Some Observations on the Universality of the Late-Closure Strategy

Marica De Vincenzi¹,³ and Remo Job²

Two questionnaire studies and a reading time experiment investigated the application of the late-closure principle in Italian, a Romance language which contrasts with English with respect to several linguistic properties. All the studies addressed interpretation preferences in sentences containing a complex NP followed by a relative clause (e.g. ...the son of the woman who arrived yesterday...). While the questionnaires investigated final preferences, the reading time experiment addressed also the principle governing the initial attachment of a relative clause to a complex NP. Furthermore, through a manipulation of the type of preposition within the complex NP, we investigated the role of the thematic structure of the complex NP in initial and final parsing. The results showed that the late-closure principle applies in Italian to the initial parsing without being affected by the thematic structure of the complex NP. Final interpretation instead shows an effect of pragmatic preference and an effect of thematic structure on syntactic revisions. The results are discussed in terms of a parsing model that adopts syntactic parsing strategies and makes modular use of linguistic information. Some implications for the relationship between syntactic theories and the human parser are also addressed.

INTRODUCTION

The purpose of the present research is to assess whether the grammatically defined principle of late closure (LC) applies in Italian and to...
discuss whether it qualifies as a universal parsing principle. Here we will present the results of two questionnaire studies and an on-line experiment that we conducted in Italian.

Starting with Kimball (1973) and Frazier and Fodor (1978), we have seen in parsing the proposal of strategies that are defined over the geometry of the phrase marker of a sentence, regardless of what particular phrase types are involved. Some examples of such strategies are the right association (Kimball, 1973), minimal attachment and the late-closure strategy (Frazier and Fodor, 1978), the superstrategy (Fodor, 1979), the recent filler strategy (Frazier, Clifton, & Randall, 1983), the active filler strategy (Frazier, 1987), and the minimal chain principle (De Vincenzi, 1991). The basic idea in all these strategies is that they are directly derived from a simple principle: Choose to do whatever costs the least effort in terms of computation. This choice is derived by a basic cognitive reason, namely, the restrictions on short-term memory (STM) in terms of memory and computational space and the fact that, the more structured the material to be stored, the smaller the demand it makes on the STM space (Miller, 1956). Given the fact that these principles are based on cognitive needs and that they are not tied to any language-specific aspect, we expect them to be universal.

Let's now examine late closure in more detail. Late closure (Frazier, 1978) says that, if grammatically permissible, the human parser will attach the new items onto the clause or phrase currently being processed. The strategy generalizes across several constructions: It explains the intuitive preferences that people have in constructions like the following: In Example (1) below there is a preference to attach the verb particle to the lower verb (smash) and not to the higher one (call); in (2) the possessive preferentially associates with the lower NP Mary rather than to the higher NP the boy whom Sam introduced to Mary; in (3) the PP to Mary tends to be attached to the last NP constituent (the letter) rather than to the higher NP or to the VP; in (4) the PP in a box tends to be attached to the last NP the boy (contained in a PP), rather than to the higher NP, even though the latter is the only semantically acceptable attachment; in (5) the adverb is preferentially attached to the lower verb left rather than to the higher one said; in (6) the past participle allungato (diluted) is preferentially attached to the last NP lo zio (the uncle), even though the high attachment is the only plausible one. Examples (4) and (6) are particularly interesting because they show that even despite semantic incongruity there is a detectable late-closure preference.

(1) Joe called the friend that had smashed his new car up.
(2) I met the boy whom Sam introduced to Mary's friend.
(3) John read the note, the memo, and the letter to Mary.
(4) A gift to a boy in a box. (Abney, 1988).
(5) John said that Tom left yesterday.
(6) Il vino dello zio allungato con l'acqua. (The wine of the uncle diluted with water.)

Not all the constructions are present in English and in Italian: Constructions (3) through (5) are found in both languages and with exactly the same preferences, but constructions (1) and (2) are found only in English, while construction (6) is found only in Italian, due to the possibility of postnominal adjectives. The fact that the intuitive preferences in reading these different constructions can be subsumed under the same parsing strategy is therefore quite impressive. It is easy to image a system that instead applies a new strategy each time a new construction or a different language is encountered. On the contrary, the fact that these different constructions exhibit the same preferences and in different languages, such as English and Italian, calls for an explanation and shows that the language comprehension system cannot be a random collection of whatever clue can be gained from a superficial analysis of the string.

EXPERIMENTAL STUDIES ON LATE CLOSURE

Experimental studies conducted in English with on-line measurements such as reading times and auditory presentation (Frazier, 1978; Slowiatzcek, 1981) have shown that late closure is an effective strategy for speakers/listeners of English. However, a study conducted in Spanish by Cuetos and Mitchell (1988) challenged the universality of late closure. In a questionnaire study they investigated the preference for the attachment of relative clauses (henceforth, called RC) in syntactically ambiguous constructions of the form: NP1- of NP2- RC. Using sentences like (7) they found a 63% early closure (EC) preference in the RC attachment, that is a preference to interpret the RC that was in the living room as referring to NP1 (the book) rather than to NP2 (the girl):

(7) Pedro was looking at the book of the girl that was in the living room.

The questionnaire data were replicated in a self-paced reading study, using the same material as in the questionnaire study. The attachment site of the RC was disambiguated on the segment following the RC—in
(8a) the last segment which is a gerundive clause. A sample of the constructions used is given in (8). The latter three constructions have been used as control for (8a):

(8) a. Pedro was looking at the book of the girl/that was in the living room/watching TV.
   b. Pedro was looking at the girl/that was in the living room/watching TV.
   c. Pedro was looking at the book and the girl/that was in the living room/watching TV.
   d. Pedro amused himself with the brother of the girl/that was in the living room/watching TV.

Contrary to the predictions of late closure, Cuetos and Mitchell (1988) found that the reading time on the critical segment (i.e., the last one) in (8a) was slower than in any other condition, therefore suggesting that the RC had initially been attached to the first NP and that, when the disambiguating information of the gerundive clause arrived, subjects had to revise the RC attachment from the first NP to the second NP. The authors then proposed that late closure does not apply in Spanish, at least to the processing of RCs. They presented a model of a parser that does not have universal parsing strategies, but rather arbitrary strategies. We then decided to test the RC attachment preference in Italian, a romance language similar to Spanish with respect to several linguistic properties.

In the first study we presented the Cuetos and Mitchell (1988) material translated into Italian in a questionnaire form, asking subjects their preferred interpretation. The subjects were 90 students of the University of Padova. They received written instructions on how to fill out the questionnaire. The questionnaire contained the 24 sentences translated from Spanish and 30 other sentences which had a variety of different interpretations.

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4 The experimental and the filler sentences were randomized in four different orders. Each sentence was followed by the two possible answers and subjects had to check one. The order of the answer (the LC or the EC interpretation) was balanced, so that across subjects each sentence appeared an equal number of times with the order of the answer EC–LC and with the order LC–EC:

Someone shot the servant of the actress who was on the balcony.

the servant was on the balcony —
the actress was on the balcony —
syntactic structures. The results replicated those of Cuetos and Mitchell, in that we got a 65% EC preference for RC attachment.

The question to ask now is: What is the reason for this EC preference? Cuetos and Mitchell (1988) suggested that the EC strategy in the RC construction in Spanish can be caused by a difference between the Spanish and English distribution of the adjectives. In Spanish adjectives can follow the noun, giving (among other situations) rise to constructions of the form in Example (11):

(11) NP- Adj- RC

They suggested that, given the existence in the language of forms like (11), a local strategy to connect the RC to the NP in structure like (11) evolves in Spanish and furthermore it generalizes to the class of constructions of the following form: NP- modifying constituent - RC. This means then when a structure of the form NP- PP- RC is found, then the "local" strategy overrides late closure and determines the EC preferences they found in Spanish. Given that Italian can have postnominal adjectives as Spanish does, the questionnaire preference for EC in Italian is then expected. However, two facts go against the Cuetos and Mitchell (1988) explanation. The first is that their explanation would predict an EC preference for all the constructions we presented in Examples (3)–(6) in Italian, given the fact that they are all of the same form as (11). Instead, they all showed a late closure preference in interpretation, some of them [(4)–(6)] even despite semantic plausibility. It seems highly implausible that people first apply the local strategy and arrive at an EC interpretation and then, despite the fact that the EC interpretation is the only semantically acceptable one, they still try to apply the late-closure interpretation.

The second objection is that, according to the Cuetos and Mitchell (1988) explanation, we should expect a LC preference with the same material in English, a prenominal adjective language. However, Clifton (1988) showed that the same EC preference found in Spanish is also found in English. In a questionnaire study using the same material as Cuetos and Mitchell, Clifton found an EC preference (55% vs. 36%). This finding shows that the EC preference is not a special-purpose routine in the parser only for Spanish and Italian. It rules out the language-specific explanation and calls for an explanation that applies equally to Spanish and English.

Finally, note that the fact that similar closure preferences have been found in a prenominal adjective language (English) and pre- or postnom-
inal adjective languages (Spanish and Italian) does not exclude that there can be different effects of closure in these two classes of languages. As noted by Frazier (1990) in English there is an unambiguous way of conveying the EC meaning of (12a), namely, with the possessive construction (12b):

(12) a. The daughter of the woman who was on the balcony.
   b. The woman's daughter who was on the balcony.

So, in English the use of NP1 and NP2 RC1 could violate the Gricean maxim of clarity (be clear, avoid ambiguity): For the EC reading the speaker chooses an ambiguous structure when an unambiguous one is available in the language. But in Spanish and Italian, where a possessive construction is not available, as it is in English, this EC disambiguation is not possible. Therefore the NP1 and NP2 RC structure is more ambiguous toward EC in Spanish and Italian than in English. Note that this explanation could account for the slightly lower percent of EC preference in English (55%) than in Spanish (63%) and Italian (65%).

**FURTHER INVESTIGATIONS ON LATE CLOSURE**

All the data discussed in the preceding paragraphs were derived from the same set of material, therefore giving rise to the possibility that the results we got were simply due to the specific set of material. We then tested in a questionnaire 16 other sentences with the same structural ambiguity (NP1- PP NP2- RC), translated from a questionnaire administered to American subjects by Clifton (1988). This latter material differed from the Spanish material in that both NPs were human, and half of the sentence had the preposition of (13a), and the other half the preposition with (13b):

(13) a. Someone shot the servant of the actress who was on the balcony.
   b. Nobody knew the boy with the strange girl-friend who was sitting in the kitchen.

The results showed that the attachment preference is influenced by the preposition within the complex NP. In particular, in sentences with the preposition of there is a tendency toward the EC attachment (55% in American, 51% in Italian). For the preposition with there is a strong preference for the LC attachment (64% in English, 70% in Italian).
Taken all together, the questionnaire data from Spanish, English, and Italian show the following: (1) that there is a final EC attachment preference; 2) that the final attachment preference is influenced by the type of preposition within the complex NP. In particular the fact that the EC preference has been found not only in Spanish and Italian, which are both romance languages, but also in English, requires an explanation to the counter-evidence to LC that generalizes across typologically different languages.

The first general question that we should address is whether the final attachment preferences shown by the questionnaires are the same as the initial attachment preferences. It is in fact possible to hypothesize that, in the on-line processing of a sentence, there is an initial LC preference to attach the RC to the last NP, a preference which is later over-ridden by other factors. Notice that the Spanish on-line experiment used a pragmatic disambiguation that arrived quite late with respect to the point of ambiguity, namely, on a constituent following the ambiguous RC [cf. examples (7) above]. The fact that the resolution of the ambiguity is on a constituent following the RC constitutes a problem because the constituent can be attached not only to the RC, but to the verb of the main clause: This is true either when the disambiguating segment is a gerundive clause or a subordinate temporal clause or a prepositional phrase. The examples in (14) that simply vary the content of the final constituent, make very evident such a structural possibility:

(14) a. Pedro was spying the girl-friend of the brother that was in the living room watching through the key hole.
   b. Pedro was spying the girl-friend of the brother that was in the living room with his little sister.
   c. Pedro was in love with the daughter of the teacher who lived down the road when he was young.

In (14a) Pedro can be spying watching through the key hole, in (14b) he can be spying together with his little sister, in (14c), he could have been in love when he was young. The Cuetos and Mitchell (1988) material, then, not only had the structural ambiguity on the attachment of the RC but also had a structural ambiguity on the attachment of the final constituent to the RC or to the main clause. This seems to us a problem in the experiment because it introduced the possibility that the reading times on the final segment did not reflect the attachment of the final constituent to the RC, but rather the attachment of the final constituent to the main verb.
Therefore, a way (1) to avoid the confounding effect due to introducing the disambiguation on a further constituent and (2) to disentangle initial from later parsing preferences seems to be to have a syntactic disambiguation in the RC itself.

Clifton (1988) tested the on-line preferences in the RC attachment in a self-paced experiment which used 16 sentences similar to those in (15). The sentences contain a syntactic disambiguation within the RC, given by the agreement between the reflexive and the head of the RC:

\[(15)\] a. The doctor called in/the son of the pretty nurse who hurt herself.
   b. The doctor called in/the son of the pretty nurse who hurt himself.

\[a’\]. Anthony hated/the boy with the pretty student who was purposely drawing attention to herself.
\[b’\]. Anthony hated/the boy with the pretty student who was purposely drawing attention to himself.

The results showed that the LC conditions [(15a) and (15a’)] were read significantly faster than their EC counterparts [(15b) and (15b’)]. Therefore, the data showed that, contrary to the questionnaire and to the Spanish experiment, LC is the initially preferred attachment in English.

The next question to ask is then: What is the factor which masks the initial LC preference? Frazier (1990) proposed that there is a tendency (called the "relevance principle"), to construe a phrase as relevant to the main assertion of a sentence: Other things being equal (e.g., all interpretations are grammatical, informative, and appropriate to discourse), preferentially construe a phrase as being relevant to the main assertion of the current sentence.

Let’s take (16) to illustrate the principle:

\[(16)\] Julie met the friend of the man . . .

The main assertion, in the present case, is the main clause NP-verb-NP1 “Julie met the friend . . . .” Since the friend is part of the main assertion, there would be a preference to take the RC as modifying the friend rather than the man which is not part of the main assertion. The relevance principle predicts that in cases where the reader/listener does not have any other information about the NPs in the complex NP, then a RC with referential content should reduce the pressure to modify the first NP the friend, because both NPs necessitate identification. However when the content of the RC is context-dependent—for example, locative content—then the perceiver has to add assumptions about a shared sit-
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uination where the RC can be used identificationally. In this latter case, then, the perceiver should have a stronger tendency to follow the relevance principle, i.e., a greater tendency toward an EC attachment. Frazer and Clifton tested the predictions in a questionnaire study using sentences like (16a) and (16b):

(16) Julie met the friend of the man . . .
   a. Julie met the friend of the man who reads news on Saturday Night Live.
   b. Julie met the friend of the man who was in the living room.

The results showed a higher percentage of early closure responses for the locative (16b) RCs (70% EC choices) than for the identificational (16b) RCs (59% EC choices). This study therefore supports the view that a pragmatic principle disguises the effects of LC in the structures under discussion. 5

At this point the questions that we want to address are: (1) Whether in a Romance language like Italian the LC principle is operative in the initial attachment of modifiers to complex NPs. (2) Furthermore, both the English and the Italian questionnaire data showed a strong preposition effect in the final attachment preferences [cf. Examples (13)]. But how exactly can this preposition effect be characterized? It does not show up in the on-line experiment in English, which suggests it does not involve the initial syntactic analysis. However, given that it shows up in the final preferences which we saw subject to the dictates of the relevance principle, how then does this preposition effect interact with the relevance principle?

To answer these questions we used material which had a syntactic disambiguation within the ambiguous constituent. Subjects had to read the sentence segment by segment, so that we could get an on-line measure that reflected the processing preferences as the words were first recognized. However, given that we also wanted to investigate the preposition effect and its interaction with the relevance principle, we also asked

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5 De Vincenzi and Job (1989) further investigated the pragmatic effect that a locative RC has on attachment. Their hypothesis, based on pragmatic considerations and inspired to the Gricean maxim of quantity, predicts that there should be an EC bias with complex NPs that have the form: nonhuman NP1 - human NP2 - locative RCs.

The hypothesis was confirmed by the results of a questionnaire study that they conducted with Italian subjects. Given that 60% of the sentences in the Cuetos and Mitchell (1988) material had the structure in (1) (nonhuman NP1, human NP2- locative RC), the EC preference can be explained as a pragmatic bias.
subjects to answer a comprehension question which asked to what NP the relative clause attached. The time to read and answer the comprehension questions were off-line measures, in that they reflected a later stage of processing on the experimental sentence.

**ON-LINE EXPERIMENT**

**Method**

*Subjects.* The subjects were 40 students of the University of Roma, native speakers of Italian.

*Materials.* The material consisted of 16 sentences, 8 of which had the preposition *di* (of), and the remaining 8 had prepositions with lexical content: *con, nel* or *sul* (with, in the, on the).

(17) NP - verb - [NP1 - of NP2- RC].
(18) NP- verb - [NP1 - with NP2- RC].

The RCs were subject relatives, i.e., the head of the clause was the subject of the clause. This was done in order to have the (gender) agreement of the verb that disambiguates the attachment. From a syntactic point of view, RCs are considered postnominal adjuncts of the noun, that is, there are not a complement of an N, nor subcategorized by it. Therefore they are analyzed as attached at an N-bar level and sister to an N-bar. As for the RCs’ position in Italian complex NPs, it is usually the final one because the RCs follow both the argument and adjunct complements of the noun. Therefore in (17) and (18) both the EC and LC attachment of the RC are perfectly legitimate.

As for the difference between (17) and (18), it can be characterized as a difference between having a complement (17) or an adjunct (18) of

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6 In fact in Italian the past participle usually agrees with the subject when the verb is conjugated with *essere* (to be). It has an invariable ending *-o* when the verb is conjugated with *avere* (to have). Only rarely the past participle may agree with the object. Therefore the material always had RCs with verbs conjugated with *essere*. The relative clauses were always restrictive. While in general the appositive or restrictive use of a relative clause is disambiguated by the context of use, in isolation (as it is the case in the experiment) they are usually disambiguated by an intonative contour. In particular appositive RCs usually have a pause after their antecedent or a descending tone on the RC. In writing, a comma usually separates the appositive RC from its antecedent. Given that we had no comma in the experiment, we forced a restrictive interpretation of the RC.
the NP. The preposition of in fact usually introduces complements of the noun, which are constituents subcategorized by the noun itself. In fact most of the NP1s we used were binary place relations, like daughter of, mother of, cousin of, which necessitate a second noun to define the relation. By contrast the cases in (18), where the PP contains the preposition with, are cases of adjunct of NP1, because they are not subcategorized by NP1. That a constituent is subcategorized by an NP or not can be paraphrased by saying that the constituent is more or less tight to the head NP. This is rendered in both syntactic and semantic terms: In syntactic terms, it is usually assumed that complements of NP attach to an N-bar level and are sister to the noun (N). Adjuncts instead are assumed to attach to an N-bar level and are sisters to an N-bar level as well. In conclusion, the description of the complex NP in (17) and (18) can be rewritten in the following form:

(17) NP verb [NP1 (of) argument adjunct].
(18) NP verb [NP1 (with) adjunct adjunct].

Each sentence had an early closure (a) and a late closure (b) version. An example of the conditions is given in (19) and (20). The literal English translation is given in parentheses. Slashes indicate segmentation. The segments between double slashes are the critical ones, containing the relative clauses. The critical segment was followed by another segment. The reason for doing this was to avoid the confounding of final sentence reading effects with the closure effects.

The comprehension task [indicated as in (19) and (20) consisted of a question. It was presented on the screen, all at once, immediately after the subject pressed the button at the end of the last segment of the sentence. The question queried the relative clause attachment. It was followed by the two nouns to which the relative clause could attach. The reciprocal order of the two nouns in the question was counter-balanced in order to avoid biases. The subjects had to answer by pushing a left- or a right-hand button, corresponding to whether the correct noun appeared on the left- or to the right-hand side of the screen.

(19) Preposition di (of)
   a. L'avvocato diffida \ del padre \ della ragazza \ che si è tradita \ al processo.
   b. L'avvocato diffida \ del padre \ della ragazza \ che si è tradito \ al processo.
Chi si tradi? Ragazza - Padre
a. The lawyer suspects of \ the father \ of the girl \ who betrayed herself \ at the trial.
b. The lawyer suspects of \ the father \ of the girl \ who betrayed himself \ at the trial.

Who betrayed-self? Girl - Father

(20) Prepositions with, in the, on the
a. Tutti ammirano \ il signore \ con la figlia \ che si e messa \ a cantare un’opera.
b. Tutti ammirano \ il signore \ con la figlia \ che si e messo \ a cantare un’opera.

Chi canto? Signore - Figlia

In English:

a. Everybody admires \ the man \ with the daughter \ who started herself \ to sing an opera.
b. Everybody admires \ the man \ with the daughter \ who started himself \ to sing an opera.

Who sang? Men - Daughter

In addition to the 16 experimental sentences, there were 60 filler sentences. The filler sentences were declarative sentences and questions. Predictions. When the parser encounters the RC, it should attach it to an N-bar level of NP1 or NP2. The operations are syntactically equivalent in either case. However if the parser follows the late-closure parsing principle, then it should prefer to attach the RC to the N-bar level of NP2, because NP2 (the last constituent being parsed) is linearly closer to the RC. In the time it takes to answer the comprehension question and in the percentage of accurate responses, subjects should be slower and make more errors in the LC condition following the sentence containing the preposition of because the relevance principle should sometimes force a revision of the initial analysis.

Procedure. Sentences were presented using a moving-window, non-cumulative self-paced presentation. The reading time on each segment of the sentence, the time to answer the comprehension question, and the answer to the question were recorded. The design was a repeated-measured design incorporating a Latin square. Each subject saw no more than one version from each sentence pair, and each subject was exposed to all conditions. Order of presentation of the sentences was randomized
for each subject. This means that each subject saw a total of 76 sentences: 16 experimental sentences plus 60 filler sentences.

**Results**

The data for Experiment 1 are presented in Table I. The mean reading times (RTs) were computed for each segment. Analyses of Variance (ANOVAs) were conducted on the RTs for each segment with both subjects (F1) and items (F2) as random effects. There were two variables with two levels each: closure (early vs. late) and preposition (di vs. with). ANOVAs performed on the fourth segment (the critical one) showed the following significant effects: The late-closure conditions were read faster than the early-closure conditions [main effect of closure, \( F(1, 39) = 11.26, p < .002; F(2, 14) = 15.40, p < .002 \)]. ANOVAs performed on the fifth segment showed that the late-closure conditions were read faster than the early-closure conditions [main effect of closure, \( F(1, 39) = 5.51, p < .02 \)], but the effect was not significant in the item analysis (\( F(2) > .10 \)). Questions following sentences with the preposition *di* were answered more accurately in the early-closure condition than questions in the late-closure condition and this difference was not present for the questions following the sentences with the preposition *con* [interaction of closure and preposition, \( F(1, 39) = 19.74, P < .001; F(2, 14) = 30.94, p < .001 \)]. No significant effect was found in the time to answer the comprehension question.

**Discussion**

The results of this experiment showed that there is an initial preference for analyzing the relative clause as attached to the last NP, there-

| Table I. Average Reading Time (RT) for All Responses in Each Segment in the Different Experimental Conditions; the Critical Disambiguating Segment (#4) Is Underlined |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                  | Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | RT         | % Correct  |
| Preposition *di*| Early closure | 1136 | 884 | 913 | 1104 | 1106 | 2137 | 0.93 |
|                  | Late closure  | 1138 | 862 | 866 | 993 | 1017 | 2148 | 0.71 |
| Preposition *con*| Early closure | 1000 | 830 | 883 | 1126 | 1113 | 2110 | 0.81 |
|                  | Late closure  | 1012 | 831 | 961 | 1013 | 1046 | 1926 | 0.86 |
fore supporting the late-closure strategy. However, on the following comprehension question, which reflected later processing of the experimental sentence, the results showed a preference to take the RC as modifier of the first NP, and this preference was present only for the cases with the preposition *di*.

The on-line data have a straightforward interpretation, in that they show that the initial attachment is done according to the LC principle, and consequently is influenced simply by structural considerations. However, the off-line data regarding the preposition *di* (*of*) are more complex to explain. If we look at only correct trials we see (Table II) that the time to answer the comprehension question showed a main effect of closure \( F_2(2, 14) = 8.94, p < .01 \) with LC sentences answered faster. This effect was due to the LC conditions for sentences with the preposition *of*, which became consistently faster when only the correct trials are considered. This entails that the question answering time in the wrong trials—that is, mainly in the LC condition with the preposition *of*—had long RTs. Those were exactly the trials where, if LC applied initially and then the relevance Principle applied, we expected a revision of the initial LC preference.

However the question now is: How does this principle of relevance interact with the argument–adjunct difference we found? The explanation we suggest situates the off-line effects at a pragmatic/semantic level, but it capitalizes on the thematic structure of the complex NP. The difference between the structure in (17) and (18) can be seen as an asymmetry between an adjunct and an argument in letting a following modifier attach to a previous lexical head. The argument–adjunct distinction hints at a distinction in thematic structure. In the (a) cases, where NP2 is an argument of NP1, NP1 is the theta assigner which assigns a thematic role

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**Table II.** Average Response Time (RT) for Correct Responses Only in the Different Experimental Conditions

<table>
<thead>
<tr>
<th>Preposition</th>
<th>Questions' RT</th>
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<tbody>
<tr>
<td><em>di</em></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>2111</td>
</tr>
<tr>
<td>LC</td>
<td>1985</td>
</tr>
<tr>
<td><em>con</em></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>2087</td>
</tr>
<tr>
<td>LC</td>
<td>1830</td>
</tr>
</tbody>
</table>

*EC = early closure; LC = late closure.*
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The syntactic parser initially attaches the RC to NP2. The pragmatic parser, which applies at the level of the discourse representation, following the relevance principle, favors an EC interpretation. If at the level of the discourse representation NP1 is available, then the parser, in some cases, reanalyzes the structure as an EC structure in order to get a more pragmatically plausible analysis. We suggest that NP1 is available to be construed with the RC when the RC is within the thematic domain of NP1, i.e., a modifier of an argument of NP1. The RC is not the thematic domain of NP1 when it is a modifier of an adjunct of NP1. The reason is that, when an adjunct intervenes between NP1 and the RC, there is in fact another thematic domain, the one of the adjunct, intervening between NP1 and the RC. A definition of thematic domain has already been formulated in the psycholinguistic literature by Prichett (1988) to propose a principle to account for the different degrees of difficulty of syntactic reanalysis:

- **Theta domain:** A is in the \( G \) theta domain of B iff A receives the \( G \) theta role from B or if A is dominated by a constituent that receives that \( G \) theta role from B.
- **Theta reanalysis constraint:** Syntactic reanalysis which reinterprets a theta marked constituent as outside of its current theta domain is costly.

The difference in question answering time between correct only and total trials shows that the reanalyses actually occur at the answering time. At that point, given that the disambiguating segment is no longer visible (and the verb of the question is past tense, so no gender morpheme is available), subjects can sometime revise the initial LC analyses, overlooking the gender agreement. However, they do this revision only in cases where the reanalysis is not too costly, namely when the RC can be reanalyzed as within the same theta-domain. The pragmatic principle suggests an attachment of the RC as adjunct of NP1, i.e., in the theta-domain of NP1. When NP2 is an argument of NP1, then NP2 is in the domain of NP1 and the RC, being dominated by NP2, is in the domain

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7 There is no doubt that, with the sentence available in front of them, subjects did not misinterpret. But the self-paced methodology put them under some time pressure, which can lead to a loss of verbatim information in STM. This fact suggests a more general interpretation of the relevance principle, namely, as a tendency to construe a phrase as relevant to the main assertion of a sentence, sometimes even despite the grammatical analysis.
of NP1 as well. Revision of the RC attachment from NP2 to NP1 is still within the same theta domain, and therefore not costly. However, when NP2 is an adjunct of NP1, NP2 is in the theta domain of the preposition, and the RC, being dominated by NP2, is in the domain of the preposition as well. The revision of the RC attachment from NP2 to NP1 would then move the RC within another theta domain and is therefore predicted to be costly.

Our hypothesis, then, explains also the off-line results in Italian and in English where there is an EC preference for the preposition of but an LC preference for the preposition with. Furthermore we predict that in general the cases where the modifier of NP1 is an adjunct should behave as favoring a LC attachment of a following modifier. This prediction is in fact confirmed by recent data by Mitchell and Cuetos (1991): They found an LC preference in Spanish with cloze data, using sentences like (21):

(21) Peter was looking at the books which belonged to the girl who/ which . . .

This difference is perfectly explainable under our hypothesis, once we consider that the RC which belonged to the girl is an adjunct and therefore it should block a reanalysis of the second RC that was in the living room to the highest NP1, because it is not in the theta domain of NP1 but rather in the domain of the first RC which belonged to the girl.

CONCLUSIONS

The experimental findings lead us to several considerations. Regarding the generalizability of LC across different languages, we have found that the LC principle is operative in Italian, specifically in the attachment of modifiers to complex NPs. This fact supports the view of LC as a universal parsing strategy.

Regarding the operating characteristics of the parser we have found the following:

1. The initial parsing is done according to syntactic preferences, while pragmatic preferences affect only final interpretation, therefore suggesting a modular use of linguistic information.
2. Syntactic revisions are done according to the thematic structure of the constituent being revised. Thematic roles play a considerable role in
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parsing: Rayner, Carlson, and Frazier (1983) claim that they guide reanalysis, Tanenhaus and Carlson (1988) that they guide the filler-gap process, and Stowe (1989) that they guide initial syntactic analysis. In this debate, the present findings seem to support the view that thematic structure plays a role in reanalysis, not in the initial syntactic attachment, and in particular that it constitutes the interface with pragmatic preferences.

Overall, then, the present research supports a view of the parser as obeying universal parsing strategies and a modular organization, once we pay closer attention to the timing of the particular effects and linguistically analyze in more detail the structures being considered.

A Final Remark

Finally, our results seem to have some interest for the relation between syntactic theories and the human parser. English is a language that allows preposition stranding, which gives the possibility of sentences like (22):

(22) a. John likes pictures of certain flowers.
   b. What does John like pictures of?

However (23) shows that when the preposition has lexical content, the extraction of a constituent is marginal:

(23) John likes pictures with certain flowers.
   ?? What does John like pictures with?

As pointed out to us by L. Rizzi, this contrast shows that the preposition with acts as a barrier for extraction. If in fact, following Chomsky (1986), maximal projections are barriers for extraction unless they are theta-marked then of is not a barrier because it is an argument of the NP, while with is a barrier because it is an adjunct of NP. This analysis allows an interesting parallel with our data, where we found that the preposition with acts as a barrier for reanalyzing a constituent out of its domain. In other words, our data could be seen as empirical evidence of an element which constitutes a barrier to some syntactic operations, reflected in parsing results. If this is correct, our data constitute another piece of evidence that the human parser has a direct use of syntactic knowledge (cf. Fodor, 1989).
REFERENCES


