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How to Resolve Structural Ambiguities

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One of the central aims of psycholinguistic research is to provide a systematic account of how people interpret structurally ambiguous sentences. This paper contrasts two alternative accounts: The Garden Path Theory (e.g., Frazier and Rayner, 1982; Ferreira and Clifton, 1986), and the Referential Theory (e.g., Altmann, 1987; Altmann and Steedman, 1988; Crain and Steedman, 1985). Both theories acknowledge the influence of discourse representations on the ultimate interpretation people assign to ambiguous sentences; however, according to the Garden Path Theory, semantic/pragmatic factors tell only part of the story. This account maintains that syntactically based strategies are needed as well. These strategies are seen to determine which of the possible analyses is adopted (at least initially) for structurally ambiguous sentences.

According to the Referential Theory, the processes by which discourse representations are constructed also suffice to explain how structural ambiguities are resolved. On this account, discourse representations decide the analysis that is pursued, both within and outside of context. In context, the preferred interpretation is the one that best fits the perceiver's mental model of the discourse situation. In the absence of context, decisions are rendered according to the relative complexity of the alternative mental representations, which are computed in parallel. The interpretation is selected that requires the fewest extensions to the perceiver's discourse model. The necessary modifications to discourse representations are viewed as "accommodations of presuppositional failures" that must be made when sentences are presented without supporting context. The purpose of this paper is to spell out and empirically test this discourse-based explanation of ambiguity resolution in the so-called null context.

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1. The Garden Path Theory

On the Garden Path Theory, both in reading and listening people initially compute only a single analysis of most structural ambiguities (though they may opt to reanalyze, if the meaning or context dictates). People are guided to this unique analysis by strategies that are based solely on the structural properties of sentences. These strategies are seen to exert their influence on perceivers whether sentences are encountered in or out of context. For example, the strategy called Minimal Attachment instructs the perceiver to pursue a phrase marker with as few non-terminal nodes as possible. This strategy is invoked to explain why people systematically favor the sentential complement analysis (a) over the relative clause analysis (b) of sentences such as (1):

(1) *John told the woman that he liked the story.*
  (a) *John told [the woman] [that he liked the story].*
  (b) *John told [the woman [that he liked]] [the story].*

The sentential complement analysis in (a) is preferred because it requires the postulation of fewer nodes at the moment during parsing at which the NP "the woman" is incorporated into the phrase marker under construction.

In some sentences, the decision to pursue the Minimal Attachment in resolving an ambiguity has the dire consequence that subsequent information in the sentence cannot be accommodated into the analysis under construction. This is illustrated in the classic "garden path" sentences (2) and (3), due to Bever (1970). In a later section of the paper we focus on a variation of this phenomenon, illustrated in (4).

(2) *The horse raced past the barn fell.*
(3) *The boats floated down the river sank.*
(4) *The students furnished answers before the exam received high marks.*

The initial verbs in these sentences ("raced", "floated" and "furnished") are morphologically ambiguous; that is, the past-tense and past-participle forms are the same for these verbs. The garden path phenomenon shows that perceivers systematically choose the simple past form, rather than the past participle form. This is explained by the strategy of Minimal Attachment, because the structure corresponding to the simple past interpretation requires the postulation of fewer non-terminal nodes than the reduced relative clause analysis. By choosing the simple past form, the perceiver avoids computing the more complex syntactic analysis, but only at a price, since this means that material encountered later on cannot be incorporated into the analysis.

A challenge to the Garden Path Theory is the existence of sentences that have the same grammatical structure as the classic examples, but which do not induce perceptible garden path effects as predicted by syntactic parsing strategies. The contrast between (5) and (6) indicates that real world knowledge is sometimes sufficient to keep the parser on the right track (Crain and Steedman, 1985; p. 339).

(5) *The teachers taught by the Berlitz method passed the test.*
(6) *The children taught by the Berlitz method passed the test.*

Sentences that are more plausible on the reduced relative clause analysis, such as in (6), do not evoke garden path effects. Advocates of the Garden Path Theory respond that semantic plausibility exerts its influence only after the syntactic parsing strategies have applied. The prediction is that even sentences like (6) induce brief, albeit unconscious garden path effects that are subsequently overridden by real world knowledge (i.e., that children are more likely to be taught than to teach).

In a number of recent studies researchers have used "on-line" measures of processing difficulty to determine whether sentences like (6) induce "local" garden path effects. The results of these studies are mixed. Two studies have asked whether semantic plausibility is able to lead the perceiver to avoid garden paths in sentences beginning with an inanimate NP, such as in (7). Recording subjects' moment-by-moment eye-movements during reading, Ferreira and Clifton (1986) demonstrated that perceivers sustain a slight but measurable garden path effect in reading sentences like (7). However, using the same technique, but with redesigned materials, Trueswell, Tanenhaus and Garnsey (1989) found no evidence of garden path effects.[1] In the Trueswell et al study, structurally ambiguous sentences like (7) displayed the same eye-movement profile as unambiguous sentences like (8).

(7) *The evidence examined by the lawyer turned out to be unreliable.*
(8) *The crops grown at the farm were not handled properly.*

In testing between the competing theories another series of experimental studies has focused on the choice of determiner on people's decisions about which grammatical structure to adopt in cases of structural ambiguity. For example, Crain and Steedman (1985) and Portner (1989) showed that if the initial NP contained either an indefinite determiner, as in (9), or a "bare plural" NP, as in (10), no perceptible garden path effects were detected in experiments using variations of the self-paced reading technique (see Section 5 below).[2]

(9) *A teacher taught at Columbia is no good.* (Portner, 1989; p. 44)
(10) *Teachers taught at Columbia are no good.*

In order to understand why changes in the determiner should eliminate garden path effects, it will be helpful to present the Referential Theory in more detail.

2. The Referential Theory

One basic tenet of the Referential Theory is that people pursue multiple analyses of structurally ambiguous sentences. It is supposed, further, that all but one analysis are quickly discarded on pragmatic grounds. When ambiguous sentences are presented in context, the reading that is retained is the one that best fits the discourse situation. This is called the Principle of Referential Success by Crain and Steedman (1985).

The Principle of Referential Success:

> If there is a reading that succeeds in referring to an entity already established in the perceiver's mental model of the domain of discourse, then it is favored over one that does not.

The Referential Theory contends that semantics and pragmatics suffice even to explain how ambiguities are resolved outside of context. To explain sentence interpretation in the so-called null context, the Referential Theory proposes that perceivers actively attempt to construct a mental representation of a situation that is consistent with the utterance of the sentence in question. In addition to the characters and events depicted by the sentence itself, the construction of a mental model sometimes requires people to represent information that the sentence **presupposes**, not just what it **asserts**. The process of augmenting one's mental model to represent the presuppositional content of sentences has been called "the accommodation of presuppositional failure" by Lewis (1979), "extending the context" by Stalnaker (1974) and Kartunnen (1974), and the "addition of presuppositions to the conversational context of an utterance" by Soames (1982).

According to the Referential Theory, the accommodation of presuppositional failure plays a critical role in explaining which interpretation is assigned to an ambiguous sentence that is encountered outside of context. On this account, the perceiver attempts to construct representations corresponding to all meanings of a sentence but, due to limited working memory resources, settles on the interpretation that requires the fewest modifications in establishing a coherent discourse representation. Crain and Steedman (1985) call this the Principle of Parsimony.

The Principle of Parsimony:

> If there is a reading that carries fewer unsatisfied but consistent presuppositions than any other, then that reading will be adopted and the presuppositions in question will be incorporated in the perceiver's mental model.

In our recent research we have sought to extend the Principle of Parsimony to a wider array of linguistic phenomena.

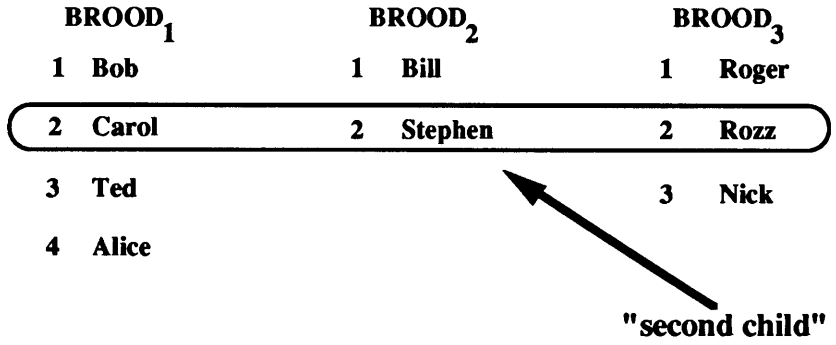
3. Extending the Principle of Parsimony

The remainder of the paper spells out the Principle of Parsimony in more detail. Section 5 presents an experimental investigation of the role of the Principle of Parsimony accounting for how syntactic ambiguities are resolved. But, first, we will indicate how it can be used to explain a number of facts about semantic ambiguity resolution. As with structural ambiguities, people exhibit systematic preferences for resolving semantic ambiguities. And, they often find it difficult to identify the dispreferred interpretations.

Examples (11) - (13) illustrate a semantic ambiguity inherent in the phrase "second child."

(11) *A second child walked into the room.*
(12) *A second child has emotional problems.*
(13) *Rozz is a happy second child.*
(14) ? *Texas is a second state.*

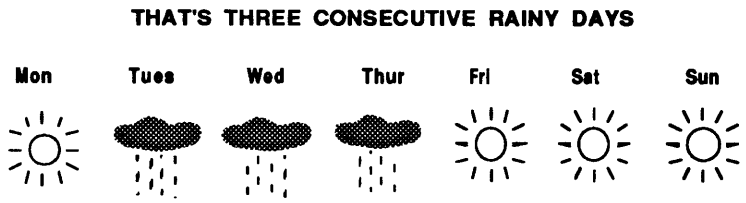
In (11), the preferred interpretation of "second child" would have the reader suppose that there is some set of children already under discussion, and that one member of this set had previously walked into the room. While this sentence is slightly odd outside of context, the cost associated with the accommodation of these presuppositions is not so great as to render the sentence anomalous. In fact it seems that the process whereby presuppositions are accommodated is less costly than recovering the alternative interpretation of "second child" which is indicated in (12) and (13). Examples (12) and (13) use the phrase "second child" differently, to refer to children who are second in chronological age among their siblings. Each of us probably knows several second children, each one being the second offspring in age from some family. Let us call this ordered set of offspring, a brood. Based on our knowledge that children come in broods, the alternative interpretation of "second child," indicated in (12) and (13), is available in certain linguistic or nonlinguistic contexts. The extension of this interpretation of the phrase "second child" is a **structured set**, as illustrated in the diagram below. The anomaly of the phrase "second state" in (14) shows the unavailability of a corresponding structured set interpretation of the noun "state."



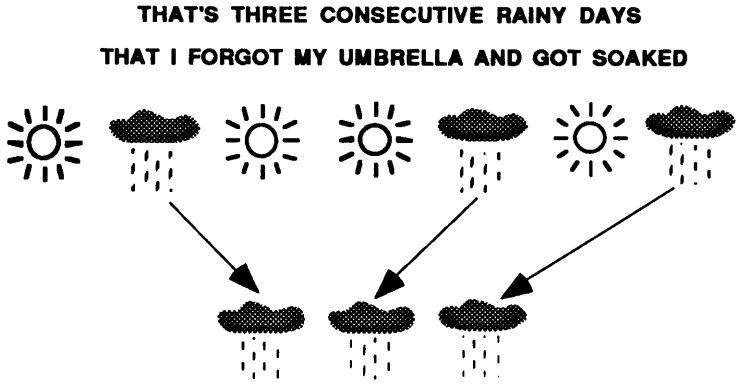
A related ambiguity arises with the phrase "three consecutive rainy days." This is indicated in (15) and (16):

(15) *That's three consecutive rainy days.*
(16) *That's three consecutive rainy days that I forgot my umbrella.*

Notice that the preferred reading of (15) is non-compositional. According to this interpretation it has been *[rainy [three [consecutive days]]]*. The following figure illustrates this interpretation:



On the compositional interpretation the three consecutive rainy days on which the speaker forgot his umbrella need not have been successive days of the week. This is depicted in the following figure.



To explain the existence of ambiguities like "second child" and "three consecutive rainy days" it will be helpful to distinguish three semantic categories of adjectival modifiers, which we will refer to as **constrainers, simple selectors** and **mappable selectors**. The distinction between a constrainer and a simple selector turns on whether the smallest phrase containing the modifier has as its extension an individual or a set. So, for instance, relative and absolute adjectives such as "tall" or "red" are constrainers. This is attested by the fact that the extension of "tall mountain" is a set of many mountains. By contrast, "tallest" is a simple selector, since only one individual is the tallest mountain. This explains the oddity of preceding "tallest" with the indefinite determiner, as in "a tallest mountain." To permit phrases like "a second child" and "every second child", we introduce the category of mappable selectors. The appropriate argument for a mappable selector is a set of sets, or **structured set**. One example of a structured set is the concept of brood introduced earlier. Mappable selectors, which include both ordinals and superlatives, return sets as values, rather than individuals. These category distinctions can be summarized as follows:

(17) Constrainers (absolute and relative adjectives)
= functions from sets to sets (e.g., *tall mountain*)

(18) Simple selectors (ordinals and superlative adjectives)
= functions from sets to individuals (e.g., *tallest mountain*)

(19) Mappable selectors (ordinals and superlative adjectives)
= functions from structured sets to sets (e.g., *second child*)

Consider now the phrase "second youngest child," which contains both an ordinal and a superlative. This phrase is (syntactically and semantically) ambiguous. The preferred interpretation takes the ordinal and the superlative as a constituent, meaning the second youngest of some unspecified set of children. It is our contention that this interpretation is favored due to the cognitive effort required to construct a structured set as compared to an unstructured set interpretation. We attribute this division of labor to the Principle of Parsimony, which measures cognitive effort in terms of the number of accommodations that must be made to one's mental model of

the domain of discourse. It should be pointed out, however, that this "least effort" principle of ambiguity resolution, although quite powerful in the null context, is overruled by the Principle of Referential Success. That is, when the phrase "second youngest child" is used in an appropriate context, the structured set interpretation is selected. One such context is given in (20).

(20) *It is rare for a youngest child to ascend the throne; indeed, George is only the second youngest child to do so in modern times.*

In the context given in (20), the phrase "youngest child" is used to identify a structured set, a set of all children who are last in birth ordering in their own brood. The ordinal "second" combines with "youngest child" to yield an individual who is the second member of the structured set of "youngest children."

The construction of a structured set interpretation from scratch, however, is a task of significant proportions, as attested by semantic anomalies such as the oddity of "Texas is a second state," as compared to "John is a second child." However, even when a structured set reading of a noun can be accommodated, because of its availability as part of our background knowledge, this reading often remains as the dispreferred interpretation, as examples (11) and (15) illustrate. The default preference for unstructured sets over structured sets can be overridden if the unstructured set interpretation itself requires the accommodation of unmet presuppositions. For example, in (21) the NP "a fourth finger" can either be used with the presupposition that three fingers have already been found (an unstructured set), or it might refer to the structured set of "pinky fingers" that an archaeologist has collected, for instance.

(21) *That (fossil) is a fourth finger.*

The world of sports provides a great many nouns that give rise to structured set interpretations. One relevant example is given in the seemingly contradictory sentences (22) and (23). Example (22) exhibits the usual, default preference for the unstructured set reading of "homers." Here, "three consecutive homers" means consecutive at-bats by different players. However, the same phrase is given a structured set reading in (23). There the homers under discussion are a subset of Reggie Jackson's at-bats. The difference between the unstructured set and structured set interpretations explains why (22) and (23) are not contradictory (for people who have basic knowledge about baseball).

(22) *There have never been three consecutive homers in a world series game.*
(23) *Reggie Jackson hit three consecutive homers in the third game of the 1978 world series.*

It is worth noting a difference between this example and the earlier example of "consecutive rainy days." Recall that in the preferred reading of the earlier example, the modifier "rainy" was interpreted as outside the scope of "consecutive," resulting in a non-compositional meaning. In the present case, compositionality is not at issue because "consecutive" is adjacent to the lexical item "homers." Nevertheless the same preference for the unstructured set interpretation arises here as well.

As a final example note that "quarters," as in the quarters of a basketball game, refers to a structured set, whereas "quarters" in the monetary sense refers to an unstructured set. This explains why it is reasonable to say "That was a dirty fourth quarter" (which one might hear at a basketball game in Detroit, for instance), but it is difficult to accommodate the presuppositions of the alternative reading, just as it is difficult to interpret the sentence "That was a dirty fourth dime."

4. Further Extensions of the Principle of Parsimony

So far we have seen how the Principle of Parsimony can be extended to explain semantic ambiguity resolution. It remains to apply the principle to cases of structural ambiguity resolution. In the remainder of this paper we will focus on the presuppositions inherent in the use of the definite determiner, as compared to the presuppositions associated with other determiners, such as "only", "even" and "too." Sentences (24) and (25) illustrate one of the contrasts that we have investigated.

(24) *The students furnished answers before the exam received high marks.*
(25) *Only students furnished answers before the exam received high marks.*

Another contrast is between sentences like (25), with "only" followed directly by a noun, and ones like (26), in which the initial noun phrase also contains an adjective:

(26) *Only dishonest students furnished answers before the exam received high marks.*

Based on differences in the presuppositional content among these sentences, the Principle of Parsimony predicts that sentences (24) and (26) should evoke garden path effects, but sentences like (25) should not.

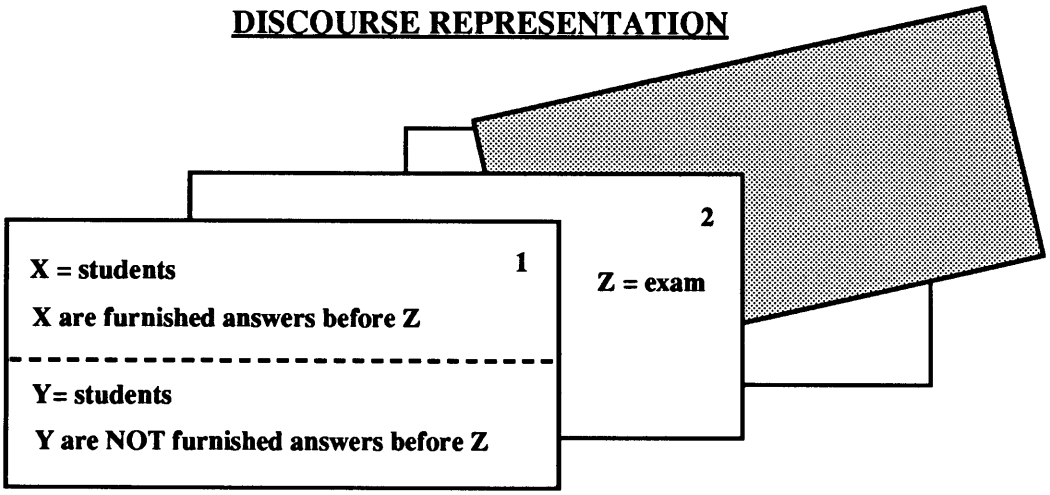
For purposes of exposition it will be useful to frame our account of these differences in the accommodation of unmet presuppositions within the theory of discourse representation proposed by Heim (1982), called "file change semantics." In file change semantics, a discourse representation is conceived of as a box of file cards. Certain file cards can be accessed at any time: These represent the background knowledge or "common ground" that participants bring to any discourse. But in addition, the discourse participants may add new file cards or write on old ones, as demanded by the current discourse. A new card is added whenever a new entity is introduced. This is done, for example, in response to indefinite NPs such as "a student" or "some students." We contrast this with definite descriptions like "the students." Here, the use of the definite determiner suggests that a file card should already exist, either as part of the file cards that comprise the background knowledge of the participants, or as the result of having been introduced into the set of file cards that have been created during the current discourse. In either case, if no card can be located corresponding to the entity in question, then a new file card must be added. In other words, this requires the accommodation of a presuppositional failure.

Other types of determiners introduce further complications in effecting modifications to files to accommodate unsatisfied presuppositions. In discussing determiners such as "even" and "only," Karttunen and Peters (1979) propose that NPs like "even President Bush" or "only students" carry an "existential implication"

that there are other individuals under consideration besides the one(s) mentioned by the head noun. For instance, consider the sentence "Even President Bush thinks Dan is an idiot" carries the presupposition that there are other people besides Bush that think the same thing (i.e., that Dan Rather is an idiot, or Dan Quayle, perhaps).

Now consider sentences that begin with "only," such as (25). Again, the NP "only students" presupposes that there are other individuals under consideration that are being contrasted with students. Suppose, then, that "only students" is encountered in the null context (in a psycholinguistic experiment). Not only does the perceiver have to create a new file card for **students**, s/he also has to extend the current file cards to accommodate the additional presupposition that there are other individuals under consideration being contrasted with students. This extension requires the creation of a **contrast set**. Following the Principle of Parsimony, the perceiver attempts to make the minimal modifications. One change that is required seems clear: A new file card must be created, corresponding to **students**. With this card in place, the perceiver can turn to the other presupposition -- the existence of a contrast set.

One way to accommodate this presupposition would be to add another new file card to identify the contrast set. The problem with this alternative is that no details about the nature of the contrast set have been provided: it could be **teachers, dropouts, auditors** and so on. A second possibility is to partition the file card that has just been created for **students**. The alternatives are graphically depicted in the following figure.



Only students furnished answers before the exam...

It would be eminently reasonable to take this second tack of partitioning an existing file card if information for forming the contrast set is available somewhere in the sentence itself. In example (25), the morphological ambiguity of the verb "furnished" allows the words following "only students" to be analyzed as a modifying phrase. This merely requires the division of the file card corresponding to **students** into two sets: Students who have been furnished answers and students who have not been furnished answers. These considerations have led us to propose that as a pragmatic

default perceivers favor the modification of currently available discourse referents over the creation of new ones. This simple "least effort" principle is a straightforward extension of the Principle of Parsimony.

Now let us consider what should happen, according to this extension of the Principle of Parsimony, if the initial NP also contains an adjective, as in example (26). Again, encountering this phrase outside of context would cause the perceiver to create a new file card, this time representing **dishonest students**. As in (25), the determiner "only" requires a contrast set. Following the pragmatic default we just mentioned, the contrast set can be introduced by partitioning the newly created card corresponding to dishonest students to include a set of honest students. Assuming that parsing proceeds on-line, both of these changes to the file cards can be made immediately. By the time the ambiguous phrase is reached, then, the perceiver will have satisfied the presupposition associated with "only dishonest students." If this reasoning is correct, we would expect people to **misanalyze** the ambiguous phrase "furnished answers..." as a comment rather that a modifier. Thus, they will be led up the garden path.

We predict, therefore, that sentences beginning with NPs with both the determiner "only" and an adjective should evoke garden path effects, just like sentences whose initial NP contains the definite determiner "the." By contrast, sentences beginning with NPs with the determiner "only" directly followed by the head noun should **not** evoke garden path effects.

5. An Experimental Study

We tested these predictions of the extended Principle of Parsimony in an experiment using a self-paced reading task. In this experiment, subjects read sentences displayed on a CRT one word at a time. Subjects called up each new word by pressing one of two keys marked "yes" or "no." Subjects were instructed to press the "yes" key as long as each word could be grammatically incorporated into the previous material. Either key press continued to bring up new words, which accumulated on the screen. The computer recorded the duration (in milliseconds) between the onset of each new word and the next key press. The experiment included 32 classic garden path sentences (target sentences). The referential properties of these sentences were manipulated by making minimal changes in the initial noun phrases. Each sentence was presented in 4 versions (A-D), illustrated by the following examples.

A) *The students furnished answers before the exam received high marks.*
B) *Only students furnished answers before the exam received high marks.*
C) *The dishonest students furnished answers before the exam received high marks.*
D) *Only dishonest students furnished answers before the exam received high marks.*

Notice that the syntactic structure of these sentences is held constant, and all versions contained morphologically ambiguous verbs, such as "furnished". These sentences were mixed with 16 control sentences which contained unambiguous verbs. The control sentences were presented in the same 4 versions (E-H) as the target sentences:

E) *The hunters bitten by ticks worried about getting Lyme disease.*
F) *Only hunters bitten by ticks worried about getting Lyme disease.*
G) *The young hunters bitten by ticks worried about getting Lyme disease.*
H) *Only young hunters bitten by ticks worried about getting Lyme disease.*

All sentences were interspersed among 92 fillers, making a total of 140 trials. Filler sentences comprised a variety of structures to discourage subjects from identifying the test sentences. There were 4 lists of stimuli. The 4 versions for each of the target sentences and the control sentences were rotated through the 4 lists, so that there was an equal number of sentences (target and control) of each version in each list. Each subject was presented with one list, and each list was presented to 8 subjects. Thus, a total of 32 subjects participated in this experiment. They were all native speakers of English and were naive as to the purpose of the experiment.

In order to contrast the predictions of the Garden Path Theory and the Referential Theory, the reaction time data for each sentence were divided into 4 regions. The first region contains the initial noun phrase; the second region is the first verb phrase which is ambiguous for the target sentences; the third region consists of the second verb (i.e., the disambiguating item for the target sentences); and the final region contains the remainder of the sentence minus the last word. The last word was eliminated in order to avoid "wrap-up" effects which add considerable variability to the data. The mean reaction time for each region is presented in figure 1.

Region 1	**Region 2**	**Region 3**	**Region 4**
The/Only (dishonest) students	*furnished...*	*received*	*high...*
The/Only (young) hunters	*bitten...*	*worried*	*about...*

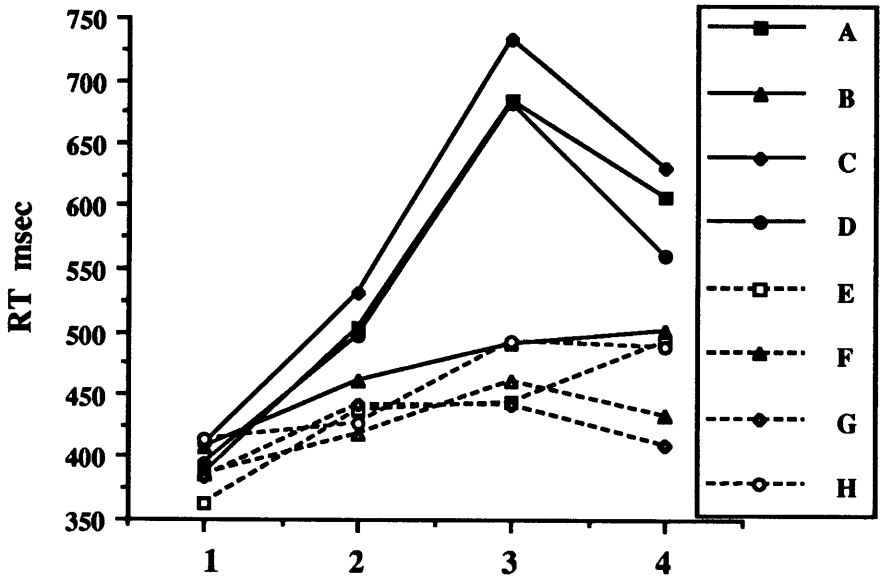


Figure 1. Mean reaction time per word by region

The points in each region represent the average time subjects took to read each word in that region. Only those responses that correctly recognized the sentences as grammatical were used in the analysis.

The findings are as follows. There were no significant differences in reaction times among the different versions of the test sentences in Region 1. In region 2, the sentences with the ambiguous verb grouped together, and yielded slightly longer reaction times than their unambiguous counterparts. The differences in the third region, however, were significant. Among the target sentences, words in Version A sentences took longer to read than in Version B sentences ($F_1(1,32)=6.59$, $p < .02$; $F_2(1,32)=3.31$, $p < .08$). Version D sentences also took significantly longer to read than Version B sentences ($F_1(1,32)=4.96$, $p < .03$; $F_2(1,32)=5.58$, $p < .03$). On the other hand, Version B sentences patterned like their unambiguous control counterparts (Versions E & F) ($F_1(1,32)=0.87$, $p < .36$). As expected, there were significant differences between Versions A, C, and D sentences on the one hand, and the unambiguous controls on the other.

The results clearly confirm the predictions of the Referential Theory. First note the contrast between Versions A and B, that is, between sentences beginning with "the" versus "only". The Garden Path theory would predict no differences in response times between the two versions, since they have the same syntactic structure. However, people were clearly garden pathed by the former but not by the latter. This is shown by the differences in response time between them in the disambiguating regions, regions 3 and 4. The second contrast is between Versions B and D; that is, between target sentences with the determiner "only" directly followed by a noun, and ones in which the noun phrase also contained an adjective. While the Garden Path Theory would again predict no differences in response time, the Referential Theory predicts that the addition of an adjective should induce garden path effects. This is exactly what happened.

6. Summary

We began by contrasting two models of ambiguity resolution: The Garden Path Theory and the Referential Theory. The Garden Path Theory maintains that people initially use structurally based strategies for resolving ambiguities, while conceding that in real world contexts the interpretation that ultimately wins out is the one that matches the context. A different set of principles for ambiguity resolution is offered by the Referential Theory. The Referential Theory contends that there is no such thing as a "null context". When people attempt to understand sentences outside of context, they actively create a mental context, that is, a discourse representation that the sentence would have had if it had been presented in a real context. According to the Referential Theory, there is no need to postulate additional structurally-based principles by which people resolve ambiguity. Taking advantage of the insights from formal semantics and discourse representation theory, one of the basic principles of ambiguity resolution within the Referential Theory was extended in this paper to handle a broader range of linguistic phenomena. The "file change semantics" of Heim (1982) was invoked to depict the process of creating a mental context and accommodating presuppositional failures. The final section of the paper tested some detailed predictions of the Referential Theory concerning the kinds of sentences that should eliminate or creat garden paths effects. With syntax held constant, we saw

that changes in lexical material in the initial NP of sentences were sufficient to induce radical differences in people's on-line perceptions of grammaticality. The differences were predicted by the Referential Theory, but resist explanation by the Garden Path Theory.

Acknowledgement

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Notes

1. Trueswell et al (1989) argue that half of the "inanimate" NPs in the Ferreira and Clifton study were possible agents of the sentence (e.g., "The car towed..."). Their study also included more appropriate controls, such as (8), instead of unreduced relatives (e.g. "that was"), which were used in the control sentences of Ferreira and Clifton (1986).

2. Additional factors have also proven to eliminate garden path effects. For example, Portner (1989) found that changes in the tense (past versus future) and the nature of the disambiguating verb phrase (whether it predicated a Stage-level versus an Individual-level property) resulted in a substantial reduction in perceptual difficulty. Portner acknowledges that these findings are consistent with the Referential Theory (but not the Garden Path Theory), but he advances an alternative semantic account that is limited to indefinite NPs.

References

Altmann, J. (1987). Modularity and interaction in sentence processing. In J. Garfield (ed.) *Modularity in Knowledge Representation and Natural Language Processing*. Cambridge, MA: MIT Press.

Altmann, J. and Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition, 30,* 191-238.

Bever, T. (1970). The cognitive basis for linguistic structures. In J.R.Hayes (ed.) *Cognition and the Development of Language*. New York: John Wiley and Sons.

Crain, S. and Steedman, M. (1985). On not being led up the garden path: the use of context by the psychological parser. In D.Dowty, L.Karttunen and A.Zwicky (eds.) *Natural Language Parsing: Psychological, Computational, and Theoretical Perspectives*. Cambridge: Cambridge University Press.

Ferreira, F. and Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25,* 348-368.

Frazier, L. and Rayner, K. (1982). Making and correcting errors during sentence comprehension: eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology, 14,* 178-210.

Heim, I. (1982). *The Semantics of Definite and Indefinite Noun Phrases*. Ph.D Dissertation, University of Massachusetts, Amherst, MA.

Karttunen, L. (1974). Presupposition and linguistic context. *Theoretical Linguistics, 1,* 181-194.

Karttunen, L. and Peters, S. (1979). Conventional implicature. In Choon-Kyu Oh and David A. Dinneen (eds.) *Syntax and Semantics, Vol. XI: Presupposition*. New York: Academic Press.

Lewis, D. (1979). Scorekeeping in a language game. *Journal of Philosophical Logic, 8,* 339-359.

Portner, P. (1989). Processing indefinite noun phrases in quantified sentences. ms. Amherst, MA: University of Massachusetts.

Soames, S. (1982). How presuppositions are inherited: a solution to the projection problem. *Linguistic Inquiry, 13,* 483-545.

Stalnaker, R. (1974). Pragmatic presuppositions. In Milton K. Munitz and Peter K. Unger (eds.), *Semantics and Philosophy*. New York: New York University Press.

Trueswell, J., Tanenhaus, M. and Garnsey, S. (1989). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. Paper posted at the Second CUNY Conference on Sentence Processing. New York, March, 1989.