced* has an intransitive reading so that no load is required via the Property of Thematic Assignment. On the other hand, structure (18b) requires a load of $2 * x_\theta$ PLUs since 1) the noun phrase *the horse* is in a position that can receive a thematic role, but currently does not and 2) the operator O_i is in a position that may be associated with a thematic role, but is not yet associated with one.[9] Thus the difference between the processing loads of structures (18a) and (18b) is $2 * x_\theta$ PLUs. Since this sentence is a strong garden-path sentence, it is hypothesized that a load difference of $2 * x_\theta$ PLUs is greater than the allowable limit, P PLUs:

(19) $2 * x_\theta > P$

Consider now (20), a sentence whose structure and local ambiguities are very similar to those in (3):

(20) The bird found in the room was dead.

Although the structures and local ambiguities in (20) and (3) are similar, (3) causes a garden-path effect while, surprisingly, (20) does not. To determine why (20) is not a garden-path sentence we need to examine the local ambiguity when the word *found* is read:

(21) a. $[_{IP}$ $[_{NP}$ the bird] $[_{VP}$ $[_{V'}$ $[_{V}$ found]]]]

b. $[_{IP}$ $[_{NP}$ the $[_{N'}$ $[_{N'}$ bird$_i$] $[_{CP}$ O_i found]]] $[_{I'}$]]

The crucial difference between the verb *found* and the verb *raced* is that *found* is obligatorily transitive, while *raced* is optionally intransitive. Since the θ-grid of the verb *found* is not filled in structure (21a), this representation is associated with x_θ PLUs of memory load. Like structure (18b), structure (21b) requires $2 * x_\theta$ PLUs. Thus the difference between the processing loads of structures (21a) and (21b) is $2 * x_\theta - x_\theta$ PLUs $= x_\theta$ PLUs. Since this difference is less than the preference factor P, both structures are maintained and a garden-path effect is avoided as desired.[10]

The Properties of Thematic Assignment and Reception make many further garden-path predictions, among them:

(23) a. # I put the candy on the table in my mouth.

b. # The Russian women loved died.

c. # John told the man that Mary kissed that Bill saw Phil.

See Gibson (1990) for derivations of the garden-path status of these sentences within the framework described here.

4 The Property of Recency Preference

Although the Properties of Thematic Assignment and Reception account for numerous garden-path effects and preferred readings of ambiguous input, they do not account for the Late Closure effects presented in (4):

(4a) # Since she jogs a mile seems light work.

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[9] In fact, this operator will be associated with a thematic role as soon as a gap-positing algorithm links it with the object of the passive participle *raced*. However, when the attachment is initially made, no such link yet exists: the operator will initially be unassociated with a thematic role.

[10] Note that the principle of Minimal Attachment makes the wrong prediction in (20): this example is wrongly predicted to be identical to (3) and thus a garden-path.

Pritchett attempts to account for the lack of garden-path effect in (20) by altering the Theta Reanalysis Constraint in such a way that (20) does not violate the new constraint while garden-path sentences like (3) still do. Crucial to his argument is his claim that there is a strong preference for the matrix clause reading of the word *found* when it is initially input. However, Kurtzman (1985) found that both matrix clause and reduced relative clause readings of verbs like *found* were equally easy to process as soon as they were read, contrary to Pritchett's claim. For example, consider the sentences in (22):

(22) a. The monkeys chased his...

b. The monkeys chased were...

Kurtzman found that partial sentences like those in (22) did not vary significantly in parsing difficulty. Thus Pritchett's claim that words like *found* or *chased* are initially analyzed as matrix verbs appears to be incorrect. Furthermore, note that a parallel model of processing makes exactly the right predictions here.

(4b) Bill thought John died yesterday.

First consider (4a). There are two possible attachments of the NP *a mile*: 1) as direct object of the verb *jogs*; and 2) as subject of the matrix clause to follow. Consider these two structures:

(24) a. $[_{IP}$ $[_{CP}$ since $[_{IP}$ $[_{NP}$ she $]$ $[_{VP}$ $[_{V'}$ $[_{V}$ jogs $]$ $[_{NP}$ a mile $]$ $]]]]$ $[_{IP}$ $]]$

b. $[_{IP}$ $[_{CP}$ since $[_{IP}$ $[_{NP}$ she $]$ $[_{VP}$ jogs $]]]$ $[_{IP}$ $[_{NP}$ a mile $]$ $[_{I'}$ $]]]$

There is no load associated with structure (24a) by the Properties of Thematic Assignment and Reception since all arguments receive thematic roles and all thematic roles are assigned. Structure (24b), on the other hand is associated with x_θ PLUs since the NP *a mile* currently lacks a thematic role in this structure. However this is the only load associated with (24b). Thus the load difference between the two structures is only x_θ PLUs by the Properties of Thematic Assignment and Reception, not enough to cause a garden-path effect.

It turns out that this problem is solved by incorporating a structural property derived from a principle similar to Late Closure into the framework described thus far. The intuition behind the Principle of Late Closure and its predecessors (Kimball (1973)) is that new structures prefer to be attached to structures associated with more recent words in the input string. For example, in (4b), the preferred attachment for the adverb *yesterday* is as modifier of the more recently occurring clause: the most deeply embedded one. The property that I present here, the Property of Recency Preference (PRP), makes this intuition explicit.

(25) The Property of Recency Preference (PRP):
The load associated with the structure resulting from an attachment of structure X = (number of more recent words that would also allow an attachment of structure X) $*x_{RP}$ PLUs.

Hence given two possible attachment sites, the structure resulting from attachment to the more recent word will be associated with no load via the Property of Recency Preference, while the structure resulting from attachment to the less recent word will be associated with x_{RP} PLUs.

Consider the PRP with respect to sentence (4b). At the point of parsing the word *yesterday*, there are two possible attachments: either as a modifier of the embedded clause headed by *died* or as modifier of the matrix clause headed by *thought*. The structure that results from attaching this adverb as modifier of the embedded clause is associated with no load via the Property of Recency Preference, since the word *died* is the most recently occurring attachment site in the input string. However, the structure that results from attaching this adverb to the matrix clause is associated with x_{RP} PLUs, since there is a more recent word in the input string, the word *died*, to which this adverb could attach. Since the interpretation which links the adverb *yesterday* with the embedded clause is the strongly preferred reading in (4b), I hypothesize that the load difference between the structures resulting from the two possible attachment sites is significant:

(26) $x_{RP} > P$

The existence of a garden-path effect in (4a) can now be explained. Structure (24a) is associated with no load via the Property of Recency Preference since the NP *a mile* is attached to a structure headed by the most recent word in the input string, *jogs*. Structure (24b), on the other hand, represents attachment to the CP headed by *since*. Thus this structure is associated with x_{RP} PLUs by the PRP. Since this structure also contains a thematic role-less NP, the total load associated with this structure is $x_{RP} + x_\theta$ PLUs. Structure (24a) is associated with no load whatsoever. Thus the load difference between the two structures is $x_{RP} + x_\theta$ PLUs, enough to cause a strong local preference and hence a garden-path.

Although the Property of Recency Preference is very similar to Frazier's principle of Late Closure, there is an important difference. Unlike the principle of Late Closure, the PRP is not stipulated to act on its own: it can interact with other properties. Thus we expect to find situations where the PRP interacts with the Properties of Thematic Assignment and Reception in the prediction of behavior in ambiguous situations. In fact, many such cases occur. First consider (27), a sentence whose garden-path effect is unexplained without the PRP:

(27) # I convinced her children are noisy.

(27) is locally ambiguous over the span of the words *her children*. Two parses for the input string *I convinced her children* are given in (28):

(28) a. $[_{IP}$ $[_{NP}$ I $]$ $[_{VP}$ $[_{V'}$ $[_{V}$ convinced $]$ $[_{NP}$ her children $]$ $]]]$

b. $[_{IP}$ $[_{NP}$ I $]$ $[_{VP}$ $[_{V'}$ $[_{V}$ convinced $]$ $[_{NP}$ her $]$ $[_{CP}$ $[_{IP}$ $[_{NP}$ children $]$ $]]]]]$

In structure (28a) the words *her children* correspond to the noun phrase object of *convinced*. In (28b), the word *her* is the noun phrase object of *convinced* and the word *children* is the subject of the complement clause of *convinced*. Structure (28a) is strongly preferred over (28b) and a garden-path effect results for (27).

In order to see how this garden-path effect can be predicted in this framework, consider the loads associated with each of the structures in (28). First, let us consider the Property of Recency Preference. The attachment of the NP representation of the word *children* to form (28a) requires no PRP load since the attachment involves the most recent word in the input string, *her*. On the other hand, the attachment of *children* as the subject of the CP complement to *convinced* involves making an attachment to the verb *convinced*, a less recent word in the input string. Thus there is a load of x_{RP} PLUs associated with (28b).

Consider now the Properties of Thematic Assignment and Reception. Structure (28a) has a load of x_θ PLUs since the verb *convinced* has a yet unassigned thematic role. Structure (28b) is associated with a load of x_θ PLUs since the noun phrase *children* requires a thematic role and does not yet receive one. Thus the total load difference between the two structures is $x_\theta + x_{RP} - x_\theta$ PLUs = x_{RP} PLUs. Thus (27) induces a garden-path effect, as desired.

Furthermore, the combination of the properties also explains the lack of difficulty in the sentences in (10):

(10a) I gave her earrings on her birthday.
(10b) I gave her earrings to Sally.

In order to formulate an inequality representing the state of affairs in (10), consider the parse state after the word *earrings* is read:

(29) a. $[_{IP}$ $[_{NP}$ I $]$ $[_{VP}$ $[_{V'}$ $[_V$ gave $]$ $[_{NP}$ her earrings $]$ $]]]$
b. $[_{IP}$ $[_{NP}$ I $]$ $[_{VP}$ $[_{V'}$ $[_V$ gave $]$ $[_{NP}$ her $]$ $[_{NP}$ earrings $]$ $]]]$

The verb *gave* subcategorizes for either two noun phrases or for a noun phrase and a prepositional phrase (*cf.* Kayne (1984), Larson (1988)). First consider the load associated with the structures in (29) with respect to the Property of Recency Preference. The derivation of this load is similar to that for the structures in (28). Structure (29a) is associated with no load by the PRP since *earrings* attaches to *her*, the most recent word. However, structure (29b) is associated with a load of x_{RP} PLUs since the attachment necessary to form this structure involves a less recent word, *gave*. Now consider the loads associated with the structures in (29) with respect to the Properties of Thematic Assignment and Reception. Structure (29a) is associated with a load of x_θ PLUs since a thematic role is yet unassigned by the verb *gave* in this structure. On the other hand, structure (29b) is associated with no load due either the PTA or the PTR since all thematic roles are assigned and all thematic elements receive thematic roles. Note that this is the crucial difference between (10) and (27). Thus the load difference between structures (29a) and (29b) is $x_{RP} - x_\theta$ PLUs. Since neither (10a) nor (10b) is a garden-path sentence, I hypothesize that this load difference is not significant:

(30) $x_{RP} - x_\theta \leq P$

Thus we have the following inequalities:

(31) a. $x_\theta \leq P$
b. $2 * x_\theta > P$
c. $x_{RP} > P$
d. $x_{RP} - x_\theta \leq P$

This set of inequalities is consistent. It identifies the solution space depicted in Figure 1.

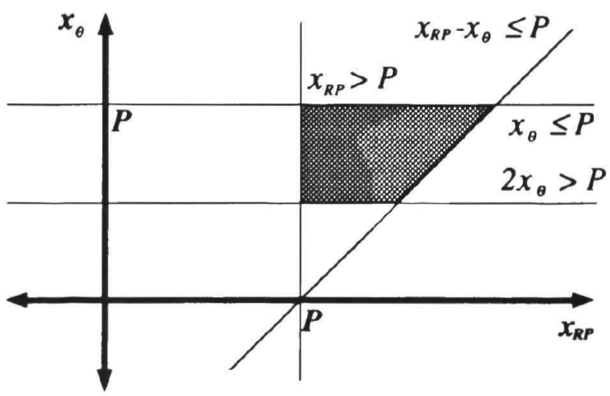

Figure 1: The Solution Space for the Inequalities in (31)

5 Conclusions

This paper has presented a parallel model of human sentence processing in which it is assumed that the ease or difficulty in parsing a given sentence is due to multiple coexisting properties of the sentence. Three independent properties were presented: two that follow from the θ-Criterion, and the third, a property that prefers attachments involving more recent words. These three properties were shown to interact to correctly predict previously unexplained results with respect to a number of local ambiguities. Furthermore, no stipulations regarding reanalysis are necessary: all reanalysis is assumed to be expensive. Thus the framework presented here makes better predictions with respect to the data considered here than the currently accepted serial models of language processing.

6 References

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