An Investigation of Late Closure: The Role of Syntax, Thematic Structure, and Pragmatics in Initial and Final Interpretation

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Four reading-time experiments investigated the application of the late closure principle in Italian. The experiments tested the principle governing the initial attachment of different types of modifiers (relative clause, adjectival phrase, and prepositional phrase) to a complex noun phrase. By manipulating the type of preposition within the complex noun phrase, the authors investigated the role of the thematic structure in initial and final parsing. The results show that the late closure principle applies to initial parsing in Italian without being affected by the thematic structure of the complex noun phrase. Final interpretation, however, 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.

The purpose of this research was to assess whether late closure, an assumed universal sentence parsing principle (Frazier, 1978), applies in Italian. In this article we study the attachment of different types of modifiers to complex noun phrases, drawing a distinction between initial and final interpretation and trying to identify what variables (syntactic, semantic, and pragmatic) affect what stage in the comprehension process. The results of four on-line experiments conducted in Italian are presented.

Kimball (1973) and Frazier and Fodor (1978) proposed strategies that apply to the initial parsing of a sentence as soon as each word is perceived. Some examples of such strategies are right association (Kimball, 1973), minimal attachment and late closure (Frazier & Fodor, 1978), superstrategy (Fodor, 1979), recent filler strategy (Frazier, Clifton, & Randall, 1983), active filler strategy (Frazier, 1987), and the minimal chain principle (De Vincenzi, 1991). The basic idea in all of these strategies is that they are directly derived from a simple principle: Choose to do whatever costs the least effort in terms of computation to interpret the incoming linguistic input before it decays. This choice is motivated by a basic cognitive reason, namely, the restrictions on short-term memory in terms of memory and computational space and the fact that more structured material makes smaller demands on short-term memory (Miller, 1956). Given the fact that these principles are based on cognitive needs and that they are tied to the sequential character of any natural language, we expect them to be universal.

According to the principle of late closure (Frazier & Fodor, 1978), the human parser, if grammatically permissible, will attach the new items into the clause or phrase currently being processed. The late closure strategy (as well as the other strategies mentioned above) is defined over the geometry of the phrase marker of the sentence, regardless of what particular phrase types are involved. This feature explains why the strategy generalizes across several different constructions (De Vincenzi & Job, 1993; Frazier, 1990) and it also predicts that it should generalize to the attachment of different types of constituents within the same construction. Another goal of this article was then to test the generalizability of late closure within the same construction by varying the type of constituent that is attached to a complex noun phrase: relative clauses in Experiment 1, adjectival phrases in Experiment 2, and prepositional phrases in Experiment 3.

Furthermore, another important characteristic of late closure, as well as the other syntactic parsing strategies mentioned above, is that they assign lexical material to a position in a phrase marker of a sentence without any reference to semantic or thematic relations. This does not preclude any thematic effects on parsing decisions. However, it predicts that an initial late closure effect should be independent of the thematic structure of the construction to which it applies. We tested this prediction in Experiment 1 and in Experiment 2, systematically varying the argument structure of the complex noun phrase to which a constituent is attached and trying to tease apart initial parsing decisions from final interpretation effects.

Finally, in Experiment 4 we manipulated the size of the presentation segment of the complex noun phrase to which the relative clause attaches to assess the effect of segmentation on the initial attachment preferences.
Investigations on Relative Clause Attachment

Many recent studies on late closure have focused on a particular application of the principle, namely, to cases in which there is a syntactic ambiguity in the attachment of a relative clause to a complex noun phrase. An example is given in Sentence 1:

John likes the daughter of the woman that came yesterday. (1)

The relative clause that came yesterday can syntactically attach to the first noun phrase (NP1) the daughter or to the second noun phrase (NP2) the woman. Several studies have investigated what factors influence final interpretation preferences and also the time course of the interpretation. We briefly present the findings concerning both final interpretation preferences and on-line processing.

Regarding final interpretation preferences, several questionnaire studies have been carried out in different languages. In these studies participants are instructed to indicate the first interpretation of a given sentence.

In sentences like Sentence 1, questionnaires conducted in English (Clifton, 1988), Spanish (Cuetos & Mitchell, 1988), and Italian (De Vincenzi & Job, 1989, 1993) have shown an early closure preference to take the relative clause as modifying the first noun (NP1). This preference seems determined by a pragmatic reason. Frazier (1990) proposed that there is a tendency to construe a phrase as relevant to the main assertion of a sentence. This tendency stems from the application of the relevance principle:

The relevance principle: 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. (Frazier, 1990, p. 321)

Sentence 2 illustrates the principle:

Julie met the friend of the man. (2)

The main assertion is the main clause NP-verb-NP1 Julie met the friend. The relative clause should, following the relevance principle, modify the friend rather than the man, which is not part of the main assertion. When the reader-listener does not have any other information about the NPs in the complex noun phrase, the relevance principle permits a relative clause to modify either the first or the second NP because both NPs require identification. However, when the content of the relative clause is relatively uninformative out of context (e.g., a locative relative clause), then the perceiver has to add assumptions about a shared situation to allow the relative clause to be used identificationally. In this latter case, then, the perceiver should have a stronger tendency to follow the relevance principle and modify NP1 with the relative clause. Frazier and Clifton (Clifton, 1988) tested the predictions in a questionnaire study by using sentences like Sentences 3b and 3c.

Julie met the friend of the man. (3a)

Julie met the friend of the man who reads news on Saturday Night Live. (3b)

The results showed a higher percentage of early closure responses for the locative (Sentence 3c) relative clauses (70% NP1 choices) than for the identificational (Sentence 3b) relative clauses (59% NP1 choices). This study, therefore, supports the view that a pragmatic principle influences attachment preferences in the structure under discussion.

Further research has shown that final interpretation preferences are also affected by the thematic structure of the complex noun phrase. The thematic structure of the complex noun can be changed by varying the argument status of the prepositional phrase contained in it. A prepositional phrase is considered an argument of a noun if it is subcategorized by it; its meaning, in the sense of its thematic role, is determined by the noun of which it is an argument. An adjunct prepositional phrase, instead, gets its meaning from the particular preposition present in it.

A preposition like of usually is not a thematic role assigner. Its meaning is dependent on the particular noun it modifies. If we consider the meaning of glass of NP2, house of NP2, daughter of NP2, the thematic role of NP2 (material, possession, or kinship) is determined by the first noun. Therefore, prepositional phrases with the preposition of are considered arguments of NP1.

However, prepositions like with, over, near, and above are thematic role assigners because their meaning is much less dependent on the particular NP1 they modify. If we consider a glass on the table, a house on the hill, and the daughter on the couch, the thematic role of NP2 is always a locative, regardless of the meaning of NP1. In this case the prepositional phrases are considered adjuncts of NP1.

Further research has shown that final interpretation preferences in the structure under discussion.

Questionnaire studies conducted in English and Spanish (Gilboy, Sopena, Clifton, & Frazier, 1995) and Italian (De Vincenzi & Job, 1989, 1993) tested final interpretation preferences by using sentences that varied the argument status of the prepositional phrase in the complex noun phrase. Sentence 4 is an example of NP2 being an argument of NP1, and Sentence 5 is an example of NP2 being an adjunct of NP1.

Someone shot the servant of the actress who was on the balcony. (4)

Nobody knew the boy with the strange girlfriend who was sitting in the kitchen. (5)

1 Cuetos and Mitchell (1988) reported a 58% late closure preference in a population of English students. According to Mitchell and Cuetos (1991) the discrepancy with Clifton's (1988) data could be due either to the different set of material used in the studies or to a dialect variation between the two populations used (English and American speakers).

2 In syntactic terms, it is usually assumed that arguments of a noun attach to the syntactic tree at the same level of the head noun. Adjuncts instead are assumed to attach at a higher point in the syntactic tree.
The results showed a late closure preference, in which the relative clause is most often interpreted as modifying NP2 for sentences containing the preposition with as in Sentence 5. The interpretation of these results is that readers preferentially attach a modifier inside the current thematic domain. In cases like Sentence 4 the last thematic domain is NP1 the servant, and therefore, the relative clause is free to attach to NP1 or NP2, following pragmatic preferences. However, in Sentence 5, the last thematic domain is the prepositional phrase with the strange girl-friend, and therefore, the relative clause is preferentially interpreted as modifying this last constituent. In summary, final interpretations regarding the attachment of a relative clause to a complex noun phrase seem to reflect pragmatic preferences and thematic effects quite consistently across three different languages.

Regarding the on-line measure of comprehension processes, the data are much less consistent both within a single language and across languages. In English, Frazier and Clifton (in press) have tested the comprehension of sentences like Sentence 6 in an experiment in which eye movements were measured during reading. The attachment of the relative clause was grammatically disambiguated within the relative clause by the agreement between the reflexive and the head of the relative clause:

Fred never met the daughter of the fireman who shot himself. (6a)

Fred never met the daughter of the fireman who shot herself. (6b)

The late closure conditions (indicated by Sentence 6a) were read significantly faster than their early closure counterparts (indicated by Sentence 6b). The same pattern was obtained in a self-paced reading time experiment (Clifton, 1988) that also included sentences that varied the argument structure of the complex noun phrase, as shown in the contrast of Sentence 6 and Sentence 7. Slashes indicate how the sentences were segmented for presentation.

Anthony hated the boy with the pretty student who was purposely drawing attention to herself. (7a)

Anthony hated the boy with the pretty student who was purposely drawing attention to himself. (7b)

However, with material that had a pragmatic disambiguation, as in Sentence 8, a series of self-paced experiments (Carreiras & Clifton, 1993) showed no difference between the English late closure (indicated by Sentence 7a) and early closure (indicated by Sentence 7b) conditions.

The police arrested the brother of the nursemaid who recently gave birth to twins. (8a)

The police arrested the sister of the handyman who recently gave birth to twins. (8b)

In Spanish, several on-line experiments that measured self-paced reading time (Carreiras & Clifton, 1993; Cuetos & Mitchell, 1988) showed a facilitation for early closure structures. These experiments used pragmatic disambiguation, and one of them (Carreiras & Clifton, 1993, Experiment 5) used grammatical disambiguation, given by the gender agreement between the head of the relative clause and the past participle (see Sentence 9):

La policía detuvo al hermano de la portera que estuvo acusada de hurto. (The police arrested the robber of the female reporter who was accused of robbery) (9a)

La policía detuvo a la hermana del portero que estuvo acusada de hurto. (The police arrested the sister of the male porter who was accused of robbery) (9b)

Reading times on the second frame were faster for the early closure conditions (indicated by Sentence 9a) than for the Late Closure condition (indicated by Sentence 9b).3

In summary, the off-line data seem to indicate consistently effects of pragmatic and thematic structure on final interpretation. It is much more difficult to provide a unified account of the on-line data, which show initial interpretation effects. For grammatically disambiguated English sentences (Frazier & Clifton, in press) there may be a late closure preference, regardless of the argument structure of the complex noun phrase. With other types of disambiguation (and considering only complex noun phrases containing the preposition of), no closure preference is detectable. In Spanish, available on-line experiments (Carreiras & Clifton, 1993; Cuetos & Mitchell, 1988) used only complex noun phrases containing the preposition of. These experiments showed an early closure effect for either grammatical (gender agreement) or pragmatic disambiguation. It seems, therefore, that although there is consensus on what factors influence the overall comprehension process in the attachment of a relative clause to a complex noun phrase, there is empirical disagreement about what determines initial interpretation.

The Present Research

As pointed out in the introduction, in our research we investigated whether the late closure principle applies in Italian to the attachment of modifiers to complex noun phrases. We have already found (De Vincenzi & Job, 1989) that final interpretation reflects the influence of pragmatic and thematic factors. However, the fact that final interpretation is

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3 A late closure effect in Spanish has recently been obtained by Gilboy and Sopena (1993). The sentences had a pragmatic disambiguation and were segmented in three frames:

- a. A telegram arrived for the doctor of the invalid who administered the medication every hour.
- b. A telegram arrived for the doctor of the invalid who received medication every hour.

The reading time on the last segment showed a late closure advantage.
influenced by nonsyntactic preferences does not exclude the possibility that there can be an initial stage of processing in which the parser uses only phrase-structural information to construct a syntactic representation and applies specific strategies, such as late closure, to initially resolve structural ambiguities. In this view of sentence processing (Frazier, 1978; Frazier & Fodor, 1978; Rayner, Carlson, & Frazier, 1983), nonstructural information such as meaning, thematic structure, pragmatic relations, and plausibility are not initially consulted but are used in subsequent reanalysis and interpretative processes.

Given that syntactic effects are usually not as available to introspection as semantic effects are (Flores D'Arcais, 1982), sentence-final measures are not good candidates to decide whether or not there are syntactic effects in comprehending sentences. To study the relative timing of various sources of information, we must use an on-line measure of sentence processing. The best candidate is the eye movement technique, which does not impose any artificial segmentation on the input. However, the moving-window self-paced reading paradigm is also a widely used technique. In this paradigm, participants read sentences word by word, or constituent by constituent, and every time they press a button the previous word disappears and the next one appears in sequential position. A number of studies (Ferreira & Henderson, 1990; Just, Carpenter, & Woolley, 1982) have compared eye movement recording to self-paced moving-window in noncumulative and cumulative fashion. In particular, Ferreira and Henderson found that eye movement recording and noncumulative self-paced presentation can both reveal initial syntactic effects, whereas the cumulative presentation method (in which all segments remain on the screen) does not. They argued that when participants are reading phrase-sized segments, the reading-time measure reflects both initial parsing and subsequent reanalysis.

Given that we were interested in measuring initial effects, we, therefore, chose the moving-window, noncumulative presentation procedure that was self-paced and segmented the sentences in small chunks. In particular, we used sentences that were grammatically disambiguated within the ambiguously attached phrase (e.g., the relative clause) and considered the critical segment to be the one carrying the disambiguation. The reason for disambiguating the attachment quickly and concentrating on the immediate response to this disambiguation is that a recent study on sentence parsing (Clifton, Speer, & Abney, 1991) has suggested that reading-time measures taken immediately on encountering the disambiguating information reflect syntactic preferences, whereas reading-time measures taken later in the sentence reflect thematic preferences. Therefore, to disentangle possible effects of disambiguation from sentence-final wrap-up effects, we always kept the disambiguating segment separated from the subsequent (final) segment. However, because we also wanted to investigate the effect of the preposition used in the complex noun phrase and its interaction with the relevance principle, we also asked participants to answer a comprehension question about the relative clause attachment.

In Experiment 1 we tested late closure in the attachment of a relative clause to a complex noun phrase. Using prepositions like di (of) and con (with), we manipulated the type of preposition within the complex noun phrase. The former preposition transmits a thematic role from the head noun, whereas the latter assigns its own thematic role. The purpose of this manipulation was to see whether the argument structure of the complex noun phrase affects the initial application of late closure. In Experiment 2 we tested the same hypotheses by using a different type of constituent: an adjective instead of a relative clause. In Experiment 3 we tested the application of late closure in the attachment of yet another type of constituent: a prepositional phrase. Experiment 4 was similar to Experiment 1, but we used a different segmentation of the sentence.

Experiment 1: Relative Clauses

Method

Participants. The participants were 40 students of the University of Roma, who were all native speakers of Italian.

Materials. The material consisted of 16 sentences: 8 of which had the preposition di (of), and 8 of which had the preposition with lexical content con (with).

NP-verb-(NP-of NP2-relative clause) (10)

NP-verb-(NP1-with NP2-relative clause) (11)

The relative clauses were subject relatives, that is, the head of the clause was the subject of the clause. We did this to permit (gender) agreement of the verb to disambiguate the attachment. In singular forms, gender marking on the verb is always a for agreement with a feminine noun and o for agreement with a masculine noun. Gender marking on the noun is more variable. The most productive class uses a for feminine and o for masculine marking, but several exceptions exist. For example, several masculine and feminine nouns end in e. In all cases, gender marking is unambiguously given by the noun article. To generalize our test to different noun classes, we used both nouns with the common a and o marking and nouns such as preside (headmaster), in which the gender marking is given by the article.

Relative clauses are considered postnominal adjuncts of the noun. They are not subcategorized by it. Relative clauses in Italian are usually the final element in complex noun phrases because the relative clause follows both the argument and adjunct complements of the noun. Therefore, in Sentences 10 and 11 both the early closure and late closure attachment of the relative clause are perfectly legitimate.

The difference between the complex noun phrases in Sentences 10 and 11 is due to the fact that the former contains an argument prepositional phrase, whereas the latter contains an adjunct prepositional phrase.

Each sentence had an early closure and a late closure version. An example of the conditions is given in Table 1. The complete list of the material is given in Appendix A.

The critical segment in Table 1 (Segment 4) was followed by another segment to avoid the confounding of final-sentence reading effects.

4 The relative clauses were always restrictive. Although in general, the restrictive or nonrestrictive 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, nonrestrictive relative clauses usually have a pause after their antecedent or a descending tone on the relative clause. In writing, a comma usually separates the nonrestrictive relative clause from its antecedent. Given that we had no comma in the experiment, we forced a restrictive interpretation of the relative clause.
INVESTIGATION OF LATE CLOSURE

The comprehension task consisted of answering a question. The question was presented on the screen, all at once, immediately after the participant pressed the button at the end of the last segment of the sentence. The question queried the relative clause attachment. The question never carried any gender marking (which would immediately disambiguate what the correct answer was), and this was ensured by using the past simple (passato remoto) form of the verb. The question was followed by the two nouns to which the relative clause could attach. To avoid order biases, we counterbalanced the reciprocal order of the two nouns in the question. The participants had to answer by pressing a left or a right button corresponding to whether the correct noun appeared to the left or to the right side of the screen.

Besides the 16 experimental sentences, there were 60 filler sentences, each followed by a comprehension question. The filler sentences were different types of declarative sentences and questions.

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

Predictions. If the parser follows the late closure principle, then it should prefer to attach the relative clause to NP2 because NP2 is the constituent currently being parsed. When the disambiguating information arrives there should be a revision of the initial decision for the early closure cases. These operations should be reflected in shorter reading times for the late closure cases than for the early closure cases. Participants should be slower and make more errors in answering questions following late closure than early closure sentences, at least in sentences containing the preposition di (of) because the relevance principle should sometimes force a revision of the initial analysis.

If the relevance principle affects initial parsing decisions, then the initial parsing decisions should mimic the final preferences seen in the questionnaire studies cited earlier. Accordingly, there should be an early closure preference for the sentences containing the preposition di. This should lead to faster reading time on the disambiguating segment and on the final comprehension question and to fewer errors in the early closure than the late closure condition. However, there should be a late closure preference for the sentences containing the preposition with in the reading time on the disambiguating segment and in the final comprehension question.

Results

The data for Experiment 1 are presented in Table 2. The mean reading times were computed for each segment. Reading times that were less than 100 ms or greater than 2,500 ms (less than 5% of the data) were excluded from further analysis. Analyses of variance (ANOVAs) were conducted on the reading times 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 of vs. with).

On the first segment there was a significant effect of closure: The group of sentences containing the preposition di were read 59 ms slower than those containing the
preposition with, $F_1(1, 39) = 7.42, \text{MSE} = 18,663, p < .01; F_2(1, 14) = 5.46, \text{MSE} = 5,600, p < .04$; this probably reflects differences in segment length. The average length of this first segment was four characters longer for sentences containing the preposition of than for sentences containing the preposition with. The reading times on the second and third segments showed no significant effects.

ANOVAS performed on the fourth segment—the critical one—revealed that the late closure conditions were read faster than the early closure conditions: $F_1(1, 39) = 17.35, \text{MSE} = 25,337, p < .001; F_2(1, 14) = 5.20, \text{MSE} = 14,944, p < .04$. The interaction of closure and preposition was not significant. On the fifth segment there were no significant effects.

For the comprehension data, a significant effect of closure emerged—early closure conditions were responded to more accurately than late closure conditions: $F_1(1, 39) = 4.16, \text{MSE} = 555, p < .05; F_2(1, 14) = 7.01, \text{MSE} = 61, p < .02$. The interaction of closure and preposition qualified this effect: $F_1(1, 39) = 20.18, \text{MSE} = 381, p < .001; F_2(1, 14) = 28.33, \text{MSE} = 61, p < .001$. Sentences with the preposition of were comprehended more accurately in the early closure than in the late closure condition, but this difference was not present for sentences with the preposition with.

Participants were faster answering the comprehension questions in the late closure than in the early closure condition for sentences with the preposition with, but this difference was not present for sentences with the preposition of—Closure × Preposition interaction: $F_1(1, 39) = 5.50, \text{MSE} = 99,619, p < .02; F_2(1, 14) = 4.21, \text{MSE} = 28,141, p < .06$. However, if only correct trials are looked at (Table 3), the time to answer the comprehension question shows a main effect of closure in the item analysis, $F_2(1, 14) = 6.30, \text{MSE} = 44,704, p < .02$, with late closure sentences answered faster. No other effect or interaction reached significance.

**Discussion**

The results of this experiment show that there is an initial preference for analyzing the relative clause as being attached to the last NP for both sentence types, supporting the operation of the late closure strategy independently of the thematic structure of the complex noun phrase. These on-line data have a straightforward interpretation, in that they show that the initial attachment is done according to the late closure principle, and, consequently, it is influenced simply by structural considerations.

On the following comprehension question, which reflects later processing of the sentence, the results show a preference for sentences with the preposition of to take the relative clause as modifier of the first NP. This off-line result is predicted by the relevance principle, and it resembles the questionnaire studies in that it shows an early closure preference only for sentences containing the preposition of.

However, the question is: Why does the relevance principle affect only the attachment to complex noun phrases containing the preposition of? The explanation we suggest situates the off-line effects at a pragmatic-semantic level, but it capitalizes on the thematic structure of the complex noun phrase. The difference between the structures in Sentences 10 and 11 can be seen as an asymmetry between an adjunct and an argument in letting a following modifier attach to a previous lexical head. The distinction argument-adjunct suggests a distinction in thematic structure. In Sentence 9 in which NP2 is an argument of NP1, NP1 is the theta assigner that assigns a thematic role to NP2. In Sentence 11, instead, in which the prepositional phrase is an adjunct of NP1, it is the preposition with that assigns the thematic role to NP2.

The syntactic parser initially attaches the relative clause to NP2. The pragmatic parser, which applies at the level of the discourse representation, following the relevance principle, favors an early closure interpretation. If at the level of the discourse representation NP1 is available, then the parser may reanalyze the structure as an early closure structure to get a more pragmatically plausible analysis. We suggest that NP1 is available to be construed with the relative clause when the relative clause is within the thematic domain of NP1, that is, a

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Table 2

<table>
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<tr>
<th>Condition</th>
<th>Segment 1</th>
<th>Segment 2</th>
<th>Segment 3</th>
<th>Segment 4</th>
<th>Segment 5</th>
<th>RT</th>
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<td>Argument</td>
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<td>839</td>
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*Note.* Segment 4 is the critical disambiguating segment.

Table 3

<table>
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<th>Condition</th>
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<td>Preposition with</td>
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modifier of an argument of NP1. The relative clause is not in 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 relative clause, there is in fact another thematic domain, the one of the adjunct, intervening between NP1 and the relative clause. A definition of thematic domain has already been formulated in the psycholinguistic literature by Pritchett (1988; see also Frazier & Clifton, in press):

Theta domain: A is in the G theta domain of B if A receives the G theta-role from B or if A is dominated by a constituent that receives the G theta role from B. (Pritchett, 1988, p. 545)

On the basis of this definition, we propose a principle to account for the difficulties of syntactic reanalysis:

**Thematic reanalysis constraint:** To reinterpret a constituent as outside of its current thematic domain is costly.

The difference in question-answering time between correct only and total trials shows that the realanalysis actually occurs at 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), participants can sometimes revise the initial late closure analyses, overlooking the gender agreement. However, they do this revision only in those cases in which the reanalysis is not too costly, namely when the relative clause can be reanalyzed as within the same thematic domain. The relevance principle suggests that the relative clause should be attached to NP1. In sentences containing the preposition of, the only thematic assigner is NP1, and the relative clause is in its domain. Revision of the relative clause attachment from NP2 to NP1 is still within the same thematic domain and, therefore, is not costly. However, in sentences containing the preposition with, the last thematic assigner is the preposition with, and the relative clause is in its domain. The revision of the relative clause attachment from NP2 to NP1 would then move the relative clause to another thematic domain and is, therefore, predicted to be costly.

Our hypothesis, then, explains the off-line results in Italian and in English in which there is an early closure preference for the proposition of but a late closure preference for the proposition with. Furthermore, we predict that in general the cases in which the modifier of NP1 is an adjunct, it should favor a late closure attachment of a following modifier. This prediction is in fact confirmed by recent data on final interpretation by Gilboy et al. (1995) and by Mitchell and Cuetos (1991). The latter authors, in particular, found a late closure preference in Spanish with cloze data, using sentences like Sentence 12, in which the complex noun phrase contains two relative clauses: NP-relative clause 1-relative clause 2:

Peter was looking at the book which belonged to the girl that was in the living room. (12)

The difference between the early closure preference in the Cuetos and Mitchell (1988) questionnaire and the late closure preference in the Mitchell and Cuetos (1991) questionnaire is also explained by our hypothesis. The relative clause which belonged to the girl is an adjunct, and, therefore, it should block a reanalysis of the second relative clause that was in the living room to the highest NP1 because the second relative clause is not in the thematic domain of NP1 but rather in the domain of the first relative clause.

**Experiment 2: Adjectival Phrases**

As discussed in the introduction, the late closure strategy simply states that an item is attached to the most recently postulated constituent. Nothing more specific is said about the particular kind of item that has to be attached (a noun, a verb, an adverb, a relative clause, an adjective, a preposition) nor about the constituent to which the item is attached. The goal of Experiment 2 was to study whether late closure applies also to the attachment of adjectives to complex noun phrases.

In Italian, the possibility of having postnominal adjectives gives rise to an ambiguity in the attachment of an adjective to a previous complex noun phrase as in Sentence 13, in which either the seat or the bus can be red:

Il sedile dell’autobus rosso.
(The seat of the bus red.) (13)

The attachment can be disambiguated by the agreement between a noun and the adjective, when the nouns have different gender and the adjective changes ending according to the gender (in Italian some adjectives, like those ending in e, are not inflected for gender: for example, importante [important] or audace [audacious]). In Sentence 14a the adjective modifies the first noun (seat), and in Sentence 14b it modifies the second noun (car):

Il sedile dell’autobus rosso.
(The seat [+M] of the car [+F] red [+M].) (14a)

Il sedile dell’autobus rosso.
(The seat [+M] of the car [+F] red [+F].) (14b)

If late closure applies, then the cases in which the adjective modifies the second NP (as in Sentence 14b) should be easier to process than the cases in which the adjective modifies the first NP (as in Sentence 14a).

Furthermore, the parser should also be sensitive to the same variables that were operating in the attachment of relative clauses. For example, it should be sensitive to the type of preposition that is used. This means that there should be an

---

5 It is clear that with the sentence available in front of them, participants did not misinterpret the sentence. However, the self-paced methodology put them under some time pressure, which can lead to a loss of verbatim information in short-term memory.

6 Pritchett (1988) proposed a principle of reanalysis similar to ours. "Theta reanalysis constraint: Syntactic reanalysis which reinterpret a theta marked constituent as outside of its current theta domain is costly" (p. 545).

The two proposals differ in a crucial aspect: Pritchett's constraint says that only the revision of a thematically marked constituent is costly. This entails that the reanalysis of a relative clause should never be costly because relative clauses are never assigned a thematic role (they are always adjuncts).
overall late closure preference in the on-line measurements
(like in the reading time on the disambiguating segment).
However, in off-line measurements, such as the answer to a
comprehension question, this preference should be affected by
the pragmatic preference to modify the first NP in the case of the
preposition of.

Method

Participants. The participants were 40 students of the University of
Roma, who were all native speakers of Italian.

Materials. The material consisted of 16 sentences: 8 of which had
the preposition di (of), whereas the remaining 8 had prepositions with
lexical content con, nel, or sul (with, in the, and on the). The structure of
the sentences was as in Sentence 15.

NP verb (NP1 of NP2 adjective phrase(AP)) (15a)

NP verb (NP1 with/in the/on the/NP2 AP) (15b)

We used qualifying adjectives that had always a restrictive function.
In fact, in Italian when the adjective has an appositive function it
precedes the noun. Restrictive adjectives are considered adjuncts of
the noun. As for their position within a complex noun phrase, when
there is a complement of the noun, they can either follow the noun or
follow the noun and its complements.7 In this latter case, there is
usually a pause between the complement and the adjective. The
material included several past participles, which in Italian have the
same distribution as the adjectives. Each sentence had an early closure
and a late closure version. An example of the conditions is given in
Table 4. The complete list of the material is given in Appendix B.

In Table 4, the critical segment (segment 4) was followed by another
segment. We did this to avoid the confounding of final-sentence
reading effects with the closure effects.

The comprehension task consisted of answering a question. The
question was presented on the screen, all at once, immediately after
the participant pressed the button at the end of the last segment of the
sentence. The question queried the adjective attachment. The ques-
tion never carried gender agreement marking. It was followed by
the two nouns to which the adjective could attach. To avoid order biases,
we counterbalanced the reciprocal order of the two nouns in the
question. The participants had to answer pressing a left or a right
button corresponding to whether the correct noun appeared to the left
or to the right side of the screen.

Besides the 16 experimental sentences, there were 88 filler sen-
tences. The filler sentences were declarative sentences, questions, and
some structurally unambiguous WH questions (such as which noun,
noun phrase-verb).

Procedure. The experimental procedure and the design were the
same as in Experiment 1. Each participant saw a total of 104 sentences:
16 experimental sentences plus 88 filler sentences.

Predictions. The predictions were the same as for the relative
clause experiment. If the parser follows the late closure principle, then
it should prefer to attach the adjective to NP2 because NP2 is the last
constituent being parsed. Participants should be slower and make
more errors answering questions in the late closure condition, at least
in sentences containing the preposition di (of) because the relevance
principle should sometimes force a revision of the initial analysis.

Table 4

<table>
<thead>
<tr>
<th>Condition</th>
<th>English</th>
<th>Italian</th>
<th>Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early closure</td>
<td>Che cosa era fuori?</td>
<td>Che cosa era fuori?</td>
<td></td>
</tr>
<tr>
<td>Late closure</td>
<td>Che cosa era fuori?</td>
<td>Che cosa era fuori?</td>
<td></td>
</tr>
</tbody>
</table>

Note: Dashes indicate segmentation. The segments between double slashes are the critical ones containing the adjective. Segment length is expressed in number of characters. F = female; M = male.

7 The reciprocal order of phrases within a complex noun phrase is also determined by phonological considerations, namely, that longer phrases usually follow shorter ones.
INVESTIGATION OF LATE CLOSURE

Results

The data for Experiment 2 are presented in Table 5. The mean reading times were computed for each segment. Reading times that were less than 100 ms or greater than 2,500 ms (less than 5% of the data) were excluded from further analysis.

ANOVARs were conducted on the reading times for each segment with both subjects and items as random effects. There were two variables with two levels each: closure (early vs. late) and preposition (of vs. with, in the, and on the).

On the first segment there was a significant effect of preposition: The group of sentences containing the preposition of were read 56 ms slower than those containing the prepositions with lexical content, \(F(1, 39) = 7.42, \text{MSE} = 18,663, p < .01\), but the difference was not significant in the item analysis \(F(2, 1)\). This difference probably reflects differences in segment length. The average length of this first segment was three characters longer for sentences containing the preposition of than for sentences containing the prepositions with lexical content. The reading times on the second and third segments showed no significant effects.

ANOVARs performed on the fourth segment (the critical one) showed that the late closure conditions were read significantly faster than the early closure conditions: \(F(1, 39) = 5.73, \text{MSE} = 15,927, p < .02\); \(F(2, 14) = 4.72, \text{MSE} = 4,282, p < .05\). The interaction of closure and preposition was not significant.

On the final segment, sentences with the preposition of were read significantly faster than those with the prepositions with lexical content, \(F(1, 39) = 4.41, \text{MSE} = 17,551, p < .04\), but the effect was not significant in the items analysis \(F(2, 1)\).

In the comprehension data, questions following sentences with the preposition of were answered more accurately in the early closure condition than in the late closure condition. This difference was not present for the questions following sentences with the prepositions with lexical content—Closure \times Preposition interaction: \(F(1, 39) = 33.2, \text{MSE} = 274, p < .001\); \(F(2, 14) = 6.34, \text{MSE} = 285, p < .02\).

Participants were faster in answering questions following a sentence with the preposition of than following a sentence with prepositions with lexical content: \(F(1, 39) = 16.62, \text{MSE} = 286,328, p < .001\); \(F(2, 14) = 4.48, \text{MSE} = 226,529, p < .053\).

Discussion

The results of this experiment replicated those of Experiment 1, in which relative clause attachment was tested. They confirmed that there is an initial preference for analyzing the adjective as attached to the last NP, supporting the late closure strategy. However, on the comprehension question, which reflects later processing of the sentence, there was a preference for sentences with the preposition of to take the adjective as modifier of the first NP. This result also confirmed the findings of Experiment 1 on relative clause attachment and the questionnaire data.

A new result is that the comprehension questions for sentences with the preposition of were answered faster than the others (and there was also a marginal reading-time advantage for a sentence with the preposition of on the final segment). We suggest that this result was due to the greater syntactic complexity of a sentence with the structure NP-preposition-adjective. As we mentioned earlier, when the adjective follows a complement of the noun, there is a pause preceding it (cf. Giorgi, 1988). The pause is more marked when the adjective follows an adjunct of the noun. It has recently been proposed by G. Cinque (personal communication, 1992) that in such structures the adjective is in a sort of right dislocated position, that is, attached to a higher node in the syntactic phrase marker.

Experiment 3: Prepositional Phrases

We designed Experiment 3 to test whether there is a late closure effect in the attachment of a prepositional phrase (henceforth PP) to a preceding complex noun phrase. In Sentence 16 the PP near the woman can either be constructed with the NP the couch as the couch near the woman or with the NP the cat as the cat near the woman.

The cat on the couch near the woman (16)

According to the late closure strategy, there should be an initial preference for interpreting the PP as modifier of the second noun, that is, the couch. The PP attachment cannot be disambiguated by grammatical means such as gender or number agreement between the PP and the noun it modifies. The attachment can only be disambiguated by semantic

<table>
<thead>
<tr>
<th>Adjunct</th>
<th>Argument</th>
<th>Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>RT</th>
<th>% correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early closure</td>
<td>1,058</td>
<td>703</td>
<td>726</td>
<td>821</td>
<td>913</td>
<td>2,207</td>
<td>91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late closure</td>
<td>1,039</td>
<td>698</td>
<td>737</td>
<td>779</td>
<td>876</td>
<td>2,394</td>
<td>64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Segment 4 is the critical disambiguating segment.
information or world knowledge considerations toward a late closure attachment as in Sentence 17a or toward an early closure attachment as in Sentence 17b.

The cat on the couch with a nice cover (17a)

The cat on the couch in the bag (17b)

In Sentence 17a the PP with a nice cover is attached to the NP the couch because couches usually have covers, but cats do not. In Sentence 17b the PP in the bag is attached to the NP the cat because couches usually do not fit into bags. We prepared a set of 24 sentences of the form shown in Sentence 16. Given that the disambiguation is semantic or is based on world knowledge, we first collected questionnaire data to make sure that the semantic-world knowledge disambiguation was effective. We gave 40 participants a set of sentences like Sentence 16 and asked them to indicate their interpretation. We then selected the items in which the preferred disambiguation was chosen at least 90% of the time. We chose 15 pairs of sentences to use in the on-line experiment.

Method

Participants. The participants were 36 students of the University of Roma, who were all native speakers of Italian.

Materials. The material consisted of 15 sets of sentences illustrated in Table 6. Each set had an early closure sentence, a late closure sentence, and two lexical control sentences: there is a control sentence for early closure, and there is a control sentence for late closure. The late closure and early closure sentences had a complex noun phrase in subject position containing the PP attachment ambiguity. The form of the complex noun phrase was NP-PP1-PP2. The second PP, always contained in the third presentation segment, had an attachment ambiguity, in that it could either attach to the first NP (NP1) or to the NP contained in PP1 (NP2). The control conditions always contained the same PP as PP2 in the third segment. In the preceding segments the late closure control contained the NP that had appeared as PP2 in the experimental sentences, whereas the early closure control contained NP1. These conditions provided a lexical control for the reading time of the PP2. It is not possible to compare directly the reading time on PP2 of the late closure and early closure sentences because PP2 contains different items in the late closure and early closure version.

The complete list of the material is given in Appendix C.

The comprehension task consisted of answering a question. In this experiment the questions did not query the ambiguity because the answers could be given simply on the basis of plausibility; the questions queried some other information of the sentence, just to keep participants focused on comprehending the sentences. Therefore, in this experiment we did not analyze the data regarding the comprehension task.

Besides the 15 experimental sentences, there were 50 filler sentences. The filler sentences were declarative sentences, questions, and some structurally unambiguous WH questions (like which N-NP-V).

Procedure. The experimental procedure and the design were the same as Experiments 1 and 2. Each participant saw a total of 65 sentences: 15 experimental sentences plus 50 filler sentences.

Predictions. The predictions refer to the reading times on the critical ambiguous segment (the third one). If participants follow late closure, they should initially attach PP2 to the second NP. Segment 3 reading time in the late closure condition should not be different from its control, whereas reading times in the early closure condition should be longer than reading times for its control because a revision from the initial late closure attachment to the early closure attachment should be done.

If the initial attachment is instead the early closure one, then the reading-time difference should go in the opposite direction.

If the initial attachment does not follow any late closure or early closure preference, two outcomes can be expected: If the attachment is immediately determined by semantic information or world knowledge, then there should be no difference between the experimental and control conditions. If instead ambiguous sentences are harder to process than unambiguous ones, then we should expect faster reading times for the control conditions.

For the comprehension questions no predictions are made because they were regarding information not related to attachment preferences.

Results

The data for Experiment 3 are presented in Table 7. The mean reading times were computed for each segment. Reading times that were less than 100 ms or greater than 2,500 ms (less than 5% of the data) were excluded from further analysis. ANOVAS were conducted on the reading times for each segment with both subjects and items as random effects. There were two variables with two levels each: closure (early vs. late) and ambiguity (closure condition vs. control condition).

On the first segment there was a marginally significant effect of ambiguity: The control sentences were read 35 ms slower than those containing the ambiguity, $F_1(1, 35) = 6.01, MSE = 7,300, p < .02; F_2(1, 14) = 3.49, MSE = 10,746, p < .09$, probably reflecting differences in segment length. The average length of this first segment was one character longer for the control sentences than for sentences containing the ambiguity.

On the second segment there was a significant effect of ambiguity: The ambiguous sentences were read 120 ms slower than the control sentences, $F_1(1, 35) = 30.92, MSE = 16,500, p < .001; F_2(1, 14) = 24.17, MSE = 8,819, p < .001$. This also probably reflects differences in segment length. The average length of this segment was eight characters longer for the ambiguous sentences than for the controls.

ANOVA performed on the third segment (the critical one) showed the following significant effects: The control conditions were read faster than the closure conditions (main effect of ambiguity), $F_1(1, 35) = 7.74, MSE = 23,372, p < .009; F_2(1, 14) = 9.25, MSE = 8,257, p < .009$. There was a significant interaction of closure and ambiguity: $F_1(1, 35) = 4.5, MSE = 25,613, p < .04; F_2(1, 14) = 4.52, MSE = 8,961, p < .05$. Pairwise comparisons showed that the late closure condition and its control did not differ significantly in reading time, $t_1, p > .3; t_2 > .6$, whereas the early closure condition was read significantly slower than its control: $t_1(35) = 3.03, p < .005; t_2(14) = 2.91, p < .01$.

On the final segment there was a significant effect of ambiguity: The ambiguous sentences were read 220 ms slower than the control sentences, $F_1(1, 35) = 43.97, MSE = 39,505, p < .001; F_2(1, 14) = 12.76, MSE = 57,117, p < .003$. This again probably reflects differences in segment length. The average length of this segment was five characters longer for the ambiguous sentences than for the control sentences.
Table 6
Example Sentences and Average Segment Lengths Used in Experiment 3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Italian</th>
<th>English</th>
<th>Completion task</th>
<th>Segment length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early closure</td>
<td>Il cucciolo/nella scatola/ con la coda bianca/ e' per Maria.</td>
<td>The puppy/in the box/ with a white tail/ is for Maria.</td>
<td>Che cosa e' per Maria? Il cucciolo o il pacchetto What is for Maria? The puppy or the parcel.</td>
<td>8 12 14 18</td>
</tr>
<tr>
<td>Control</td>
<td>Stamattina/il cucciolo/ con la coda bianca/ era sparito.</td>
<td>This morning/the puppy/ with the white tail/ has disappeared.</td>
<td>Che cucciolo aolo e' sparito? Con la coda bianca o con la coda beige? Which puppy has disappeared? With the white tail or with the beige tail</td>
<td></td>
</tr>
<tr>
<td>Late closure</td>
<td>Il cucciolo/nella scatola/ con l'interno blu/ e' per Maria.</td>
<td>The puppy/in the box/ with a blue interior/ is for Maria.</td>
<td>Che cosa e' per Maria? Il cucciolo o il pacchetto What is for Maria? The puppy or the parcel.</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Stamattina/la scatola/ con l'interno blu/ era sparita.</td>
<td>This morning/the box/ with the blue interior/ had disappeared.</td>
<td>Che scatola e' sparita? Con l'interno blu o con l'interno beige Which box disappeared? With the blue interior or with the beige interior</td>
<td></td>
</tr>
</tbody>
</table>

**Sentence type**
- Ambiguous
- Control

**Note.** Slashes indicate segmentation. The segments between double slashes are the critical ones containing the second prepositional phrase. Segment length is expressed in number of characters.
Table 7
Average Reading Time (in Milliseconds) by Different Conditions in Experiment 3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Segment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Early closure</td>
<td>721</td>
<td>743</td>
<td>876</td>
<td>1,135</td>
<td></td>
</tr>
<tr>
<td>Late closure</td>
<td>738</td>
<td>729</td>
<td>809</td>
<td>1,082</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early closure</td>
<td>743</td>
<td>608</td>
<td>749</td>
<td>893</td>
<td></td>
</tr>
<tr>
<td>Late closure</td>
<td>785</td>
<td>626</td>
<td>795</td>
<td>884</td>
<td></td>
</tr>
</tbody>
</table>

Note. Segment 3 is the critical disambiguating segment.

Discussion

Participants initially followed the late closure principle, in that the reading times for the late closure condition were not significantly different from its control, whereas the early closure condition took significantly longer than its control. Late closure seems to apply in the attachment of prepositional phrases to a complex noun phrase. This result is interesting in two respects. First, it confirms the generalizability of late closure to the attachment of different types of constituents within the same construction. Second, in this experiment, contrary to the previous two, the disambiguation was semantic or world knowledge, not grammatical. If semantic or world knowledge considerations had affected immediate parsing decisions (see Taraban & McClelland, 1988), we should have found no closure preferences in reading. The fact that we found an initial closure preference in the comprehension process suggests that there is an initial stage of sentence comprehension that is unaffected by semantic and world knowledge consideration. Furthermore, the fact that the initial closure preference was a late closure preference supports the idea that the syntactic preference is a principled one inspired by the need of least effort and quick assignment (attach to the last postulated node).

The results of Experiments 1–3 show a very stable and regular pattern. However, given the reported failure to obtain late closure effects in some of the studies on relative clause attachment by using larger presentation segments (see Carreiras & Clifton, 1993; Cuetos & Mitchell, 1988), it is important to rule out the possibility that the participants’ use of the late closure strategy is induced, or otherwise favored, by the segmentation adopted here. In our experiments we used small presentation segments because, as we discussed earlier, this paradigm can reveal initial syntactic effects and not subsequent reanalysis effects (Ferreira & Henderson, 1990). This leads to a split presentation of the complex noun phrase, which may favor an attachment to the second noun. To identify any effect of segmentation on the initial late closure preference, we performed a fourth experiment in which the sentences of Experiment 1 were presented with the complex noun phrase appearing in one segment.

Experiment 4

Method

Participants. The participants were 28 students of the University of Roma, who were native speakers of Italian.

Materials. The material was the same as Experiment 1. The only difference was in the segmentation: The experimental sentences had only four segments because the nouns contained in the complex noun phrase were presented together, as Sentence 18 shows:

L’avvocato difida\del padre della ragazza\che si è tradita\al processo.

The lawyer suspects of\the father of the girl\who betrayed herself\at the trial. (18)

Procedure. The experimental procedure and the design were the same of Experiment 1. Each participant saw a total of 76 sentences: 16 experimental sentences plus 60 filler sentences. Also the segmentation of the filler sentences was modified so there would be a total of four segments for each sentence.

Results

The data for Experiment 4 are presented in Table 8. The mean reading times were computed for each segment. Reading times that were less than 100 ms or greater than 2,500 ms (less than 5% of the data) were excluded from further analysis. ANOVAs were conducted on the reading times for each segment with both subjects and items as random effects. There were two variables with two levels each: closure (early vs. late) and preposition (of vs. with).

On the first segment there was an effect of preposition: The group of sentences containing the preposition of was read 126...
ms slower than those containing the preposition with, \( F_1(1, 27) = 4.05, MSE = 66,125, p < .05 \), but the difference was not significant in the item analysis, \( F_2(1, 14) = 1.87, MSE = 49,242, p < .19 \). This again probably reflects differences in segment length. The average length of this first segment was four characters longer for sentences containing the preposition of than for sentences containing the preposition with.

The reading times on the second segment showed an effect of preposition. The group of sentences containing the preposition with was read 90 ms slower than those containing the preposition of, \( F_1(1, 27) = 4.05, MSE = 66,125, p < .02 \), but the difference was not significant in the item analysis, \( F_2(1, 14) = 1.40, MSE = 30,141, p < .25 \). This difference again probably reflects differences in segment length (the average length of this first segment was one character longer for sentences containing the preposition with than for sentences containing the preposition of). However, it may also reflect a difference in linguistic complexity: In fact, the complex noun phrase containing the preposition with has an adjunct structure and an extra thematic role assigner (the preposition with) within it, whereas the sentences containing the preposition of have an argument structure and only one thematic role assigner, NP1. There is evidence in the literature (Clifton et al., 1991) that argument prepositional phrases of a complex noun phrase are read faster than adjuncts.

ANOVA's performed on the third segment—the critical one—revealed that the late closure conditions were read faster than the early closure conditions: \( F_1(1, 27) = 4.68, MSE = 20,953, p < .04 \); \( F_2(1, 14) = 4.57, MSE = 29,998, p < .05 \). The interaction of closure and preposition was not significant. On the fourth segment, there were no significant effects.

An effect of closure emerged in the comprehension data. Early closure conditions were responded to more accurately than late closure conditions: \( F_1(1, 27) = 2.88, MSE = 1,808, p < .10 \); \( F_2(1, 14) = 11.27, MSE = 96, p < .05 \). The interaction of closure and preposition qualified this effect: \( F_1(1, 27) = 4.96, MSE = 449, p < .03 \); \( F_2(1, 14) = 7.39, MSE = 653, p < .01 \). Sentences with the preposition of were comprehended more accurately in the early closure than in the late closure condition, \( t(27) = 2.75, p < .011 \); \( t(7) = 4.13, p < .004 \), but this difference was not present for sentences with the preposition with (both is < 1).

Participants were faster answering the comprehension questions in the early closure than in the late closure condition: \( F_1(1, 27) = 6.85, MSE = 160,714, p < .01 \); \( F_2(1, 14) = 3.55, MSE = 73,868, p < .08 \). No other effect or interaction reached significance.

Discussion

Experiment 4 replicated the previous findings of an initial preference for late closure attachment and a final advantage for early closure attachment modulated by the argument structure of the complex noun phrase. The fact that we obtained a late closure effect when the complex noun phrase was presented in a single segment rules out the possibility that the effects found in Experiments 1–3 were due to the separate presentation of NP1 and NP2.

Having found that the presentation of a larger segment still results in a syntactic preference does not imply that segmentation is irrelevant for what we are able to detect of the process of sentence comprehension. Rather, some segmentations may hide the contrast between initial analysis and reanalysis operations. For example, presenting material in long, clause-sized segments could result in reading times that reflect not only initial but also later processing stages. If the preposition of encourages reanalysis to a high attachment preference, presentation of a long segment could result in the appearance of an early closure preference. This hypothesis explains the differences found between our Experiments 1 and 4 and the Spanish experiments by Cuetos and Mitchell (1988) and Carreiras and Clifton (1993).

Further cross-linguistic research with strictly similar material, mode of presentation, type of segmentation, and agreement on where and how to measure the disambiguation effect is needed to address this issue.

Conclusions

We can draw two distinct sets of conclusions from our data: one regarding the application of the syntactic parsing strategy of late closure, the other one regarding the timing of the use of different types of linguistic information by the parser.

First, we found that the late closure strategy is operative in Italian, specifically in the attachment of modifiers to complex noun phrases. Furthermore, we confirmed the generalizability of late closure, in that we have found that it applies equally to different syntactic constituent types and independently of the thematic structures of the constituents involved.

Second, our results also seem to support the view that an adjunct is immediately attached in a syntactic tree. In case of structural ambiguity, this attachment is done according to syntactic preferences (e.g., late closure). This view contrasts with the one recently proposed by Frazier and Clifton (in press) that adjuncts (more accurately, nonprimary phrases) are not immediately attached to a syntactic representation but rather associated in the last thematic domain. Their theory predicts that on-line measures should show a late closure effect for cases in which the last thematic domain is the one containing only NP2. Instead, with a preposition like of, in which the last thematic domain is NP1, the attachment preference could be early closure because NP1 is in fact in the last thematic domain, and so pragmatic preferences are free to determine syntactic attachment preferences. However we found initial late closure effect and later early closure preferences equally for of and other lexical prepositions. This is explainable only under the hypothesis that initial syntactic attachment is not determined by thematic domains.

Footnote:

8The comparisons with earlier studies is more pertinent for the structure with the preposition of because this is the preposition mostly investigated. Therefore, we analyzed the data from Experiments 1, 2, and 4 separately for preposition of and preposition with, in spite of the fact that the interaction of closure by preposition never reached significance level. In each case the results with the preposition of showed a late closure advantage.
Third, our explanation contrasts with the tuning exposure hypothesis (Cuetos & Mitchell, 1988; Mitchell & Cuetos, 1991), according to which attachment preferences should reflect the most frequent pattern of attachment found in the language for a given construction or at least the subjective exposure to a given attachment. No frequency counts are available for relative clause attachment preferences in the Italian language, and, therefore, we cannot address this hypothesis empirically. Nevertheless, this hypothesis seems inconsistent with the pattern of data we obtained from a logical point of view. The tuning exposure hypothesis could in principle account for the results found with the preposition with, which shows a consistent trend in initial and final attachment preferences, provided that a late closure preference in the attachment of relative clauses to complex noun phrases would be found in the language.

However, such a hypothesis would not account for the results obtained with the preposition of, because here there is a dissociation between initial and final preference. The tuning hypothesis states that

Each time a person encounters and resolves a specific form of ambiguity, the syntactic processing mechanism adjusts itself marginally to take into account the new solution. Once the ambiguity has been resolved in a given direction, the mechanism is adjusted in such a way that there will be a slightly greater possibility of choosing that resolution in subsequent encounters with the ambiguous form in question. (Cuetos, Mitchell, & Corley, in press)

According to this account, for a given ambiguous form, the final interpretation arrived at before in previous encounters should bias the subsequent interpretations toward that interpretation; thus, it is difficult to conceive how the initial and final interpretation of an ambiguous form may differ. Furthermore, even assuming that the Tuning hypothesis may explain the initial and final interpretation asymmetry, the proposal is underspecified as to which factors may affect reinterpretation, and so any evaluation of the present data in light of such proposal may be premature.

On the other hand, a dissociation between initial and final interpretation is well captured by an account in which final interpretation is well captured by an account in which final interpretation of an ambiguous form may differ. Furthermore, even assuming that the Tuning hypothesis may explain the initial and final interpretation asymmetry, the proposal is underspecified as to which factors may affect reinterpretation, and so any evaluation of the present data in light of such proposal may be premature.

We conclude that initial parsing is done according to syntactic preferences, whereas pragmatic preferences and thematic structure affect only final interpretation. This suggests a modular use of linguistic information. In particular, the present research suggests that syntactic revisions are affected by the thematic structure of the constituent being revised. Thematic roles play a considerable role in parsing; Rayner et al. (1983) claimed that they guide reanalysis, Tanenhaus and Carlson (1988) claimed that they guide the filler-gap process, and Stowe (1989) claimed that they guide initial syntactic analysis. In this debate, our findings seem to support the view that thematic structure plays a role in reanalysis and not in the initial syntactic attachment.

Overall, then, our research supports a view of the parser as obeying universal parsing strategies with a modular organization once we paid close attention to the timing of the particular effects and provided a detailed linguistic analysis of the structures being considered.

References


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Appendix A
Relative Clause Experiment

1. Il dottore chiamò il figlio della signora che si era ferita -o, ad una mano. 
Chi si ferì? Figlio - signora.

2. II barista guardava l’amico della donna che era silenziosa -o davanti al bar.
Chi stava in silenzio davanti al bar? Amico - donna.

3. L’avvocato diffida del padre della ragazza che si è tradita -o al processo.
Chi si tradi? Ragazza - padre.

4. Il cronista intervistò l’amico del senatore che si è ucciso -aieri notte.
Chi si uccise? Senatore - amica.

5. Il duca aveva aiutato il figlio della sarta che si è sparata -o per i debiti.
Chi si sparò? Figlio - sarta.

6. Tina riconobbe la collega del dirigente che era fuggito -a tempo fa.
Chi fuggì? Collegh - dirigente.

7. Ezio conobbe la segretaria del direttore che era svenuto -a alla festa.
Chi svenne alla festa? Direttore - segretaria.

8. Gianni flirtava con la nipote del ballerino che era seduto -a in giardino.
Chi si sedette? Ballerino - nipote.

9. Antonio odiava il ragazzo con l’amica che si è esibita -o alla festa del conte.
Chi si esibì? Ragazzo - amica.

10. Tutti ammirano il signore con la figlia che si è messa -o a cantare un’opera.
Chi cantò? Signore - figlia.

11. Nessuno invitò il regista con la bella amica che era rimasta -o da noi.
Chi rimase da noi? Regina - amica.

12. Lo zio incontrò il preside con la collega che era stata -o in ospite da noi.
Chi fu ospite da noi? Collegh - preside.

13. Luca osservò la cameriera con l’amico che si è ustionata -a un braccio.
Chi si ustionò? Cameriera - amico.

(Appendices continue)
14. Pina invidiava la cugina con il fidanzato che si è arricchito a con la droga.
Chi si arricchi? Cugina - fidanzato.
Pina envied the cousin (+F) with the boyfriend who enriched him -herself with the drug.
Who enriched -self? Cousin (+F) - boyfriend.

15. Il cuoco conosceva il cliente con la donna che si era lamentata -o del cibo.
Chi si lamentò? Donna - cliente.
The cook knew the client with the woman who complained (+F/-+M) for the food.

Appendix B
Adjectival Phrase Experiment

The (a) represents early closure sentences, (b) represents late closure sentences, and Q represents the comprehension task.

Preposition of
1a. Gli ospiti criticarono il vestito della signora alquanto bizzarro e audace.
1b. Gli ospiti criticarono il vestito della signora alquanto bizzarra e audace.
Who or what was bold?

2a. Il falegname aggiustò la porta dello studio scalcinata e fuori uso.
2b. Il falegname aggiustò la porta dello studio scalcinato e fuori uso.

3a. I bambini amavano il cane della donna zoppo e amichevole.
3b. I bambini amavano il cane della donna zoppa e amichevole.

4a. Lucia trova scomodo il sedile della macchina ammaccato nell’incidente.
4b. Lucia trova scomodo il sedile della macchina ammaccata nell’incidente.

5a. Gianni ha sostituito il laccio della scarpa rotto ma non vuole privarsene.
5b. Gianni ha sostituito il laccio della scarpa rotta ma non vuole privarsene.

6a. Hanno interrogato a lungo l’amica del poliziotto arrestata ieri mattina.
6b. Hanno interrogato a lungo l’amica del poliziotto arrestato ieri mattina.

7a. La Rai ha premiato il presentatore della trasmissione preferito dai giovani.
7b. La Rai ha premiato il presentatore della trasmissione preferita dai giovani.

8a. È stata ritrovata la rete del pescatore scomparsa in mare.
8b. È stata ritrovata la rete del pescatore scomparso in mare.

9a. La polizia ha fermato il furgone con la merce rubato ieri.
9b. La polizia ha fermato il furgone con la merce rubata ieri.

10a. The cook knew the client with the woman who complained (+F/-+M) for the food.
10b. The cook knew the client with the woman who complained (+F/-+M) for the food.


Q: Chi o che cosa era audace? Vestito - signora.
Q: Che cosa era fuori uso? Porta - studio.
Q: Chi zoppicava? Donna - cane.
Q: Cosa si ammacò? Macchina - sedile.
Q: Chi o che cosa scomparve? Pescatore - rete.
Q: Cosa rubarono? Furgone - merce.
Q: Chi o che cosa scomparve? Pescatore - rete.
Q: Who or what disappeared?

Preposition with, on the, and in the
9a. The police stopped the van (+M) with the goods (+F) stolen (+M) yesterday.
9b. The police stopped the van (+M) with the goods (+F) stolen (+M) yesterday.

Q: Cosa si ruppe? Laccio - scarpa.

Preposition with, on the, and in the
9a. The police stopped the van (+M) with the goods (+F) stolen (+M) yesterday.
9b. The police stopped the van (+M) with the goods (+F) stolen (+M) yesterday.

Appendix C

Prepositional Phrase Experiment

The (a) represents late closure sentences, (b) is early closure sentences, (c) is the control sentence for late closure, (d) is the control sentence for early closure. In Sentences 1–8, the correct answer is to the left; in Sentences 9–15, the correct answer is to the right.

1a. La ragazza/nella macchina/vicino alla banca/aveva un viso noto.
1b. La ragazza/nella macchina/vicino al finestrino/aveva un viso noto.

Q: Chi aveva un viso noto? La ragazza - il fattorino.

2b. Gli asciugamani/nell'armadio/nell'armadio/nell'armadio/vicino al bagno/erano per gli ospiti.

Q: Cos'era per gli ospiti? Gli asciugamani - i piatti.

10a. A Miriam piace molto/il pane/con le olive/nero/della Liguria.
10b. A Miriam piace molto/il pane/con le olive/nero/della Liguria.

Q: Cos'è di colore nero? Pane - olive.

11a. E' scomparsa/la spilla/nello scrigno/cesellata/da Bulgari.
11b. E' scomparsa/la spilla/nello scrigno/cesellato/da Bulgari.

Q: Cosa ha cesellato Bulgari? Scrigno - spilla.

12a. Mary left/the cup (+F)/in the sink (+M)/dirty (+M)/of coffee and went out.
12b. Mary left/the cup (+F)/in the sink (+M)/dirty (+F)/of coffee and went out.

Q: Cosa non era pulito? Lavandino - tazza.

13a. Il paziente si lamentava/del callo (+M)/sulla mano/arrossato/e dolente.
13b. Il paziente si lamentava/del callo (+M)/sulla mano/arrossato/e dolente.

Q: Cosa si arrossò? Callo - mano.

14a. Gianna era affezionata/all' veccha lampada/nel tavolo/annerita/dagli anni.
14b. Gianna era affezionata/all' veccha lampada/nel tavolo/annerito/dagli anni.

Q: Cosa s'era annerito? Lampada - tavolo.

15a. Leo regalò/la fuoriserie/con il condizionatore/appena riparata/nel condizionatore.
15b. Leo regalò/la fuoriserie/con il condizionatore/appena riparato/nel condizionatore.

Q: Cosa hanno regalato? Fuoriserie - condizionatore.

16a. L'architetto ispezionò/la lapide/sul campanile/danneggiato/dal terremoto.
16b. L'architetto ispezionò/la lapide/sul campanile/danneggiata/dal terremoto.

Q: Cosa si è danneggiato? Campanile - lapide.

Q: Where was the girl? Close to the window - close to the driver.
Q: Where was the car? Close to the bank - close to the bar.
Q: Who had a known face? The girl - the errand boy.
Q: Dov'era la ragazza? Vicino al finestrino - vicino all'autista.
Q: Dov'era la macchina? Vicino alla banca - vicino al bar.
Q: Dov'era la ragazza? Vicino al finestrino - vicino all'autista.
Q: Cosa non era pulito? Lavandino - tazza.
Q: Cosa si arrossò? Callo - mano.

What became red? Corn - hand.

What got damaged? Bell-tower - plaque.
3a. The glasses/in the cabinet/over the sink/are a gift from Sara.
3b. The glasses/in the cabinet/over the cups/are a gift from Sara.
3c. What did Sara make a present of? The glasses - the dishes.
3d. The cabinet/over the sink/over the kitchen.
Q: Where is the cabinet? Over the sink - over the bureau.
3d. The glasses/are over the cups/over the kitchen.
Q: Where is the glasses? Over the cups - over the dishes.

4a. Il bambino/nella Ritmo/all’angolo/era sparito.
4b. Il bambino/nella Ritmo/sul seggiolino/era piangendo disperato.
Q: Chi stava piangendo? Il bambino - la ragazza.
4c. La Ritmo/era all’angolo/era Maria uscita.
Q: Dove’era la Ritmo? All’angolo - nel parcheggio.
4d. Il bambino/era sul seggiolino/era Maria uscita.
Q: Dove’era il bambino? Sul seggiolino - in strada.
4a. Il baby/in the Ritmo car/at the corner/ was crying desperately.
4b. The baby/in the Ritmo car/on the (baby) car-seat/ was crying desperately.
Q: Who was crying? The baby - the girl.
4c. The Ritmo/ was/at the corner/when Maria came out.
Q: Where was the Ritmo? At the corner - in the parking lot.
4d. The baby/ was/on the car-seat/when Maria came out.
Q: Where was the baby? On the car seat - in the street.

5a. La donna/sull’autobus/nel sedile anteriore/sembrava sofferente.
5b. La donna/sull’autobus/nel sedile anteriore/sembrava sofferente.
Q: Chi sembrava sofferente? La donna - l’infermiera.
5c. L’autobus/era nella corsia di emergenza/simbolizzava sofferente.
5d. La donna/era nel sedile anteriore/stamattina.
Q: Dove’era la donna? Nel sedile anteriore - alla fermata.
5a. The woman/on the bus/in the emergency lane/looked suffering.
5b. The woman/on the bus/in the front seat/looked suffering.
Q: Who looked suffering? The woman - the nurse.
5c. The bus/ was/in the emergency lane/this morning.
Q: Where was the bus? In the emergency lane - at the final stop.
5d. The woman/ was/in the front seat/this morning.
Q: Where was the woman? In the front seat - at the bus stop.

6a. Il cucciolo/nella scatola/con l’interno blu/e’ per Maria.
6b. Il cucciolo/nella scatola/con la coda bianca/e’ per Maria.
Q: Che cosa e’ per Maria? Il cucciolo - il pacchetto.
6c. Stamattina/la scatola/con l’interno blu/era sparatita.
Q: Che scatola e’ sparatita? Con l’interno blu - con l’interno, beige
6d. Stamattina/il cucciolo/con la coda bianca/era sparito.
Q: Che cucciolo e’ sparito? Con la coda bianca - con la coda, beige.
6a. The puppy/in the box/with a blue interior/is for Maria.
6b. The puppy/in the box/with a white tail/is for Maria.
Q: What is for Maria? The puppy - the parcel.
6c. This morning/the box/with the blue interior/had disappeared.
Q: Which box disappeared? With the blue interior - with the beige interior.
6d. This morning/the puppy/with the white tail/had disappeared.
Q: Which puppy disappeared? With the white tail - with the beige tail.

7a. Il commesso/nel negozio di antichita’/al porto/era molto divertente.
7b. Il commesso/nel negozio di antichita’/alla cassa/era molto divertente.
Q: Chi era divertente? Il commesso - la cassiera.
7c. Il negozio di antichita’/era/ al porto/’l’estate scorsa.
Q: Dove’era il negozio di antichita’? Al porto - sul lungomare
7d. Il commesso/era/alla cassa/l’estate scorsa.
Q: Dove’era il commesso? Alla cassa - al banco.

8a. Le foto/sul giornale/vicino al tavolo sono di Giuliana.
8b. Le foto/sul giornale/vicino alla sveglia/sono di Giuliana.
Q: Cos’e’ di Giuliana? Le foto - le diapositive.
8c. La scatola e’/vicino al tavolo a castello/nella stanza dei ragazzi.
8d. Le foto/sono/vicino alla sveglia/nella stanza dei ragazzi.
Q: Dove sono le foto? Vicino alla sveglia - vicino ai libri.

9a. I passegeri/sul pullman/nel parcheggio/cantavano a squarciagola.
9b. I passegeri/sul pullman/nei sedili posteriori/cantavano a squarciagola.
Q: Chi cantava a squarciagola? L’autista - i passegeri.
9c. Il pullman/che era/nel parcheggio/faceva molto rumore.
Q: Cosa era nel parcheggio? Il camper - il pullmann.
9d. I passegeri/che erano/nei sedili posteriori/faccevano molto rumore.
Q: Chi era nei sedili posteriori? I controllori - i passegeri.
9a. The passengers/on the coach/in the parking lot/were singing at the top of their voices.
9b. The passengers/on the coach/in the side seats/were singing at the top of their voices.
Q: Who was singing at the top of his voice? The driver - the passenger.
9c. The coach/that was/in the parking lot/was very noisy.
Q: What was in the parking? The camper - the coach.
9d. The passengers/who were/in the side seats/were very noisy.
Q: Who was in the side seats? The ticket-inspectors - the passengers.

10a. La foto/sul giornale/vicino alla poltrona/era davvero impressionante.
10b. La foto/sul giornale/vicino all’intervista/era davvero impressionante.
Q: Cosa era impressionante? La caricatura - la foto.
10c. Il giornale/era vicino alla poltrona/l’altro giorno.
Q: Dove’era il giornale? Vicino al tavolo - vicino alla poltrona.
10d. La foto/era vicino all’intervista/l’altro giorno.
Q: Dove’era la foto? Vicino al titolo - vicino all’intervista.
10a. The picture/on the newspaper/near the armchair/ was really striking.
10b. The picture/on the newspaper/near the interview/ was really striking.
Q: What was striking? The caricature - the picture.
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10c. The newspaper was near the armchair two days ago.
Q: Where was the newspaper? Near the table - near the armchair.

11a. La senape nel panino sopra il piatto ha un gusto orribile.
Q: Cosa ha un gusto orribile? La maionese - la senape.

11c. Il panino era sopra il piatto da due giorni.
Q: Dove era il panino? Sopra il vassoio - sopra il piatto.

12a. La chiave della porta nell'ingresso era tutta arrugginita.
Q: Cosa era arrugginita? La serratura - la chiave.

13a. The sail of the boat in the bay was completely torn.
13b. The sail of the boat in the hold was completely torn.
Q: What was torn? The rope - the sail.

14a. The driver licence of the woman in the car had already expired.
14b. The driver licence of the woman in the bag had already expired.
Q: What had expired? The card - the driver licence.

15a. La tromba del suonatore nella sala non ha la sordina.
Q: Cosa non ha la sordina? Il sassofono - la tromba.

16a. The key of the door in the entrance was completely rusty.
16b. The key of the door in the pocket was completely rusty.
Q: What was rusty? The lock - the key.

17a. The door is in the entrance certainly.
Q: Where is the door? Between the bedrooms - in the entrance.

18a. La vela della barca nella baia era completamente strappata.
Q: Cosa era strappata? La fune - la vela.

19a. La chiave della porta nell'ingresso era tutta arrugginita.
Q: Cosa era arrugginita? La serratura - la chiave.

20a. The driver licence of the woman in the car of Bruna.
Q: Where was the woman? In the shop - in the car.

21a. The trumpet of the player in the hall hasn't got the mute.
13c. The barca era nella baia de molto tempo.
Q: Dove era la barca? Alla deriv - nella baia.

22a. The trumpet has been in the hall for some minutes.
Q: Where is the trumpet? On the piano - in the case.

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