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Comparing Serial and Parallel SPLT Models of Processing: evidence from Catalan[1]

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1. Introduction

In the study of human language processing, the attention to sentences containing temporary or permanent ambiguity has led to many insights. The experiment that we present here is part of this tradition. Its main goal is to contrast the predictions that a serial (garden-path) model of processing, on the one hand, and a parallel model, on the other hand, make in respect to a case of temporary ambiguity in a specific construction of Catalan. Based on the results obtained in a questionnaire in which subjects were asked to rate the difficulty of a series of sentences, it is concluded that the processing of the constructions presented here poses a challenge to both models. The comparison between the two models is resolved in favor of the garden-path model, although some adjustments to the theory as it stands might be necessary if a complete account of the data is to be obtained.

2. The case under study

In this experiment we used sentences that contained a temporary structural ambiguity, that was resolved later in the sentence. None of the sentences are finally ambiguous, but only at some point in their processing, as it happens with the so-called 'garden path sentences'.

The ambiguity of (1) is due to the fact that in Catalan, the conjunction that introduces the second term of a comparison is homonymic with a relative pronoun. They are both *que*:[2]

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[2] Notice that the PP *in Barcelona* can be argued to be attached both to the clause expressing the raining and to the one of not being sunny. As such, it is marked with a pause, indicating its dislocation:

Ha plogut més aquests tres dies que no ha fet sol, a Barcelona.

This pause makes the oral counterpart of (1) unambiguous.

(1)   Ha   plogut més en aquests tres dies que   no ha fet   sol a Barcelona
      Has.it rained more in these   three days which not has made sun in Barcelona
      que no en tot el   mes
      than not in all the month
      'It rained more in these three days that have not been sunny in Barcelona than in the
      whole month'

The sentence in (1) in which the first instance of *que* introduces a relative clause and the second instance of *que* introduces the predicted second term of the comparison, contrasts with the sentence in (2), where this order is reversed (i.e., the first *que* introduces the second term of the comparison, and the second *que* introduces a relative clause).

(2)   Ha   plogut més en aquests tres dies que no ha   fet   sol a Barcelona, que
      has.it rained more in these   three days than not it.has made sun in Barcelona, which

      hem   visitat per primer cop
      have.we visited for first   time

      "It rained more in these three days than it has been sunny in Barcelona, that we visited for the first time"

To strengthen the parallelism, in the examples of (1) and (2) both sentences are identical up to the disambiguating point, when the second *que* clause appears and the final structure of the sentence becomes clear. In other words, both sentences are equally ambiguous, since the ambiguous region is the same in each case. The sentences are also equally plausible. For this reason, any preference in parsing one over the other will have to be explained.

3. Hypotheses and predictions

Different theories of sentence processing give different accounts of the way the ambiguous sentences presented in §2 are parsed. I will first briefly present how two of such theories approach the phenomenon. We will then see, in §3.2, that they offer different predictions that can be tested in this experiment.

1.1.   The garden path account

Motivated in part by considerations of memory limitations, the garden path model assumes that the sentence is processed sequentially. The processor starts building syntactic structure with the first words it encounters, and incorporates new words coherently with the structure that is already built. In ambiguous sentences, like in non-ambiguous ones, the processor's analysis is determined by well-known processing principles such as Minimal Attachment[3] and Late Closure[4]. If new material appears in the sentence that can not be included

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[3] Do not postulate any potentially unnecessary nodes (Frazier 1978).

into the present structure, the processor re-structures its analysis to incorporate the new information. This reanalysis requires an extra effort for the processor, which is translated into time-consuming or difficulty terms.

In the case at hand, the account goes as follows. Let's examine the processing of the ambiguous sentence (1), repeated here for convenience as (3):

(3) Ha   plogut   més en aquests tres dies que   no ha fet   sol a Barcelona
     has.it rained   more in these   three days which not has made sun in Barcelona

     que no en tot el   mes
     than not in all the month

     'It rained more in these three days that have not been sunny in Barcelona than in the whole month'

In (3), when the comparative term *més*, 'more', ap4pears, the expectation of a second term of the comparison is predicted. This prediction has to be held until the right syntactic element instantiates it. Whatever fills the prediction will start by the complementizer *que*. Within the framework of a Frazier and Clifton (1996), it was hypothesized that when the first *que* appears in the sentence, the reader will start computing the second term of the comparison, since it corresponds to a primary relation:[5]

The hypothesis can be maintained until the end of the sentence, since (3') below is a perfect sentence:

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[4] If grammatically permissible, attach new items into the clause of phrase currently being processed (i.e., the clause or phrase postulated most recently) (Frazier 1978).
[5] Primary phrases and relations include: a. the subject and main predicate of any (+ or -) finite clause; b. complements and obligatory constituents of primary phrases (Frazier and Clifton 1996). The second term of a comparative sentence is included under b. A relative clause, however, is a secondary phrase.
According to the Construal Principle, a phrase XP will be first interpreted as instantiating a primary relation, and only when this hypothesis is contradicted, it will be interpreted as instantiating a secondary relation.

(3')   Ha plogut més en aquests tres dies passats que no ha fet sol a Barcelona

meaning: "it has been raining more than it has been sunny, on these last three days in Barcelona".

However, when the rest of the sentence is presented, this analysis is disconfirmed, and a reanalysis of the structure is necessary. The parser has to realize that the first *que* is a relative pronoun introducing a relative clause attached to a noun of the first term of the comparison, while the second *que* is the true introducer of the predicted second term of the comparison:
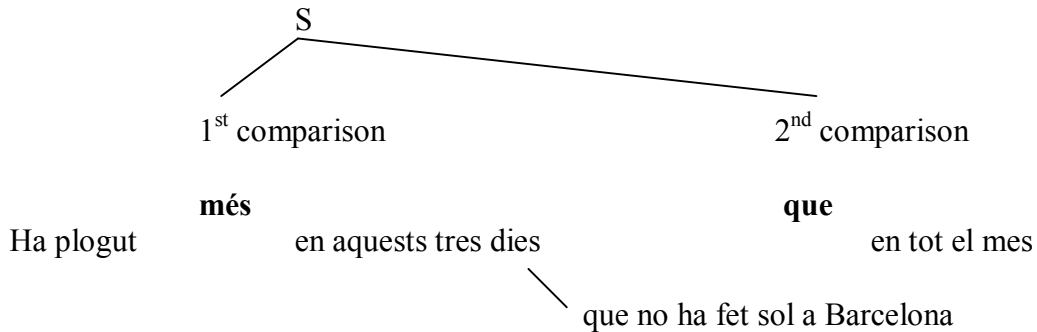
Sentences like (3) are misleading, in the sense that the preferred initial analysis is not the one that is finally adopted for the sentence. A non-misleading counterpart of the sentence above is the one presented in (2), where the second term of the comparison and the relative clause are introduced in the same order that the processor expects (i.e., instantiating predictions first).

1.2.   The parallel processing account

An alternative parallel parsing account of this kind of sentences consists on the parser computing all possible structures derived from the ambiguity of *que*, and holding them in equal status until the disambiguating information is available. Still, another possibility is that when the processor hits an ambiguous item, it holds the material unstructured until it can assign it an unambiguous interpretation. These two accounts impose a greater memory load, but they involve no initial commitment to any analysis and therefore no reanalysis.

1.3.   Predictions

I will next specify some predictions the models outlined above make in respect to the case at hand and the design of the experiment.

a. Differences in processing difficulty

A serial model of processing makes the strong prediction that the RelCl-2ndterm sentence is harder to read than the 2ndterm-RelCl one. This is so because in the first case the processor has to revise an already formed structure, while in the second case the preferred structure is confirmed and there is no revision to be made. In the experiment, this is expected to have the

result of the RelCl-2ndterm sentence being higher ranked in a scale of difficulty than the 2ndterm-RelCl one.

A parallel model of processing predicts that there be no difference in difficulty between the RelCl-2ndterm sentence and the 2ndterm-RelCl one. Since in this model both possible structures are computed when the ambiguous word is encountered, and in both cases one of them has to be systematically discarded at the disambiguation point, there is the same processing work in all cases, and no reason why discarding one hypothesis or the other should affect the processing difficulty. This scenario makes the experimental prediction that both groups of sentences will be ranked equally in a scale of difficulty.

The sentences of groups 1 and 2 in our experiment address this question.

b. Attachment preferences

As we saw before, the Construal model presented in Frazier and Clifton (1996) predicts that the 2ndterm-RelCl sentences correspond to the preferred analysis because in them the ambiguous word introduces a sentence instantiating a primary relation, and hence represent the preferred analysis.

A parallel processing model such as the parallel version of Gibson's (1998) Syntactic Prediction Locality Theory (SPLT) also predicts that the 2ndterm-RelCl sentences embody a preferred analysis. In his model, memory cost is considered in evaluating the hypothesis. In the cases at hand, it means that the processor computes both possible analyses, and chooses the less costly one. Because the filling of an expectation is always less costly than carrying it along, the non-misleading sentences are preferred over the misleading ones.

Even though both models make the same predictions as for which is the preferred analysis, they differ in still one prediction. For Gibson, a sentence in which the second term of the comparison is delayed (in the case at hand, by the introduction of a relative clause) will have the same cost, other things being equal, in an ambiguous and a non-ambiguous sentence; this cost will be higher than in sentences in which the second term of the comparison is introduced more immediately. For the garden path model, however, the difficulty is given by the ambiguity of the word *que*, which is initially interpreted, unambiguously, as introducing the second term of the comparison. If this ambiguity were not present, a sentence in which a relative clause intervenes between the two terms of the comparison should not be substantially more difficult to process than a sentence in which the relative clause is introduced at the end. That is, no garden-path will occur. The sentences of group 3 in our experiment aim to address this question.

4. Design of the experiment

The experiment took the form of a written questionnaire in which a total of 30 subjects were asked to read sentences and rate them according to their difficulty in understanding them. Each subject was given thirty-two sentences and rated them individually in 0 to 5 scales. The subjects were told that 0 meant no difficulty, 2 medium difficulty, and 5 high difficulty.
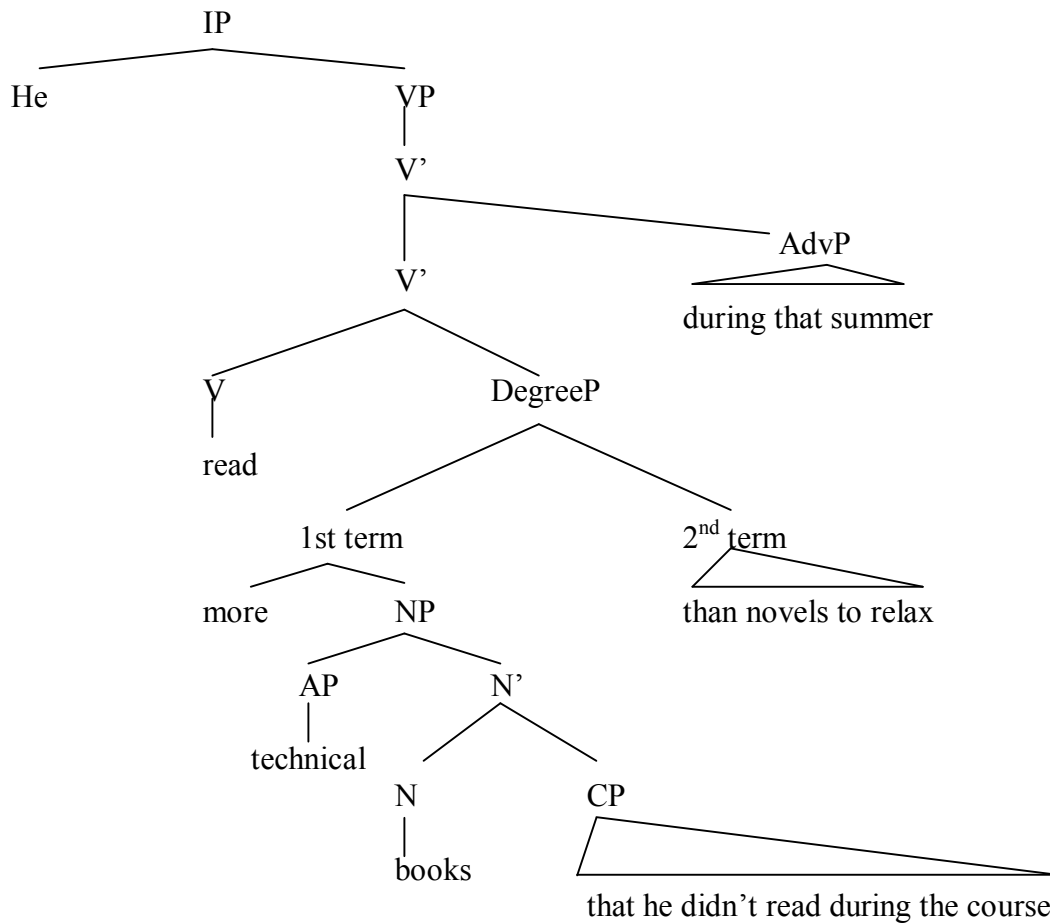
4.1 Sentences

Two groups of experimental sentences were constructed: ambiguous and unambiguous.5 There were eight temporarily ambiguous sentences with two versions of each, and eight unambiguous sentences with two versions of each. This gave a total of sixty-four sentences, which were distributed in two lists of thirty-two sentences each.

Group 1: Temporarily Ambiguous Sentences

This first group corresponds to temporarily ambiguous sentences. In one format (4a) the first instance of *que* introduces a relative clause, and the second instance of *que* introduces the second term of the comparison. This group was labeled 'misleading', because it favors the interpretation of the first *que* as introducing the expected second term of the comparison, when it is actually introducing a relative clause. An example is given below:

(4a)   Va llegir mes llibres tecnics durant l'estiu que no va llegir durant el curs, que no novel.les per a relaxar-se.
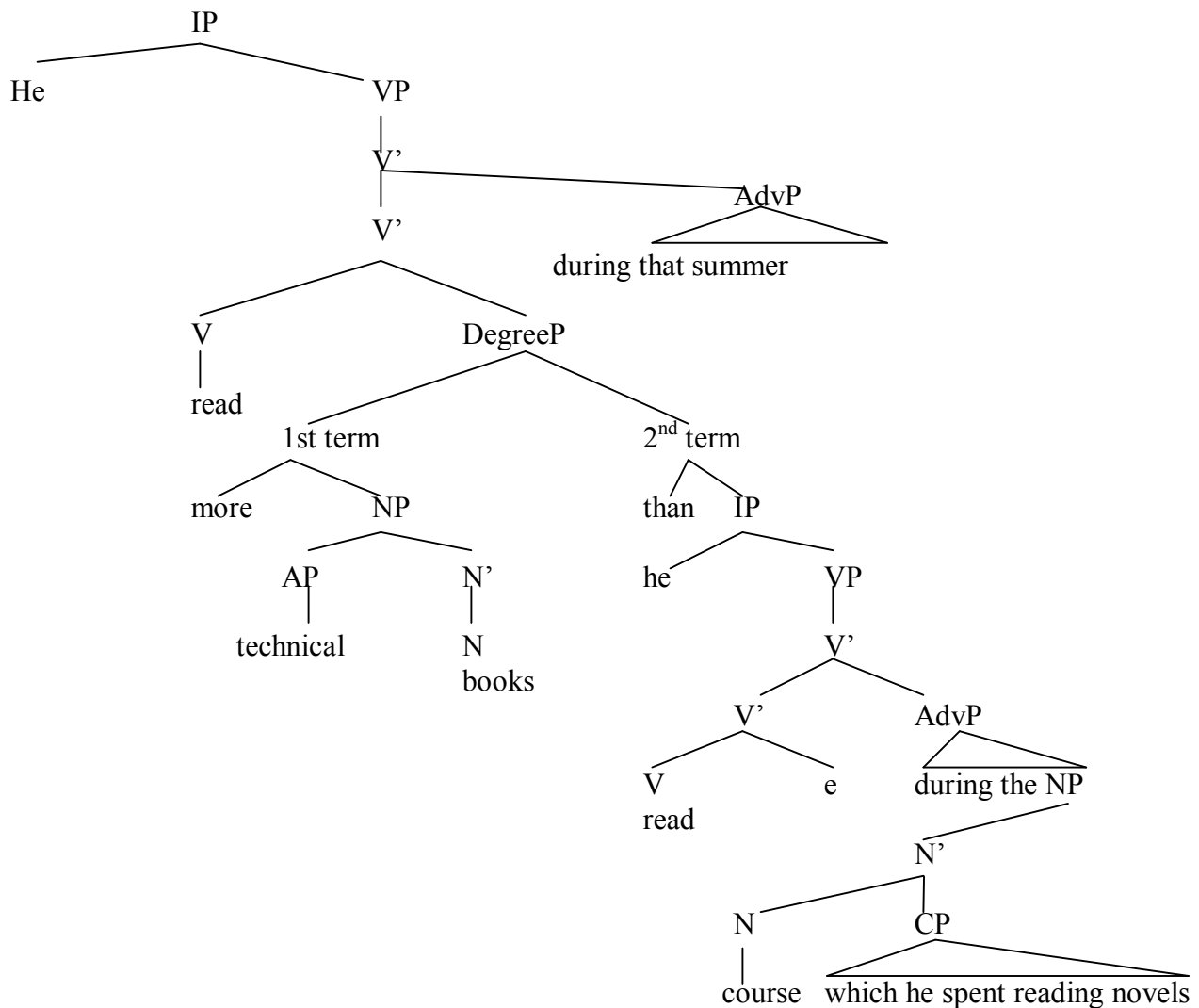
"He read more technical books during summer that he didn't read during the course, than novels to relax"

The second form of group 1 consists of comparative sentences in which the second term of the comparison is introduced by the first instance of *que*, while the second instance of *que* introduces a relative clause. These sentences are labeled 'non-misleading' since, as opposed to the ones in group 1, no ambiguous element intervenes between the prediction and its fulfillment. An example and its rough syntactic structure are given below.

(4b)   Va llegir mes llibres tecnics durant l'estiu que no va llegir durant el curs, que va passar llegint novel.les.

"He read more technical books during the summer than he read during the course, which he spent reading novels."

IP
He
VP
V'
AdvP
during that summer
V'
V
read
DegreeP
1st term
more
NP
AP
technical
N'
N
books
2nd term
than   IP
he
YP
V'
V'
V
read
e
AdvP
during the NP
N'
N
course
CP
which he spent reading novels

The sentences in group 1 form minimal pairs that start with the same string of words, which correspond to the two structures. Each subject sees only one of each pair, to avoid the

possibility that the subject is comparing the two alternatives when rating the difficulty of the sentences.

Group 2: Non-ambiguous Sentences

Sentences in group 2 had exactly the same syntactic structure as those in group 1, with two versions of each category. The relevant difference was that the relative sentence in both versions of group 2 was introduced by an unambiguous relative pronoun, which could not be taken by the introducer of the second term of the comparison. The disambiguation was made possible by using a different relative pronoun (*on* 'where', *quan* 'when', *qui* 'who'), or by using *que* preceded by a preposition (*en que*, 'in which', for example).

The reason for this group was to discard the possibility that the degree of difficulty the subjects reported was due to purely structural factors, instead of the ambiguous character of the word *que*, as assumed in the text. Therefore, these sentences acted as controllers of the ones in the former groups. At the same time, they addressed prediction b. of §3.

An example of a minimal pair is given below. In the first sentence, the relative clause intervenes between the first and second term of the comparison. In the second sentence, the relative clause is introduced after the second term of the comparison has been instantiated:

(5a)   Alguns insectes tenen més desenvolupats els organs amb els que capten estímuls visuals que la capacitat de processar aquests estímuls

"Some insects have the organs with which they capture visual stimuli more developed than the capacity to process these stimuli"

(5b)   Alguns insectes tenen més desenvolupats els organs visuals que la capacitat de processar els estímuls que capten amb aquests organs

"Some insects have the visual organs more developed than the capacity to process the stimuli that they capture with these organs"

Group 3: Fillers

This group is composed by sixteen filler sentences. These sentences are of the same length and syntactic complexity than the sentences of the former groups. They contain no ambiguity and are included just as a control for the default degree of difficulty assigned to unproblematic sentences of approximately the same length and number of embedded sentences as the ones under study. One example is given below:

(6)   Quan llegire l'ultima frase d'aquest questionari podre anar a fer coses mes interessants que aquesta

"Once I finish this questionnaire I will be able to go to do things that are more interesting than this one"

4.2 Lists

Two lists were constructed with the sentences. Each list contained thirty-two sentences: sixteen fillers from group 3 (common to both lists), eight ambiguous sentences from the group 1 (four of each structural category), and eight unambiguous sentences of the group 2 (again fours of each category). In each list there was only one sentence of the minimal pairs within groups 1 and 2.

The sentences were randomly ordered. A further restriction on the shape of the lists was applied to this result: sentences from the same condition were separated by at least one filler. Whenever this situation arose, a filler was used as separation. Fillers were allowed to be adjacent to each other.

4.3 Subjects

Thirty subjects were tested. They were all Catalan native speakers living in Barcelona. They were presented with written instructions and handed out a written questionnaire, which they completed in the presence of the experimenter. There was fifteen people tested for each list.

5. Results

To calculate the degree of difficulty of the sentences, each sentence was assigned the numeric value in the scale and the number of sentences within each type divided the total. The result is reported below:

GROUP 1a: ambiguous Relative Clause first
GROUP 1b: ambiguous Second Term Comparison first
GROUP 2a: unambiguous Relative clause first
GROUP 2b: unambiguous Second Term Comparison first
GROUP 3: fillers

Sentences	Mean
GROUP 1a	1.95
GROUP 1b	1.4
GROUP 2a	0.6
GROUP 2b	0.7
GROUP 3	0.3

6. Discussion

The results provide us with evidence to draw some conclusions about the questions raised in §1.3. As it was done then, I will here divide the discussion in two parts, addressing two different –but related—issues.

To start with, there is a substantial increase in difficulty in the misleading sentences, as opposed to all the others. The garden path account explains it by saying that these sentences involve a reanalysis of the construction the parser makes in the first instance, and hence the discomfort noticed by the subjects. The parallel processing model does not offer any account of the data. From this it is concluded that the present results can be taken as evidence in support of a model compatible with the predictions of the garden path theory.

As pointed out above, Gibson's SPLT theory also predicts that the misleading sentences be more difficult, since they embody the least economical analysis. On this point, then, the garden path account cannot be told apart from the SPLT model, and hence the importance of the next set of results.

It will be recalled that in Gibson's model any preferred analysis should have a lower memory and integration cost (translatable in our experiment as less difficult) than a non-preferred one. As a consequence, sentences in which expectations created by former elements are instantiated sooner will be less costly; that includes sentences that contain a temporary ambiguity. If so, the non-ambiguous pairs of groups 2a and 2b should present the same pattern as their counterparts in the ambiguous ones of groups 1a and 1b, since they are structurally identical and only vary on the temporary ambiguity of the latter, non-existent in the former ones.

As we saw, the results do not confirm this hypothesis. Sentences of groups 1a and 1b are rated higher in the difficulty scale. The SPLT model does not have any explanation for this pattern.

On the other hand, these results are consistent with the predictions of the garden path model, in which the higher difficulty of the sentences in groups 1a and 1b as compared with groups 2a and 2b is due by the ambiguous character of the former ones. The only result that challenges the garden path theory (and that is equally unexplained by the SPLT) is that the preferred analysis is harder when the sentence is ambiguous than when it is not. Two possible explanations suggest themselves: on the one hand, it could be that off-line judgements leave time for further analysis; on the other hand, it could be that preferred analysis are chosen more often than the alternative (e.g., 80% of the time), but are not chosen invariably (100% of the time). The data of this experiment does not shed light in any of these alternatives.

7. Conclusion

The goal of this experiment was to present some further evidence for the debate between different current models of language processing, mainly one based on serial, depth-first parsing, and one based on parallel parsing. It was argued that the results obtained in the experiment were

better explained in terms of the garden path model as outlined in its most recent version in Frazier and Clifton (1996).

Specifically, a serial processor of the kind assumed in the garden path theory can explain why the RC-first analysis is more difficult than the alternative. The reason is that a primary relation is preferred to a secondary one when parsing ambiguous sentences. Moreover, a serial processor can explain why the difference is only present with ambiguous sentences: because only in those cases the parser is garden-pathed.

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